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Standard Guide for Assessment Of Fungal Growth in Buildings[1]

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1. Scope

1.1 This guide provides a compendium of information and a menu of options for assessment of fungal growth in buildings, but does not recommend a specific course of action. Due to the wide variety of fungal problems affecting buildings and their occupants, and the wide variety of buildings, it is not possible to describe a set of uniform steps that will always be performed during an assessment (that is, a standard practice); therefore the user of this guide must decide which steps are appropriate for a given situation or building.

1.2 This guide is specific to fungal growth, which is only one potential problem in a building environment. It may be part of, but is not intended to take the place of, a comprehensive indoor air quality investigation.

1.3 This guide describes minimum steps and procedures for collecting background information on a building in question, procedures for evaluating the potential for moisture infiltration or collection, procedures for inspection for suspect fungal growth, and procedures beyond the scope of a basic survey that may be useful for specific problems.

1.4 Assessments for fungal growth may be useful wherever fungal growth is suspected, excess moisture has been present or when there are concerns regarding potential fungal growth.

1.5 Periodic fungal assessment in buildings may be a component of preventative maintenance programs.

1.6 This guide is applicable to buildings including residential (for example, single or multi-family), institutional (for example, schools, hospitals), government, public assembly, commercial (for example, office, retail), and industrial facilities.

1.7 Recommendations for developing a sampling strategy or methods for the collection and analysis of fungal samples are beyond the scope of this guide. For recommendations for developing a sampling strategy, see Ref (**1**)[2], Chapter 10.

1.8 Recommendations for remediation of fungal growth are beyond the scope of this guide.

1.9 This guide is not intended to supersede any government regulations governing the assessment of fungal growth in buildings.

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.11 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C755 Practice for Selection of Water Vapor Retarders for Thermal Insulation

C1699 Test Method for Moisture Retention Curves of Porous Building Materials Using Pressure Plates

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials

E331 Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference

E547 Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference

E631 Terminology of Building Constructions

E1105 Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E1186 Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems
E1356 Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry
E2128 Guide for Evaluating Water Leakage of Building Walls
E2270 Practice for Periodic Inspection of Building Facades for Unsafe Conditions

2.2 *Non-ASTM Standards:*
ANSI/GEI Standard MMS1001 Mold and Moisture Management Standard for New Construction

3. Terminology

3.1 *Definitions:*

3.1.1 *building envelope, n*—the outer elements of a building, both above and below ground, which divide the external from the internal environments. Commonly included are exterior walls, windows, doors, roofs and subfloors. **E631**

3.1.2 *bulk sample, n*—piece or quantity of bulk material that has been selected by some sampling process. **D653**

3.1.3 *capillary action, n*—(or *capillary migration*), of water, movement of water induced by the force of molecular attraction (surface tension) between the water and the material it contacts. **E631**

3.1.4 *condensation, n*—the process of converting a material in the gaseous phase to a liquid by decreasing temperature or by increasing pressure, or both. **E1356**

3.1.5 *exposure, n*—contact with a chemical, biological, physical, or other agent over a specified time period. **E1356**

3.1.6 *moisture content, n*—mass of water retained in the specimen divided by the dry mass of the specimen. **C1699**

3.1.7 *soot, n*—agglomerations of particles of carbon impregnated with tar, formed in the incomplete combustion of carbonaceous material. **E1356**

3.1.8 *vapor retarder, n*—a material or system that adequately impedes the transmission of water vapor under specified conditions. **E631**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *boroscope, n*—device for internal inspection of difficult access locations such as wall cavities. Its long narrow tube contains a telescope system with a number of relay lenses. Light is provided via the optical path or fiber bundles.

3.2.2 *effloresce, v*—process by which water leaches soluble salts out of concrete or mortar for surface deposit. Also *efflorescence, n,* the name for these deposits.

3.2.3 *enzyme activity, n*—measure of the quantity of active enzyme present. Enzyme activity is essential to metabolism. Specifically, beta-N-acetylhexosaminidase (NAHA) is an enzyme present in all filamentous fungi, the measurement of which has been shown to be directly proportional to the amount of fungal biomass (see **(2, 3)**.

3.2.4 *fungus (s), fungi (pl.), n*—eukaryotic, heterotrophic, absorptive organisms that usually develop a rather diffuse, branched, tubular body (that is, network of hyphae) and usually reproduce by means of spores **(4)**. The terms 'mold' and 'mildew' are frequently used by laypersons when referring to various fungal colonization.

3.2.5 *fungal spore, n*—general term for a reproductive structure in fungi. The spore is the structure that may be used for dissemination and reproduction, and may be resistant to adverse environmental conditions.

3.2.6 *hypha, n*—(pl. *hyphae*) tubular filament of fungal cells; the basic vegetative structure of the body of fungi (excluding yeasts).

3.2.7 *fungal growth, n*—vegetative portion of a fungus.

3.2.8 *infrared thermography, n*—thermal imaging, also called thermography, is the production of non-contact infrared, or "heat" pictures from which temperature measurements can be made.

