Guide for interpreting reports from inspections/ investigations of indoor mold

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Inspections and testing of indoor environments for mold growth increased dramatically in the past decade. Allergists can now be presented copies of reports and laboratory data and asked to provide an interpretation, although allergists are seldom trained to review environmental data. There is no single sampling method that is both specific for mold growth and robust enough to reliably detect mold growth. There is no standard method for these inspections or testing and no widely recognized credential for investigators, and therefore reports also vary in quality, objectives, and thoroughness. Despite these issues, observations from informed inspections coupled with results from qualified analyses of samples that are collected with a useful strategy can usually indicate whether mold growth is present in a building, but the nature of the report should be assessed before any interpretation of the results and data are attempted. This rostrum discusses objectives of inspections, describes qualifications for investigators, outlines the limitations of various sampling methods applicable to mold and to some degree endotoxin, and provides guidance for data interpretation. (J Allergy Clin Immunol 2008;121:592-7.)

Key words: *Mold, testing, indoor air, investigation, inspection*

Mold growth occurs in damp buildings, and ample evidence indicates that respiratory complaints are increased among occupants of damp buildings.[1] Regardless of mechanism, the long-established "damp building effect" on respiratory symptoms remains unexplained.[2,3] Recent studies actually extend the damp building effect beyond triggering symptoms to actually inciting new cases of asthma.[4,5] If corroborated, this effect will further increase the demand for building inspections and in turn increase the need for allergists to interpret and understand reports of such inspections.

Abbreviations used
CFU: Colony-forming units
HVAC: Heating, ventilation, and air conditioning
MVOC: Microbial volatile organic compound

The references cited above extensively discuss the health effects associated with and/or alleged to result from exposure to indoor mold growth; further discussion is beyond the scope of this rostrum. A guide for primary care physicians pertaining to indoor mold and a booklet for the lay public from the American Society for Microbiology are referenced among the Online Repository materials (available at www.jacionline.org). The purpose of this rostrum is to provide the practicing clinician with guidance on the practical objectives and methods commonly used in building inspections for mold, as well as a discussion of the uses and constraints of testing (sampling) and the reasonable interpretation of results.

BASIC MYCOLOGY

Fungi are eukaryotic organisms that are neither plant nor animal but are members of a separate kingdom.[6] Other than yeasts, fungi are composed of multicellular, thread-like hyphae; aggregated hyphae are called a mycelium. Fungi reproduce through spores. Depending on the species, spores can be produced by ordinary hyphae or on specialized hyphae, often within fruiting bodies. In the majority of fungi, the spores are adapted for airborne dispersal.[7] Fungal spores are abundant in outdoor air from early spring through fall and occur year-round in mild climates. Additional mold resources are listed in the Online Repository at www.jacionline.org.

The major taxonomic groups of fungi are the zygomycetes, ascomycetes, and basidiomycetes.[6] Asexual forms of ascomycetes (and a few basidiomycetes) produce asexual spores called conidia; these forms comprised the obsolete group deuteromycetes. Many familiar allergenic fungi, such as *Alternaria*, *Aspergillus*, *Cladosporium*, *Curvularia*, *Drechslera*, *Fusarium*, and *Penicillium* species, are conidial forms of ascomycetes.

Fungi secrete various hydrolytic enzymes and can colonize diverse materials, including many wood-based building materials.[6] Many of the common airborne fungal spores are produced by *Cladosporium*, *Alternaria*, and *Epicoccum* species that colonize leaf surfaces (phylloplanes).

Outdoor airborne spores infiltrate through doors, windows, outdoor air intakes on mechanical ventilation systems, and tiny cracks between walls and windows. Spores can also enter on the surface of people, shoes, clothing, or pets. The spores, especially from phylloplane fungi that infiltrate a building and settle out in dry dust without germinating, have been called "tabletop molds."[8] However, colonization can occur indoors when

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sufficient moisture is present. It is critical to distinguish between tabletop molds and colonization when interpreting sampling data.

Moisture is required for spores to germinate, develop mycelia, and colonize an indoor substrate. Almost any damp or wet material, such as carpeting, upholstered furniture, gypsum wallboard, ceiling tiles, wood products, shower walls and curtains, and potted plants, all can be colonized. Although central heating, ventilation, and air-conditioning (HVAC) systems with in-duct filters will remove many airborne spores, fungi can grow on air filters or on insulation lining the interior of air-handling units or air ducts.

Many fungi can amplify indoors; among the most commonly identified are species of *Cladosporium*, *Penicillium*, and *Aspergillus*. In addition, several species are known to be associated with extensive water damage, including *Aspergillus versicolor*, *Stachybotrys chartarum*, *Chaetomium globosum*, and *Ulocladium chartarum*. The last 3 are especially common on cellulose-based materials.[8] *Aureobasidium pullulans* and other yeast-like fungi can also proliferate in, for example, humidifier reservoirs, wet HVAC ducts, saunas, and whirlpool bathtub jets.

QUALIFICATIONS OF THE INSPECTOR/INVESTIGATOR

No current credential is widely recognized for inspecting buildings for water damage and mold growth. Independent trade groups issue credentials for mold inspection, and some states are beginning to require certifications/licenses, but the rigor of these programs remains variable.

Inspectors for mold growth in buildings should understand moisture, building construction, sampling techniques, and how to interpret analytic results. Most importantly, they should recognize the boundary between the environmental assessment of a building and a medical diagnosis; that is, the discovery of mold growth in a building does not always explain occupant symptoms. Physicians should recognize this latter point also and avoid relying solely on patient information to determine that buildings are the cause of symptoms: patients' observations of conditions in their workplace are not always reliable indicators of mold growth.

