QA/QC Software to Mitigate Mold, Mycobacteria and other Occupational Health Hazards in Construction

K.R. Grosskopf, Ph.D.
University of Florida
Gainesville, Florida

Mold has become a major issue for the construction industry due to potential health hazards, increasing large-sum and highly publicized litigation, negative public relations, and a tightening insurance market. In many areas of the U.S. with abundant rainfall and new construction, mold is fast becoming the successor to asbestos in health related construction claims. The co-habitation of potentially pathogenic mycobacteria with mold may additionally present occupational health risks to construction workers. In response, the Associated General Contractors of America (AGC) and the University of Florida have developed a PC-based moisture control construction checklist (MC^3) that will enable builders to quickly identify mold-forming conditions during construction or renovation, prevent the introduction of moisture into building materials and assemblies, and mitigate mold growth following exposure. A demonstration version has been developed to generate a custom mold checklist specific to project location, building type, material composition, and climate. The MC3 demo also contains developmental training modules for at-risk material delivery, storage and installation practices in U.S. construction.

Keywords: Construction, indoor air quality (IAQ), indoor environmental quality (IEQ), mold, litigation, moisture, public health

Introduction

In 1970, The U.S. Congress passed the Occupational Safety and Health Act to ensure Americans the right to safe and healthful working conditions. However, workplace hazards continue to inflict a tremendous toll in terms of both human and economic costs. In 2000, U.S. private industry employers reported 5.3 million work place injuries and 363,000 cases of occupational illness. During this time, the annual cost for occupational injuries and deaths in the U.S. was $US 123 billion in wages, lost productivity, administrative expenses and health care (NIOSH, 2003).

In 2002, the U.S. construction industry was comprised of more than 660,000 companies employing over 5,700,000 employees with $US 175 billion in payroll. The value of U.S. construction put in place during 2002 exceeded $US 1.0 trillion, or a $US 490 billion (4.7%) contribution to the Nation's gross domestic product (GDP). In spite of this prosperity, mold has become a major economic counterweight for U.S. construction due to potential health hazards, increasing large-sum and highly publicized litigation, negative public relations, and a tightening insurance market. In fact, mold is fast becoming the successor to asbestos in health-related construction claims nationwide. Most of these "sick building" lawsuits have been filed on behalf of building owners and occupants who claim construction-related mold has either caused or contributed to a host of respiratory, epidermal and neurological illnesses. New research however, suggests that construction workers may also be at risk, not only from mold, but *mycobacteria* (Rautiala, et al, 2004). Although molds produce mild myotoxins that have long been known to cause allergic reactions and worsen existing respiratory conditions, little scientific evidence exists that conclusively links mold to serious health risks. Yet the cohabitation of potentially pathogenic mycobacteria with mold may indeed present profound health risks to both construction workers and building occupants exposed to moisture entrained, organic building materials and assemblies.

In response, the Associated General Contractors of America (AGC) and the University of Florida have developed a "pilot" knowledge management and training tool, the *Moisture Control Construction Checklist* (MC^3) program. The objective of this research effort is to develop software that will enable builders to quickly identify mold-forming conditions during construction or renovation, prevent the introduction of moisture into building materials and assemblies, and mitigate microbial growth following exposure.

Literature Review

Mold and Mycobacteria in Buildings

Molds can grow on cloth, carpet, leather, wood, wallboard or anything that is made of organic material. In order to reproduce, molds release tiny spores just as plants produce seeds. These spores settle on surfaces and when conditions are favorable, they begin to consume organic material in their immediate vicinity. Sustained mold growth requires moisture, organic material (a food source), oxygen, and a suitable temperature generally in the range of 40° to 100°F. When one or more of these four conditions are unsatisfactory, the mold colony will become dormant. When favorable conditions are restored, the dormant colony will resume its metabolic activity (NAHB, 2001). The U.S. Environmental Protection Agency has reported that many and perhaps all molds can have health effects. Molds can trigger a wide range of allergic reactions in sensitive individuals, including eye, nose and throat irritation, dermatitis, and a generalized worsening of asthma or respiratory distress (AWCI, 2002). It has long been suggested that actinobacterial and fungal spores released from mold infected building materials would cause such symptoms. However, there are several other cohabitating microorganisms such as mycobacteria that have not been well characterized, and that may in part be responsible for health effects commonly attributed to mold.