Questions useful to identify a qualified inspector should address training, experience, and practices. What specialized study or professional certification do they have or additional training have they sought outside their original field? Do they rely primarily on sampling or emphasize inspection? How long have they been conducting inspections, how often do they inspect buildings, and what type or types of building or buildings do they inspect? Do they have experience sampling, and what is their rationale for determining when sampling is appropriate? Do they typically prepare a written report, and what information is included?

PURPOSE OF INSPECTION/INVESTIGATION

Three reasons for concern about fungal growth indoors are (1) health effects, (2) rot of the building's structure, and (3) depreciation caused by the mold sight or smell. Mechanisms involved in adverse health effects in damp buildings remain contentious, but most agree that a smelly, moldy building suffers structural damage and is not a desirable place to live or work. Perspective must be maintained, though, to distinguish between small areas of mold growth in a shower or on a refrigerator gasket and large areas of colonization caused by a systemic building problem.

The physical inspection of the building is the most important part in any investigation of suspected mold growth indoors, and it should have a clear and specific purpose. To determine whether the building is "safe" is too vague and subjective a purpose to be useful. The purpose might be to determine whether mold colonization is present, to locate areas of mold growth, to determine whether mold growth has affected the indoor air quality, or to assess whether colonized material was successfully removed from an area and associated dusts adequately cleaned. Sampling might be needed or might be superfluous for any particular inspection. Information obtained from sources other than the investigator should be so designated.

SAMPLING/TESTING

The goal of sampling should be to test hypotheses developed as part of the inspection.[9,10]

The null hypothesis is typically that a particular building has "normal and typical" types and amounts of airborne mold spores or that no colonized building materials or contents are present. Simply observing mold colonies disproves the latter. Addressing the former needs results from air samples collected with appropriate strategy and analyzed reliably.

Presently, no standardized protocols are available for sampling or interpreting results, and therefore recognized and validated sampling and analytic methods and equipment should be used where available.[10] A common strategy is to collect air samples from problem/complaint areas, nonproblem/noncomplaint areas, and outdoors. Note that "grab" samples for airborne mold have an inherent variability (see Fig E5 in the Online Repository at www.jacionline.org). Confidence in the outdoor sample as a useful reference thus requires that at least 2 and perhaps up to 10% of the total number of samples come from outdoors.

The purpose of source (dust, bulk, or surface) sampling typically is to confirm the presence or absence of fungal growth, increased quantities of settled spores, or both. Source samples are normally collected from discolored or dusty areas on materials or as settled dust, as for collection of allergens. Because bioaerosol concentrations can vary by orders of magnitude over short periods of time, the assessment of fungal products in dust reservoirs might provide a better estimation of long-term exposure to fungi or fungal products. Microbial volatile organic compounds (MVOCs) cause the musty, earthy odors associated with mold growth. Air samples can be collected for MVOC analysis as well. See the Online Repository at www.jacionline.org for more information.

LABORATORY TESTING

Qualifications

The American Industrial Hygiene Association accredits laboratories that perform fungal analysis (through an Environmental Microbiology program) but does not certify the individual laboratory analysts (although documented training is required). This program requires that only qualified analysts identify mold cultures (with multiple features) but permits technicians with less education and experience to identify dispersed spores that have inherently incomplete sets of features. Alternatively, the American Academy of Allergy, Asthma & Immunology and the Pan American Aerobiology Association certify proficient individuals for spore-trap analysis; however, these programs do not address

TABLE I. Advantages and disadvantages of commonly used air-sampling and analysis procedures

Methods of analysis	Commonly used sampler types	Advantages	Weaknesses
Particle microscopy	Slit impactors, filters	Provides total spore levels, easy to use, relatively quick analysis possible	Most are grab samples/Requires trained personnel/General spore groups/No viability indication
Laboratory culture	Culture-based impactors, liquid impingers, filters	Allows for species identification	Culturable only/Media effects requires trained personnel/Time consuming
Metabolite detection/measurement: immunochemistry	Liquid impingers, filter samples, cyclone samplers	Specific assays for allergens, very sensitive	Limited number of assays commercially available/Monoclonal assays might be too specific
Metabolite detection/measurement: secreted digestive enzymes (proteases)	Liquid impingers, filter samples, cyclone samplers	Independent of species, integrates activity from multiple species	Clinical relevance suggested for proteases but not established
Metabolite detection/measurement: molecular biology (PCR)	Liquid impingers, cyclone samplers, filter samples, slit impactors	Detects specific DNA sequences, eliminates the need for culturing or microscopy, very sensitive	Fungal fragments/other particles with allergens might lack DNA and would not be detected/No viability indication/No information on allergen production
Metabolite detection/measurement: biochemistry: ergosterol, β-(1,3) glucans	Liquid impingers, cyclone samplers, filter samples	Estimate of total fungal biomass	Cannot be used to identify specific fungi/Nonfungal sources might affect glucan assay

All air-sampling procedures require calibrated sampling devices.

overall quality systems in a laboratory. Samples should be analyzed by a qualified individual working within a well-designed quality system to provide a credible analysis.

Types of analysis

Different characteristics of fungi are identified by using different analytic procedures. Microscopy lumps spores into morphologic categories; growing molds in culture yields more information but detects a narrower spectrum of species. Neither of these addresses the allergenicity/antigenicity of the fungal structures nor detects allergen release into colonized substrates.[11] Thus no single type of analysis is useful in all cases, and investigators should be versed in multiple types. It should also be remembered that nonallergen fungal (glucans, proteases, other enzymes, and possibly toxins) and perhaps nonfungal (eg, endotoxin) components might be responsible for the health effects attributed to fungi in damp buildings.

Analytic methods for fungal allergens, antigens, other fungal components, and DNA have been developed recently (Table I).[12] The clinical relevance of some of these assays has not been fully documented, and some are not commercially available or have not been well validated and therefore are less frequently used.

Interpretation of results

Dose-response relationships between exposure to fungi (or fungal components) and symptoms are lacking. Credible studies that propose baseline levels for airborne fungal spores in buildings are limited[1] and are nonexistent for the relevant metabolites (ie, allergens, proteases, or glucans). Although a number of numeric standards for indoor fungi have been proposed,[13] none are currently accepted by the scientific community. However, recommendations for data interpretation have been suggested.[8,10]

There is no precise formula to distinguish "normal" or "typical" background levels or types of spores from increased levels or an atypical mix of types. The evaluation of air-sampling results is based on the comparison of the types (similar mix expected) and levels (lower indoors expected) of fungi detected indoors versus those detected outdoors. Differences between indoor and outdoor results suggest but do not confirm that mold growth is present indoors. If concentrations for individual types are greater indoors than outdoors, then an indoor source of fungal contamination should be suspected. Caution is needed, however, not to overinterpret such an observation or consider that observation definitive. Specific spore types might be quite high outdoors and infiltrate into a building on a certain day (as does pollen) but remain indoors and then exceed outdoor levels that have subsequently decreased. This can be seen with obligate plant parasites, such as rust fungi or tree pathogens (eg, *Ganoderma* species) that never colonize indoor spaces, yet can occur indoors in excess of outdoor levels on given days. Conversely, always consider the multiple possible sources of indoor airborne fungal spores, including infiltration of outdoor air, disturbance of dust reservoirs within the building, occupants, and (if present) indoor fungal growth. Which sources prevail depend on the specific conditions at the time of sampling. Increased or atypical results should be considered in conjunction with other findings.

Fungal spores are typically present on most surfaces. Therefore miscellaneous spores on surfaces do not necessarily indicate indoor fungal growth (Table II). Increased levels of a single spore type on surfaces might suggest the current or past presence of fungal growth in the vicinity of the sample location. The mix of mold types in dust can also provide a clue because spores of soil-type fungi rarely dominate in dust from houses free of visible mold or water damage but frequently do in dust from water-damaged buildings.[14] Also, certain molds (eg, *Chaetomium* and *Stachybotrys* species) rarely occur in buildings without water damage and thus can be useful indicators of water damage if recovered from multiple samples, even at low concentrations. The presence of mycelium, reproductive structures, or both on surfaces nearly always clearly indicates fungal growth on surfaces.

For air-sampling results, low counts with a distorted pattern of spore types is as useful an indicator of colonization as a total spore

TABLE II. Useful source and surface samples and analyses for fungal components

Sample type	Analysis procedures	Type of observations	Possible conclusions
Tape lift of surface	Direct microscopy	a. Fruiting structures b. Mixture of spores	a. Colonized surface b. Tabletop mold
Direct microscopy of bulk samples	Direct microscopy	a. Fruiting structures b. Hyphal penetration into material	a. Colonized material b. Colonized material
Culture analysis of: a. Small square of building paper b. Settled dust c. Swab from sanitized surface	Culture plating	a. Most cultured colonies are the same type b. Variety of mold types c. No mold recovered	a. Suggests material is colonized b. Consistent with tabletop mold c. Very clean surface or sanitizer residue collected with sample

Calibrated devices are typically not needed for source and surface samples. These can provide stronger evidence than air samples of mold colonization, but their correlation with exposure is uncertain.

count that is 10-fold greater than concurrent outdoor levels. Review of the National Aeroallergen Bureau results can provide a qualified indication of what constitutes a typical outdoor level and mix for a given region.

CRITICAL ELEMENTS OF THE ENVIRONMENTAL ASSESSMENT

Environmental assessments should be reported in a concise and interpretable format. Report formats should include the following as a minimum.

Scope of work

The aim of the survey should be spelled out explicitly in the beginning of the report. Any hypotheses tested should be stated, along with a description of the sampling that was performed to test the hypotheses.

Site and building description

The report should contain general information about the building or portion of building, including its address, size, age, number of occupants, date of assessment, and description of site contours and, if air sampling is included, weather conditions on that date. A schematic layout of the building is helpful, if available. Exterior features should be noted, including site slope, roofing, guttering, and foundation. Notes should be included on the status of interior mechanical systems, including HVAC systems, plumbing, and mechanical appliances. If any of these are excluded from the inspection, such exclusion should be noted. Some reports might include photographs of major components along with a description of any abnormalities pertaining to moisture/mold growth. Examples of a field-inspection guide (see Fig E1 at www.jacionline.org) and a field-observation record (see Fig E2 at www.jacionline.org) form can be found in the Online Repository.