Mycobacteria are acid-fast, slow-growing, Gram-positive species that take part in the decomposition of organic matter (Rautiala, et al, 2004). Rapid-growing mycobacteria are seen as visible colonies in less than 7 days, while slow-growing mycobacteria usually need several weeks before visible colonies appear. While many of the rapid-growers are considered non-pathogenic, slow-growing mycobacteria are potentially pathogenic to humans and animals. The most harmful and well-known mycobacteria are the human *tuberculosis* and *leprosy bacilli*. More prevalent strains that occur in both natural and man-made environments are *M. avium*, *M. interacellulare*, and *M. scrofulaceum*. These and other species of slow-growing mycobacteria can cause chronic pulmonary diseases resembling tuberculosis, cervical lymphadenitis, skin and other soft tissues infections (Falkinham, 1996). Since the presence of slow-growing mycobacteria is often obscured by fast-growing bacterial and fungal colonies, only until recently have slow-growers been isolated as potential causal agents in the study of moldy indoor environments.

To study the association of mycobacteria with mold and conditions known to cause mold, airborne mycobacteria, fungi and actinobacteria were sampled in five buildings under renovation. Three buildings studied had visible microbial growth on building surfaces following exposure to moisture from mechanical leaks and leaks in the building envelope. Two of these had only recently been exposed to water damage, whereas the third had been subjected to prolonged moisture over a period of years. No moisture or visible colonization was observed in the remaining two buildings studied. Mycobacteria in concentrations of 5-160 colony forming units (cfu) per m^3 were found in two of three moldy buildings and in one of the two non-moldy buildings. The highest concentrations of mycobacteria were found in the building exposed to prolonged water damage. Of 43 isolates recovered, 95% were identified as slow-growing mycobacteria, including *M. avium*, *M. interacellulare*, *M. scrofulaceum*, *M. terrae* and *M. nonchromogencium*. No mycobacteria were found in outdoor air samples within detectable limits (2cfu/m^3). By comparison, concentrations of fungal spores in air varied between 10^2-10^4 cfu/m^3 for moldy buildings, 10^2-10^3 cfu/m^3 for non-moldy buildings and 10^1-10^2 cfu/m^3 for outdoor air samples, depending on time of the year. The release of airborne mycobacteria likely originated from wetted wood and gypsum board disturbed during the dismantling and renovation process. (Rautiala, et al, 2004).

Mold and Mycobacteria During Construction

In spite of the attention given to pre-construction design and post-construction maintenance, the methods and materials employed during construction may be among the leading causes of mold and other indoor environmental hazards. Specifically, at-risk materials that are exposed to moisture during construction are the most likely sources of chronic and in many cases, irreparable mold and mycobacteria infestation. Comparatively little information however is available on mold training and education, best management practices (BMPs), and quality control/quality assurance (QA/QC) during the construction process. In addition, code conformant thresholds for moisture and mold in U.S. construction are poorly defined and enforced. Left to the discretion of the contractor, much of the U.S. building stock could become vulnerable to microbial infestation during construction and throughout occupancy.

Moisture Control Construction Checklist (MC3) Program

MC^3 is an experimental software program currently under development by the University of Florida that assembles mold identification, prevention and mitigation checklist items that apply to a specific project. A building contractor could for example, use MC3 to identify and assess mold risks specific to project location, building type, material composition, and climatology and identify likely sources of moisture and mold formation during the construction process. From this, MC^3 assembles a checklist of the most cost effective measures to first prevent the introduction of moisture into the building and then mitigate observed mold forming conditions, if any, before infestation occurs. Prior to and following construction, MC^3 facilitates pre-bid assignment of risk to subcontractors and material suppliers, continuing education and training, QA/QC planning, and a journal of measures taken to protect at-risk material delivery, storage and installation during the project.