Analytic results

Analytic results should be included for all samples, and indoor air quality measurements (eg, temperature, humidity, CO_2, CO, SO_2, NO_2, O_3, and volatile organic compounds) should be taken. A clearly explained semiquantitative scale by which the results can be judged ideally should accompany surface and bulk sample results. These results should be presented in a manner that allows interpretation as to whether the surface or material was colonized. An example of a laboratory report for analysis of surface samples (cello-tape lifts) can be found in the Online Repository (see Figs E3 and E4 at www.jacionline.org). For microscopic analysis, this might include note of any fruiting structures observed.

A report of airborne spore concentrations should include a summary of outdoor airborne spores in the same location at the time of sampling. These data estimate the portion of the indoor sample that might originate in the current outdoor air. Many reports include a ratio of indoor spores to outdoor spores for each genus in a separate column as a guide to the potential for indoor fungal amplification. Reports should provide some evaluation of the predominance or ranking of different fungal types. Indoor air samples, either viable (colony-forming units [CFU]) or nonviable (observed spores), should be quantitative, with results usually stated as spores or CFUs per cubic meter of air. And it is convenient for a report to calculate the percentage of all the spores represented by each genus or spore category. Results from air samples should include measured spore counts by genus and species when determined.

The report should also state the instruments (including type and model of sampler or measuring device), methods, and sample-collection protocols. A statement of recent calibration or calibration protocols should also be included (or available on request). Special circumstances associated with a sample (eg, HVAC fan on vs off) and prevailing meteorological conditions should also be noted.

For surface or bulk samples, a photograph of the collection site permits documentation of the size of the stain or fungal colony that was sampled. Vacuum dust samples should be quantitative when possible, with results provided as micrograms of allergen or number of CFUs per gram of dust or per square meter sampled.

Report of sample analyses

Reports of sample analyses for indoor mold vary greatly in clarity and ease of use. The reports should be designed to be helpful to the person reading them, and good reports will need the following features to be useful (Table III).

Sample log/chain of custody. A sample log documents where and how a particular sample was collected. The sample label (identification) should be recorded on the log to ensure that a reported result corresponds correctly to a specific sample, just as for clinical samples. Environmental samples will also typically have a chain of custody that lists for evidentiary purposes the sequence of individuals (with signatures with date and time of receipt) who have had custody of samples (as would be expected for samples pertaining to regulated pollutants and/or as evidence in criminal investigations).

TABLE III. Outline of items that should be included for an inspection report to be readily useful

A. Inspector
a. Identity of inspector and client
b. Relation, if any, to other parties
B. General building information
a. Location, type
b. Reason for inspection
C. Inspection findings
a. Observations
b. Measurements
i. Instruments used
ii. Findings
iii. Conclusions
D. Sampling/testing (if conducted)
a. Justification/rationale
b. Sample type, instrument used
c. Analysis type
d. Results
e. Outdoor results for air samples, weather
f. Interpretation
E. Conclusions re: presence of mold growth indoors
F. Recommendations

Ancillary laboratory information. The name of the laboratory and contact information, as well as the person with technical responsibility for the analysis, should be identified. Any certifications or accreditations held by the analyst or the laboratory should be listed. Any conflicts of interest, such as information that the laboratory is an owned subsidiary of the sampling organization or that the sampling organization is owned by or works exclusively for a remediation contractor, should be disclosed. Some states now prohibit firms from doing both environmental assessment and remediation on the same building.

The report's information should adequately convey understanding of the data's limitations. Air samples with fewer than 20 spores or colonies are difficult to interpret meaningfully because the percentage distribution is easily skewed with small total numbers. Most laboratories, for practical reasons, do not evaluate the entire sample but evaluate a fraction of the sample (traces) and extrapolate, just as aliquots of serum samples are analyzed. Spores are not always evenly distributed but can cluster on sample surfaces. This might lead to overestimates caused by including spore clusters or underestimates caused by evaluating traces without that spore type. Some protection against this is provided if spore-trap samples have at least 200 total spores counted. Similarly, culture samples should have at least 20 to 30 colonies per plate to give confidence to the interpretation.

Summary of analytic results and conclusions. Measurements and analytic results should be presented in tabular form along with a written interpretation of findings. Conclusions should be supported directly by data (sampling results and measurements) obtained during the assessment.

The report might include a statement concerning limitations constraining interpretations made from the data. For example, cautions are often included that the information only applies to a specific point in time and that conditions could have differed either before or since. These statements also might include a warning that the data provided should not override common-sense safety concerns and that the conclusions of the report should be used in context with current conditions.

Inspection report and analytic report examples

The Online Repository contains examples of a field-inspection sample log (Fig E1) and observation record (Fig E2). It also contains examples of laboratory analysis reports for cello-tape surface samples (Fig E3) and 2 versions of reports for the analysis of spore-trap air samples (Figs E4 and E5).

Information included for the client

Unfortunately, clients are often confused by reports that find mold (vs growth) and have a long list of possible health consequences and sometimes a very large estimate for removal of the problem. It should be emphasized that health consequences should be left to physicians. The report should at most have a recommendation to consult a qualified health care professional if there are areas of concern.

The question of remedial action to be taken by the client/homeowner for the building is another matter. Although there are no specific governmental guidelines for fungal presence, nearly all agencies, including the Centers for Disease Control and Prevention and the US Environmental Protection Agency, state that visible mold growth should be cleaned up properly and promptly. Guidelines for the remediation (clean-up) of mold growth are available on the internet and provide valuable general information about mold growth, an overview of procedures to expect, and where sampling might be needed after clean-up.[15]

KEY POINTS

Building inspections can be quite useful, if done well. Although the knowledge and skills needed are openly available, no single professional discipline routinely combines them, which means that physicians seeking the collaboration of an inspector have no simple and reliable means of identifying a qualified inspector but must evaluate inspectors singly.