MC3 Checklist Generation Options

The MC3 software has four options to create a checklist (Figure 1). The *Standard* checklist option (Figure 2) allows the user to view a series of pre-designed checklists. Standard checklist options are available for general contractor, subcontractor, supplier and owner (or representative) and corresponding preconstruction, construction and post-construction related activities. The *Keyword* option (Figure 3) allows the user to select one or more keywords from a list of construction terms to create a checklist pertaining to only the keyword or keywords selected. Similarly, the U.S. Construction Specifications Institute, *CSI Activities* option (Figure 4) allows the user to input one or more CSI activity codes to create a checklist pertaining to only the code or codes selected.

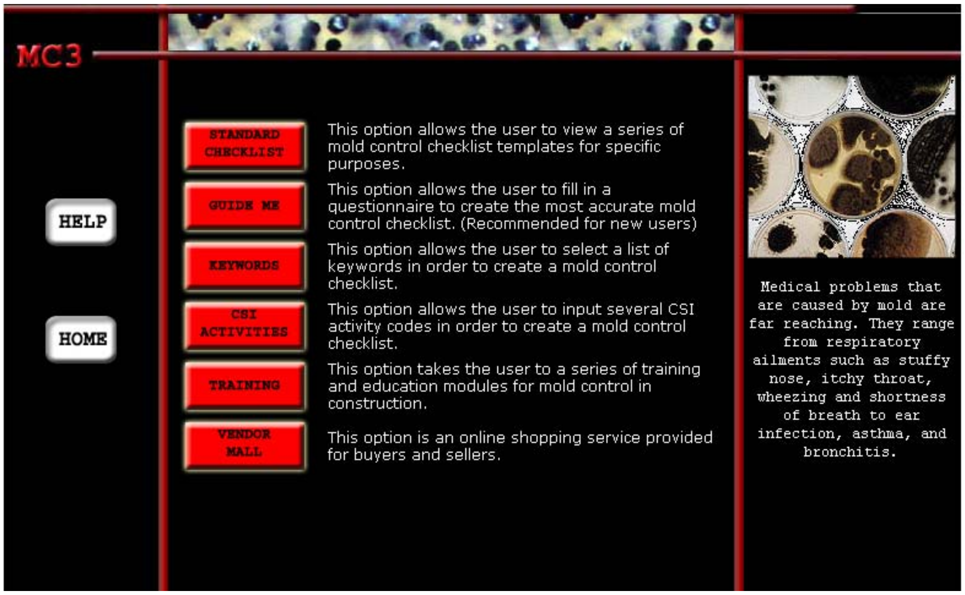

FIGURE 1.

Custom checklist generation options, MC3 demo version.

Alternatively, users may select a separate *Guide Me* option (Figure 5) that assembles a custom checklist from answers to a series of project specific questions. The *Guide Me* option was designed primarily for first-time users or users unsure of their moisture prevention and mitigation needs. This option is the most flexible and comprehensive of all checklist generation options. As the user navigates through each of the 26 *Guide Me* option screens, questions move from general to project specific. The first menu option gives the user a choice to add basic mold facts as an introduction to the checklist. The user is then asked to select one or more categories of contracting including *general contractor,* s*ubcontractor* and *supplier*. If the user selects "General Contractor" for example, the question series to follow will be modified to include only those questions that pertain to general contracting and construction management. Subsequently, only checklist items pertaining to general contractors and construction managers will be added to the checklist. Next, the user is asked to identify the project scope from a list of choices including *commercial*, *institutional*, *residential* and *industrial*; and project scale from *low-rise*, *mid-rise* and *high-rise* construction.

FIGURE 2.

“Standard” checklist sample, MC3 demo version.

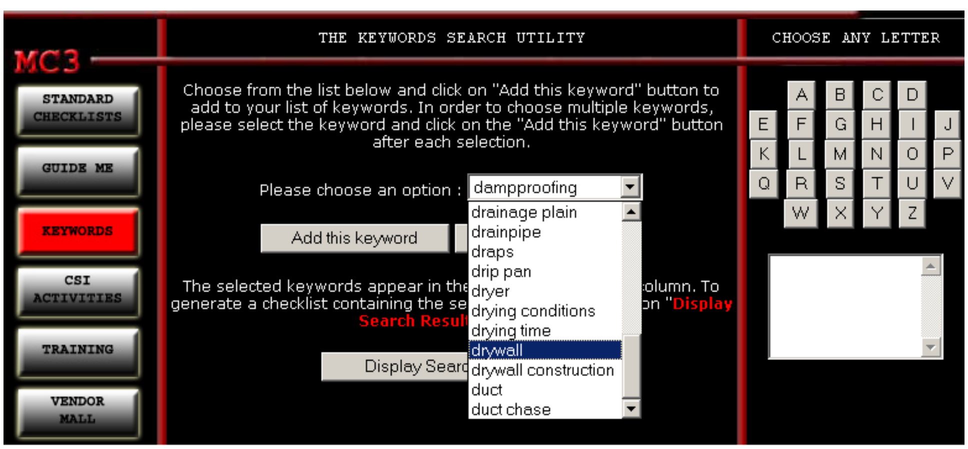

FIGURE 3.

“Keyword” checklist sample, MC3 demo version.

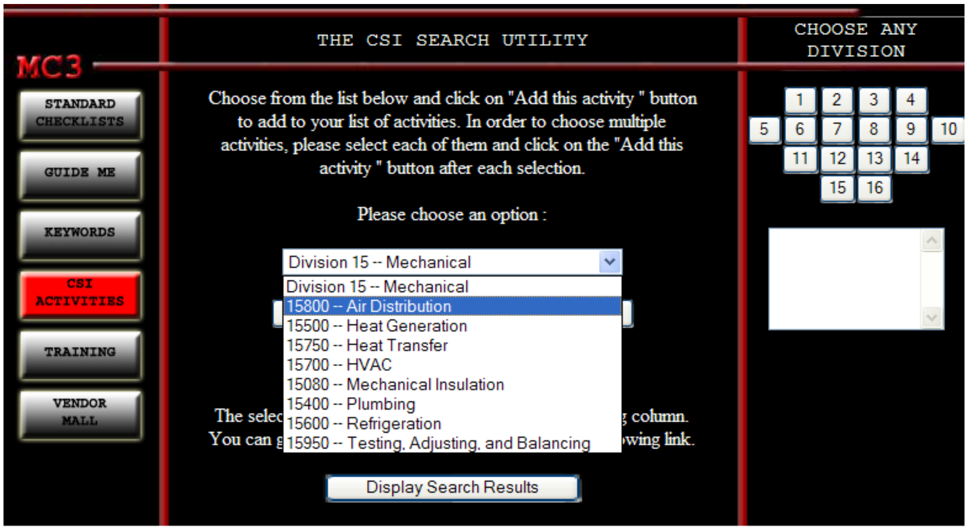

FIGURE 4.

“CSI Code” checklist sample, MC3 demo version.

In addition to building design and material specifications, climate is a significant risk factor. Moisture resistant methods and materials in northern climates may actually increase the susceptibility of buildings to mold if used in southern climates. Accordingly, *the Guide Me* option next asks the user to select the *region* of the U.S. where the project is located (Figure 6).

Although the focus of the MC3 software is to identify, prevent, and mitigate mold forming conditions during construction, the contractor’s liability begins well before the start of construction and extends well after project completion. Subsequently, the user is given the option to select one or more phases of the project life-cycle from a list that includes *pre-construction*, *construction*, and *post-construction*. One of the first lines of defense for a contractor is to reduce mold liability through assignment of risk and indemnity in the *contract documents*. Avoiding general liability policies with mold exclusions is another. For projects where contract documents have not been executed, checklist items with suggested contract addenda or supplementary conditions will be provided.