There is limited consistency in reports of inspections, even from well-qualified inspectors. This requires physicians reviewing such reports to recognize key elements of reports and be able to have some judgment of the quality of a report. These elements include statement of purpose, identification of the building, identification of the investigator, observations, other findings (including testing if conducted), conclusions, and recommendations. Environmental inspection/testing reports should not include conclusions concerning medical causation. Testing should be considered a screening tool or as ancillary to an inspection. Testing results should confirm observations or otherwise support conclusions and can provide valuable information when conducted reasonably. However, in the absence of an informed inspection, only rarely will testing support definitive conclusions.

Several basic principles of mycology and mold sampling are essential to understanding an inspection report. These include how fungi colonize damp materials and which analytic results only suggest and which results clearly indicate colonization. One should also understand the strengths and weaknesses of current sampling techniques and analytic procedures to recognize whether the conclusions in a report are soundly based.

RECOMMENDED READING

See the Online Repository at www.jacionline.org for recommended reading, examples of inspection reports, and laboratory analysis reports of spore-trap samples.

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ADDITIONAL MOLD RESOURCES

For further information on many of the topics covered in the rostrum, several sources are specifically recommended.

The *Fifth Kingdom*, 3rd edition, by Kendrick and *Fungal Biology* by Deacon provide basic information on fungal taxonomy, fungal biology, and fungal ecology.

- Kendrick B. The fifth kingdom, 3rd ed. Newburyport (MA): Mycologue Publications; 2000.
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Microorganisms in Home and Indoor Work Environments: Diversity, Health Impacts, Investigation and Control by Flannigan et al provides a thorough review of airborne microorganisms in the indoor air. Fungal growth and its control in indoor environments are described, along with the health effects of fungal exposure. Indoor investigations and analysis are also discussed. This book also presents information on identification of fungi, including approximately 100 color photographs of the most commonly isolated fungi from indoor environments.

- Flannigan B, Samson RA, Miller JD. Microorganisms in home and indoor work environments: diversity, health impacts, investigation and control. New York: Taylor and Francis; 2002.

Bioaerosols: Assessment and Control, edited by Macher, offers a comprehensive guide to the assessment and control of bioaerosols in the workplace, although the information is certainly applicable to homes as well. Individual chapters were written by experts in the field and also contain information on health effects and fungal biology.

- Macher J, editor. Bioaerosols: assessment and control. Cincinnati: American Conference of Government Industrial Hygienist; 1999.

Damp Indoor Spaces and Health, published by the Institute of Medicine from the National Academies of Science, is a comprehensive review of the relationship between damp or moldy indoor environments and adverse health effects. The focus of the book is on fungi and their metabolites. It also discusses how buildings get wet, how moisture influences microbial growth, and how to prevent and remediate moisture in buildings. This detailed review of the literature found sufficient evidence of a connection between damp indoor environments and coughing, wheezing, and asthma symptoms in sensitized individuals.

- Committee on Damp Indoor Spaces and Health. Damp indoor spaces and health. Washington (DC): National Academy Press; 2004. Available at: http://www.nap.edu/books/0309091934/html.

Guidance for Clinicians on the Recognition and Management of Health Effects Related to Mold Exposure and Moisture Indoors by Storey et al is a valuable resource for physicians published by the University of Connecticut Health Center. This publication addresses physicians' questions about exposure to indoor mold and moisture. It can help physicians identify patients and illnesses that might be related to mold; it describes health effects of mold exposure, environmental assessment, and remediation. Several clinical case studies are included, and environmental questionnaires are provided for use in assessing a patient's indoor environment. This manual is available for downloading on the internet at http://oehc.uchc.edu/clinser/MOLD GUIDE.pdf.

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Microorganisms, Mold, and Indoor Air Quality is a concise but thorough and accurate booklet produced by the American Society for Microbiology for a general audience. This is a well-balanced presentation of the issues and is available on the American Society for Microbiology website.

- Microorganisms, mold, and indoor air quality. Available at: http://www.asm.org/ASM/files/ccLibraryFiles/FILENAME/000000001277/Iaq.pdf.

Other useful mold resources on the internet include Web sites provided by the Environmental Protection Agency (http://www.epa.gov/mold/index.html) and the Centers for Disease Control and Prevention (http://www.cdc.gov/mold/default.htm).

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MVOCs

The musty or earthy smells of actively growing mold are caused by MVOCs. Some of these compounds are considered unique products of, and are hence useful markers of, mold growth.[E1] There are, however, complications of MVOC analysis that currently limit its practical usefulness. Foremost is the fact that volatile organic compounds originate from numerous sources in a structure, including insulation, carpet, wood products, and even furnishings, and thus specific identification of volatile organic compounds in a sample is needed to recognize the MVOCs. The cost of analyzing an MVOC sample is higher than for other sample types, but interpretation still usually requires multiple samples, including reference locations. MVOC concentrations vary by orders of magnitude,

depending on ventilation, substrate composition and moisture levels, and competing microorganisms. MVOC analysis can be informative but currently is not widely used.

INSPECTOR QUALIFICATIONS AND RELEVANT PROFESSIONS/TRADES

Because no current credential is widely recognized for mold inspection, some mention is appropriate for several common backgrounds of inspectors.