Next, the user is asked to indicate whether *subcontractors* will be used. Subcontractors can be trade contractors working under a general contractor or CM, or specialty contractors working under other subcontractors. A “yes” response adds subcontractor items to the checklist. A “no” or “skip” response excludes subcontractor items from the checklist. Having a workforce properly trained to identify, prevent, and mitigate mold-forming conditions during construction is key. The user is asked to indicate whether mold training and education programs exist for employees. Again, a “yes” response excludes mold-related education and training items from the checklist. A “no” or “skip” response adds training and education items to the checklist. Other MC3 pre-construction screens obtain user information on project meetings, scheduling, QA/QC programs and job site inspections.

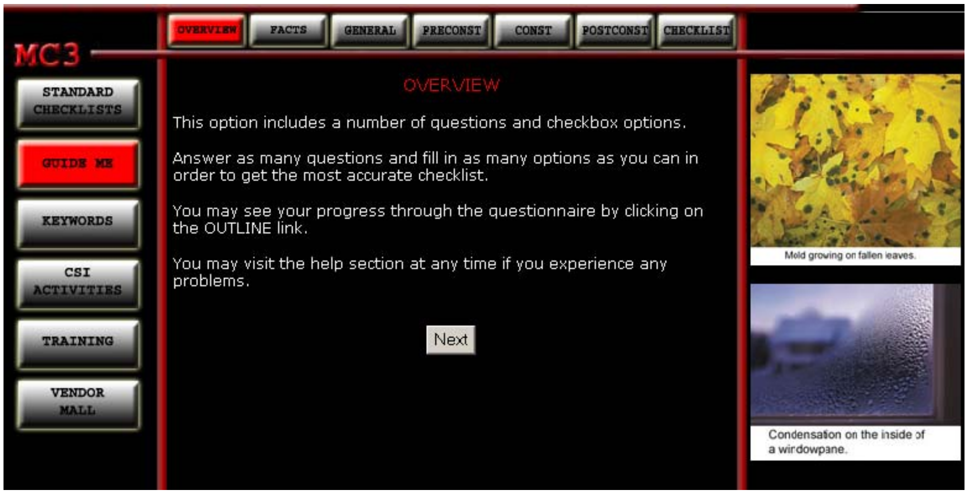

FIGURE 5.

“Guide Me” checklist sample, MC3 demo version.

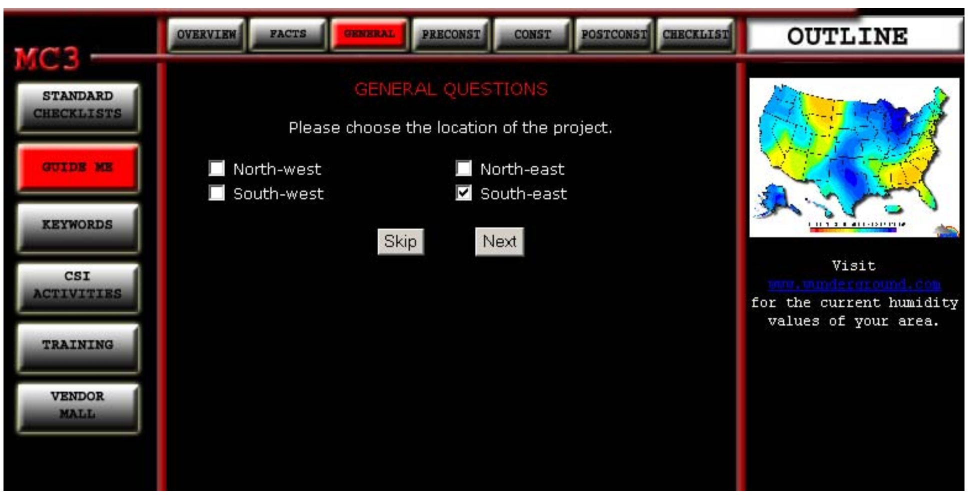

FIGURE 6.

Project location and climate, “Guide Me” checklist sample, MC3 demo version.

In preparation for construction, the user is asked to identify one or more types of materials and equipment of interest from a list of *at-risk materials* and assemblies (Figure 7). These may not only be materials and equipment the contractor, subcontractor or supplier is responsible for, but also those materials and equipment systems potentially impacting the contractor’s work. A drywall contractor for example should not only be interested in finishes, but also the weatherproofing of the building envelope and the moisture content of wood framing. Next, the user is asked to choose between one or all *delivery*, *storage* and *installation* options for the materials and systems selected on the previous screen. A material supplier for example, may only be interested in material delivery checklist items. A contractor may be interested in all three options.

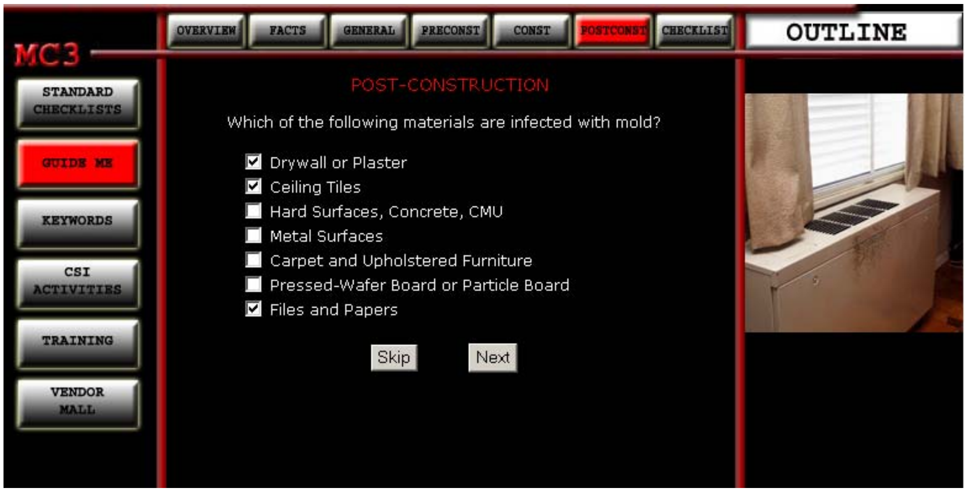

FIGURE 7.

At-risk materials and assemblies, “Guide Me” checklist sample, MC3 demo version.

Dormant mold spores can germinate within 24-48 hours after being exposed to moisture. Infestation requiring expensive mitigation and rework can occur shortly thereafter. Identifying mold and mold forming conditions during construction is the key to cost-effective prevention and mitigation. In preparation for post-construction and project handover to the owner, the user is asked to identify whether mold or mold forming conditions were observed during construction and final inspections, and what steps if any were taken to mitigate the condition. Methods to *dehydrate*, *disinfect* or *replace* materials specific to the degree and duration of moisture exposure or infestation are included. For all *Guide Me* options, the user may select one, all or any combination of menu options to broaden or narrow search parameters of interest.

MC3 Display, Print and Log File Options

For all checklist generation options, the user may select one of three display and print options. Level 1 provides a simple checklist of check boxes, bullets or short phrases. Level 2 provides a Level 1 checklist followed by a more in-depth description of each checklist item. Level 3 provides Level 1 and 2 items as well as references and websites for more information. Level 1 is considered appropriate for field level management and supervision. Level 2 is considered appropriate for training and education. Level 3 is considered appropriate for advanced research. Depending on user specified search parameters and display options, a checklist may range in length from one page to more than fifty pages.

The user may also display the checklist in printable format or create a log file. The printable format option displays the checklist on a white background in print-view HTML format. The printable format allows the checklist to be easily printed on letter or legal paper, converted to a word processing file, or saved on the user’s PC. The create log file option allows the checklist to be used as a project journal to document specific actions taken to comply with checklist items.

MC3 Education and Training

Also included is a set of training modules with self-examinations at the end of each module. The first series or *general* module (Figure 8) includes basic facts of mold and mold forming conditions as well as potential health, legal and financial risks posed by mold. Subsequent modules address methods to identify, prevent and mitigate mold and mold forming conditions during pre-construction, construction and post-construction project phases. Each training module takes the user through a series of educational screens complete with descriptive text, illustrations, streaming video and links to PDF files and websites. In addition, an outline of the subject matter content of each module is provided. Upon completion of each training module, the user is asked to complete a short examination. Correct answers are provided upon completion. In addition, users are provided references for subject matter content if more in-depth inquiry is needed.