Home inspectors know building construction, industrial hygienists measure exposures for compounds with known dose responses, and mechanical engineers understand moisture in air and often in materials. Microbiologists and mycologists can measure organism abundance, but the formal training of building scientists, and biodeterioration specialists arguably can best address water damage and mold growth, but there are relatively few specialists in these fields.

REFERENCE

E1. Horner WE, Miller JD. Microbial Volatile Organic Compounds with emphasis on those arising from filamentous fungal contaminants of buildings. ASHRAE Trans 2003;109:215-31.

Environmental Health Survey
Site Sampling Record for Laboratory Samples
Chain of Custody

EHS ID #: _____

Contact: _____
Site Address: _____

Phone #s: (H) - (W) -

FOR LAB USE ONLY
Lab Batch ID #: _____
Samples Logged In: _____
Date: _____
Due Date: _____

Investigator's Name(s): _____ Sampling Date: _____

Instructions / Special Requirements:

OnSite Measurement
IAQ-Calc ID#: 10760 / 10767
CO Instr. ID#: MR-9513 / AIM450

Indoor Air Sampling and Measurement

Fungal Air Sampling Allergenco ID#(s):

FA Sample ID#	Slide ID	Trace ID	Sample Time	Sample Location and Description	OS Sample ID#	FAS Lab ID#
A01			10 min			
A02			10 min			
A03			10 min			
A04			10 min			
A05			10 min			

Viable Sampling

Sample ID#	Sample Time	Sample Location and Description	Lab ID#
M01	20 minutes		

Bacterial Surface Sampling

Sample ID#	Surface Matrix	Sample Location and Description	Approx. Rep. Area (sq ft)	Lab ID#
B01				
B02				

Fungal Surface Sampling

Sample ID#	Surface Matrix	Sample Location and Description	Approx. Rep. Area (sq ft)	Lab ID#
S01				
S02				

Allergen Vacuum Sample

Sample ID#	Sample Media	Area Sampled (sq ft)	Sample Location and Description	Approx. Rep. Area (sq ft)	Lab ID#
V01			Child's Room		
V02			House vacuum		

Samples Relinquished by	Date/ Time	Accepted By	Date / Time

FIG E1. Sample field-inspection guide, including sample collection information. An example of an inspection form used to record observations during a field inspection of a building and to record sample collection information during an inspection is shown. Note that information on several types of samples might be recorded on this form and that the approximate number and type of samples is anticipated. This is useful for an inspection that is intended to be repetitive, to follow a similar pattern, or both, as in a housing survey or patient study. Forms for an inspection responding to an initial complaint might require more flexibility. Note also that spaces are provided for a chain-of-custody signature, which is useful regardless of the type of inspection.

ENVIRONMENTAL SURVEY	Today's Date
Name	Date of Birth

Address: _____

_____

City _____ State ____ Zip _____

Home Phone (_____) _____-_____

Work Phone (_____) _____-_____

Length of time at current residence: _____

Age of Building: _____

Number of Floors in Building _____

Days per week living in Building: _____

Patient/Client Type
ف CMH patient ف Non CMH patient
ف Pre-purchase ف Referred by _____
ف Other _____

Visit
ف Initial ف visit 2 ف visit _____

Owner/Renter Relationship to Patient/Client:
ف Self ف Parents ف Grandparents
ف Mother ف Father ف Aunt/Uncle
ف Foster home ف Other _____

Building Type
ف Single Unit ف Apartment ف Duplex
ف Townhouse ف Modular ف School
ف Office Bldg ف Mobile Home ف Church
ف Other _____

Building Owner
ف Self ف Rental ف Public
ف Government ف Business ف Other _____

Location:
ف Urban residential ف Urban commercial
ف Suburban ف Small Town ف Rural
ف Other _____

Nearby Exposures:
ف Factories ف Wooded Area ف Fields
ف Animal lots ف Highway ف Railroad
ف Other _____

Other Factors:
ف Painting ف Construction ف Duct Cleaning

Flooding:
ف Recent ف Old ف None

Heating and Air Conditioning:

Cooling: ف None
ف AC, Central ف AC, Window ف Fan, Attic
ف Fans, Ceiling ف Fan, Room ف Fan, Window
ف Other _____

Heating: ف None
ف Central, Gas ف Central, Electric ف Oil
ف Radiator, Steam ف Baseboard, Electric ف Gravity
ف Wood Burning ف Kerosene
ف Other _____

Central Humidifier: ف Yes ف No

Portable Humidifier: ف Yes ف No

Filter: changed _____ times/year
ف Fiberglass ف Pleated ف electrostatic
ف HEPA ف Other: _____

Portable Air Cleaning Device: ف None
ف Ozone ف HEPA ف Ionizer
ف Carbon

Vacuum Cleaner: ف None
ف Central ف Upright ف Canister
ف High Efficiency ف HEPA ف Water Trap

Pests: ف None
ف Cockroach ف Rodents ف Other _____
ف Frequency of insecticide use: _____

Pets:	Number	Where Permitted: Inside	Out	Bedroom
ف Dogs	____	ف	ف	ف
ف Cats	____	ف	ف	ف
ف Other _____	____	ف	ف	ف
ف Other _____	____	ف	ف	ف
ف Other _____	____	ف	ف	ف

Pg. _____ of _____

FIG E2. Example of field-observation record sheet used for a clinical study. An example of a survey form used to record data for a clinical study collecting clearly defined and predetermined observations and measurements is shown. Note that typical environmental surveys (vs clinical research) would not record date of birth. This is one page of a multipage survey form.

Released by Quality Laboratories, Inc.
Date Prepared: April 1, 200X
Project #: S0YYYY
Report #: S0YYYY-0X

DIRECT MICROSCOPIC EXAMINATION OF CELLOTAPE SAMPLES FOR FUNGI

PROJECT YYYY
YOUR TOWN, USA

Sample ID	Sample Location	Date Sampled (Date Analyzed)	Taxa [c]	Spores [a]	Hyphae [b]	Fruiting [b] Structures	Remarks
T101	105 Bathroom, Front Side, Visible Mold on Gypsum	03/31/0X (04/1/0X)	Chaetomium	A		F	(indicates colonization, determine extent of affected area)
			Penicillium/Aspergillus	F			
			Stachybotrys	M	A	A	
			Ulocladium	F			
T102	118 Room, Face of Gypsum	03/31/0X (04/1/0X)	Aspergillus	A		A	-Aspergillus conidiophores
			basidiospores	S			(indicates colonization, determine extent of affected area)
T103	110, Window Frame	03/31/0X (04/1/0X)	Cladosporium	A	F	S	(indicates colonization, possibly due to window condensation, clean window)
T104	Hallway 117 to 119, Chair molding	03/31/0X (04/1/0X)	Cladosporium	A			(consistant with Table Top Mold, unremarkable)
			smuts/ Periconia / myxomycetes	S			
			ascospores	S			

[a]Spore amounts noted as: S = Scattered Single, F = Few, A = Abundant, or M = Massive.
[b]Amounts of Hyphae/Fruiting Structures noted as: S = Scattered Single, F = Few, or A = Abundant.
[c]Commonly seen genera that are readily identifiable if present: Alternaria, Chaetomium, Eurotium, Cladosporium, Penicillium/Aspergillus, Stachybotrys.

FIG E3. Example of tape lift or cello-tape sample for mold growth (colonization) on surfaces. An example of a report from the analysis by means of direct microscopy of surface samples (cello-tape lifts) from an environmental microbiology laboratory is shown. A key finding of such analysis is whether evidence of fungal colonization is present on the sample. Note that under "Remarks," the conclusions and recommendations in parentheses are typical of what an investigator would provide as interpretation of the laboratory report in conjunction with on-site observations. These conclusions would not be expected to be provided by the laboratory but would be based on laboratory results in conjunction with the inspector's on-site observations.

Environmental Allergen Laboratory Fungal Spore Analysis by Light Microscopy

Air Sample Report

Contact: _____ Site Address: _____ Lab Batch ID#: _____

Sampling Date: _____ Date of Analysis: _____ Sampling Method: Volumetric- Total Spores

Client Sample ID:					0			A01	0			A02	0			A03
Sample Location:	Outdoor Sample															
Lab Sample ID:	Outdoor Sample					0		A01		0		A02		0		A03
Slide #	1	Time	Rate	Total	1	Time	Rate	Total	1	Time	Rate	Total	1	Time	Rate	Total
Trace #		(min)	(m^3/mn)	m^3	1	(min)	(m^3/mn)	m^3	2	(min)	(m^3/mn)	m^3	3	(min)	(m^3/mn)	m^3
Sample Volume (m3):		10	0.015	**0.15**		10	0.015	**0.15**		10	0.015	**0.15**		10	0.015	**0.15**

Fungal Spore Genera	Results				Results					Results					Results				
	Raw Count	Sweep	Predominance (%) (TS)/ m^3		Raw Count	Sweep	Predominance (%) (TS)/ m^3		Indoor Outdoor Ratio (I/O)	Raw Count	Sweep	Predominance (%) (TS)/ m^3		Indoor Outdoor Ratio (I/O)	Raw Count	Sweep	Predominance (%) (TS)/ m^3		Indoor Outdoor Ratio (I/O)
Alternaria	0	10	**ND**	ND	0	10	**ND**	ND	NA	0	10	**ND**	ND	NA	0	10	**ND**	ND	NA
Arthinium	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Ascospores	0	5	**ND**	ND	0	10	**ND**	ND	NA	0	10	**ND**	ND	NA	0	5	**ND**	ND	NA
Aspergillus / Penicillium	0	64	**ND**	ND	0	10	**ND**	ND	NA	0	5	**ND**	ND	NA	0	5	**ND**	ND	NA
Basidiospores	0	5	**ND**	ND	0	10	**ND**	ND	NA	0	10	**ND**	ND	NA	0	10	**ND**	ND	NA
Bipolaris/ Dreschleria	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Bispora	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Botrytis	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Cercospora	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Chaetomium	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Cladosporium	0	5	**ND**	ND	0	10	**ND**	ND	NA	0	5	**ND**	ND	NA	0	10	**ND**	ND	NA
Curvularia	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	32	**ND**	ND	NA
Epicoccum	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Helicomycete	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Nigrospora	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Oidium	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Periconia	0	64	**ND**	ND	0	20	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Peronospora	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Pithomyces	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Puccinia	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Smuts/Myxomycetes	0	5	**ND**	ND	0	10	**ND**	ND	NA	0	10	**ND**	ND	NA	0	10	**ND**	ND	NA
Sordaria	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Spegazzinia	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Stachybotrys	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Stemphillium	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Tetraploa	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Torula	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Ulocladium	0	64	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Unique Fungi Identified																			
Rusts	0	64	**ND**	ND	0	10	**ND**	ND	NA	0	10	**ND**	ND	NA	0	10	**ND**	ND	NA
Polythrincium	0	10	**ND**	ND	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA	0	64	**ND**	ND	NA
Pollen	0	64	**ND**		0	64	**ND**			0	64	**ND**			0	64	**ND**		
Algae	0	64	**ND**		0	64	**ND**			0	64	**ND**			0	64	**ND**		
Total Problem Spores			**0**				**0**					**0**					**0**		
Total Spores			**0**				**0**					**0**					**0**		