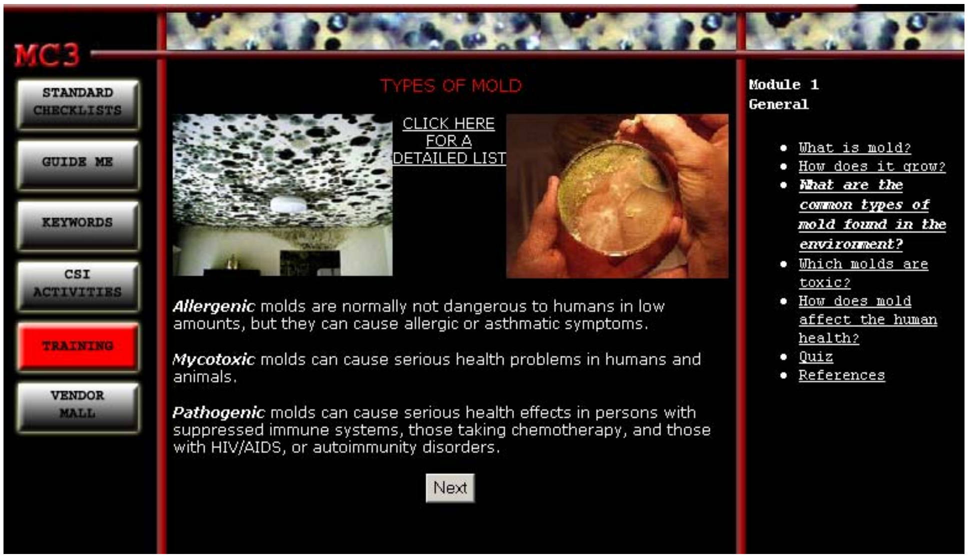

FIGURE 8.

Sample tutorial, MC3 demo version.

MC3 Software

The MC3 software has been designed to be accessed via the Internet. Software pages are ASP-driven (Active Server Pages). Checklist data is stored and queried from an MS-Access database. The software can be set up and hosted on any Windows-based computer having support for IIS (Internet Information Services) or PWS (Personal Web Server). The software is written in HTML format is compatible across all web browsers, meaning virtually any user with Internet access will be able to use the MC3 software from their desktop or laptop. Since the entire program will be stored and maintained on a single source host server, there will be no need to provide software disks to users to install or update the program. For a limited time, an MC3 demonstration version is available at http://n.1asphost.com/somjit/test3/homepage.asp (username “kgro”, password “washington123”). However, video tutorials and other graphics features are not supported on the demonstration version of this software.

Conclusions

Mold has become a major issue for the construction industry due to potential health hazards, increasing large-sum and highly publicized litigation, negative public relations, and a tightening insurance market. The co-habitation of potentially pathogenic mycobacteria with mold may additionally present occupational health risks to construction workers. The PC-based moisture control construction checklist (MC^3) will enable builders to quickly identify mold-forming conditions during construction or renovation, prevent the introduction of moisture into building materials and assemblies, and mitigate mold growth following exposure. In addition to improving occupational indoor air quality, MC3-specified methods and materials that reduce moisture infiltration may also reduce energy consumption. Latent or “moisture” loads in many buildings exceed sensible or “temperature” loads. Moisture intrusion and subsequent mold infestation, wood rot and termite colonization are also among the leading causes of structural failure and property loss. Such conditions pose added risks to buildings subject to windstorm and other natural hazards.

During project reviews, demonstrations of the MC3 concept software were presented to industry and academic evaluators. Response to the project was overwhelmingly positive. It was suggested that the MC3 software be pilot or “beta” tested prior to release. Subsequently, MC3 beta versions will be provided to 12-16 volunteer construction companies nationwide in 2005-06 to test the software under real-time conditions. Participants will include a representative cross-section of contractors and trades, company sizes and markets. The primary purpose of the beta test is to uncover errors and omissions in the content database and software architecture. A secondary purpose is to incorporate the knowledge, skills and experience of participating companies into the final software release.

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