Analyst Signature: _____ Date: _____ QC Review Chk: _____

Method of Analysis: Light Microscopy Microscope Used: Zeiss Model P Microscope ID: P1

FIG E4. Example of fungal spore-trap laboratory report, with spore types arranged alphabetically. This illustrates an example of a typical report of a spore-trap analysis from an environmental laboratory. Note that the fungal taxa are arranged alphabetically. Note also that the report provides raw counts of results, as well as results expressed in concentrations and percentages.

AIR SAMPLES FOR FUNGAL SPORES
ALLERGY CENTER
123 ELM STREET HOMETOWN, YOUR STATE

	Sample ID:	S11[d]			S12[d]			S13[d]			S14[d]		
	Sample location:	ROOF			ROOF			UPPER LEVEL			UPPER LEVEL		
	Date collected:	dd/mm/yy			dd/mm/yy			dd/mm/yy			dd/mm/yy		
	Analysis date:	dd/mm/yy			dd/mm/yy			dd/mm/yy			dd/mm/yy		
	Military time:	12:46			12:46			12:12			12:12		
	Trace:	Moderate			Moderate			Moderate			Moderate		
	Pollen:	None			None			None			None		
	Skin Scales:	Light			Moderate			Moderate			Moderate		
	TAXA	Count[a]	Particles/m^3 [b]	% of Total [b]	Count[a]	Particles/m^3 [b]	% of Total [b]	Count[a]	Particles/m^3 [b]	% of Total [b]	Count[a]	Particles/m^3 [b]	% of Total [b]
LEAF SURFACE/ OUTDOOR TAXA[c]	Alternaria												
	ascospores	171	2,850	32%	186	3,100	39%	5	83	3%	6	100	5%
	basidiospores	249	4,150	46%	207	3,450	43%	17	283	10%	13	217	11%
	Bipolaris/Drechs/Helminth							1	17	1%	2	33	2%
	Cercospora	1	17	0%									
	Cladosporium	50	833	9%	38	633	8%	6	100	4%	6	100	5%
	Curvularia												
	Epicoccum												
	Ganoderma												
	Pestalotia												
	Pithomyces												
	rusts												
	Stemphylium												
SOIL MOLD TAXA[c]	Arthrinium												
	Penicillium/Aspergillus	46	767	9%	21	350	4%	113	1,883	69%	87	1,450	71%
	Trichoderma (like)												
WATER DAMAGE TAXA[c]	Chaetomium							3	50	2%	4	67	3%
	Stachybotrys												
	Ulocladium							2	33	1%	1	17	1%
OTHER TAXA[c]	Helicomyces												
	hyaline conidia	19	317	4%	27	450	6%	16	267	10%	4	67	3%
	hyphal fragments	1	17	0%	1	17	0%						
	myxomycetes/Periconia/smut				3	50	1%						
	Nigrospora												
	Spegazzinia												
	Tetraploa												
	Torula												
	unidentified	1	17	0%				1	17	1%			
	Scopulariopsis												
	Chaetomium (like)												
	SAMPLE VOLUME (m^3):		0.060			0.060			0.060			0.060	
	Leaf Surface Group Total:	471	7,850	88%	431	7,183	89%	29	483	18%	27	450	22%
	Soil Mold Group Total:	46	767	9%	21	350	4%	113	1,883	69%	87	1,450	71%
	Water Damage Group Total							5	83	3%	5	83	4%
	Other Group Total:	21	350	4%	31	517	6%	17	283	10%	4	67	3%
	GRAND TOTAL:	538	8,970		483	8,050		164	2,730		123	2,050	

[a]Count denotes number of spores identified of given spore type; no count denotes no spores observed of the given type. Sample counts obtained by direct microscopic examination of wet-mounted slides.

[b]Concentrations and percentages rounded; values less than 0.5 may appear as zero. NA - Not Applicable

[c]The grouping of taxa within categories is based on general information about common sources or airborne spores of these taxa; these groups are not absolute and some overlap occurs. These groupings are presented only as an aid to interpretation, not as an indication of the source of spores in a particular sample.

FIG E5. Example of a fungal spore-trap laboratory report, with groups arranged by ecologic groups. This report of a spore-trap analysis from an environmental laboratory arranges the results by ecologic groups (although these groups are not absolute, see note "c" in the illustration). Note that the 4 samples represent pairs of samples collected side-by-side in 2 locations and show the variability that is intrinsic to air sampling for fungal spores. The outdoor samples (roof) with total spore concentrations of 8970 and 8050 (fungal) particles per cubic meter of air and 9% and 4% of soil-type molds are reasonably consistent. This represents a level of variability typically seen in spore-trap sampling/analysis where multiple samples are taken. Although the total concentrations indoors (upper level) are less than one third of the outdoor levels, note that the indoor samples are dominated (70%) by soil-type molds (whereas this type is <10% in the outdoor samples) and contain spores of molds associated with water damage; this mixture suggests indoor mold growth.