3.2.9 *remediation, n*—to correct a problem. Related to fungal contamination, remediation includes correcting the water and moisture problems and the cleaning, removal, and/or replacement of mold-damaged or -contaminated materials.

3.2.10 *thermal bridging, n*—a phenomenon that occurs when heat is transferred at a substantially higher rate through a component, or assembly of components in a building envelope, than through the surrounding envelope area.

4. Summary of Guide

4.1 This guide presents a framework for locating and evaluating suspect fungal growth in buildings. Topics include background information, a basic assessment strategy and additional or advanced procedures.

4.2 Components of a basic assessment strategy may include (*1*) defining a scope of work, (*2*) collecting background information on the building and building systems, (*3*) formulation of a hypothesis or hypotheses, (*4*) an on-site survey for fungi, moisture dynamics, and heating. ventilating and air conditioning (HVAC) operation, and (*5*) documentation and reporting. Every component of the basic assessment shown below may be considered optional, since even some of the most basic steps may not be needed for certain well-defined situations.

4.3 When the information from the basic assessment is insufficient to support decision-making, additional procedures for a follow-up study may include: (*1*) characterizing site moisture in greater detail to assist in locating suspect fungal growth and controlling excess moisture; (*2*) accessing surfaces likely to harbor hidden fungal growth; and/or (*3*) sampling if necessary to test a specific hypothesis.

5. Significance and Use

5.1 This guide presents options for a systematic assessment of fungal growth in buildings.

5.2 This guide allows for site-specific flexibility and professional judgment in the choice of assessment procedures. It may not be necessary to perform in its entirety the basic assessment presented below to resolve a particular problem, for example, where fungal growth is localized and the source and extent of moisture is readily observable.

5.3 Conversely, no matter how comprehensive the survey, all fungal growth may not be identified or located in a fungal assessment.

5.4 Material removal or destructive investigation may be needed to access suspect surfaces.

5.5 Using the procedures described in this guide, the investigator may have obtained the data necessary to suggest specific recommendations, for example, how to remediate the observed fungal growth, or how to prevent further fungal growth, but those recommendations are beyond the scope of this guide.

5.6 Precautions may be needed to protect the assessor and building occupants where access may disturb fungal growth.

5.7 It is the user's responsibility to protect information that may be considered confidential, or private, or both, in accordance with project contract, corporate protocol, or local, state, and federal regulations, or a combination thereof.

5.8 It may be necessary to enlist other disciplines or trade expertise to assist in some steps of the assessment, but recommendations of when to enlist and whom to enlist are beyond the scope of this guide.

6. Background Information

6.1 *Fungal Biology:*

6.1.1 *Fungal Growth*—Fungi constitute over 25 % of the earth's biomass and are naturally present in every indoor and outdoor environment. Fungal spores (small propagules emitted from surface growth) are ubiquitous in air and settled dust. Fungal growth requires sufficient available moisture that is sustained for a sufficient time, a suitable food source/substrate, and a favorable range of temperature and pH. Both active and inactive (past) growth are termed "colonization" (**5**, **6**, **7**). Fungi can become dormant only to resume growth again in response to changing environmental conditions (for example, during periodic moisture intrusions).

6.1.2 *Fungal Spore Production*—Fungal spores are produced during active growth, but may be released into the air either during active growth or dormancy. Where fungal growth is located behind a wall, wall covering, ceiling, or carpet, spores may, but are less likely to reach the occupied space through this physical barrier (the potential for infiltration depends on pressure differentials, filtration, occupant activities, barrier openings and other pathways, etc.) (**8**, **9**, **10**, **3**).

6.1.3 *Fungal Variation*—Types and concentrations of airborne or surface fungal spores at a given site as well as colonization vary substantially as they are influenced by many natural and manmade factors. Because of this variability, testing based on a limited number of samples may not be representative (**6**, **7**).

6.2 *Fungal Growth in a Building:*

6.2.1 Indoor fungal growth is generally observed on surfaces subject to one or more of these conditions:

6.2.1.1 Condensation;

6.2.1.2 Spills, leaks or floods;

6.2.1.3 Consistent wetting, such as from landscape sprinklers;

6.2.1.4 Sustained elevated humidity;

6.2.1.5 Wicking due to capillary action from wet material.

6.2.2 Whether or not fungal growth actually occurs is dependent on:

6.2.2.1 Substrate porosity (for example, materials such as carpet tack strip and conventional drywall are highly susceptible),

6.2.2.2 Moisture resistance (for example, some drywall, gypsum plaster and sheathing products are modified to resist moisture or to limit water storage and/or are treated with an anti-microbial agent),

6.2.2.3 Moisture duration (for example, leaks which are single events or intermittent may dry before fungal growth is initiated; elevated humidity typically does not trigger fungal growth unless it is sustained),

6.2.2.4 Air circulation and dehumidification (for example, moisture may remained trapped when sealed behind baseboards, attached furniture or vapor barriers).

6.3 *Detection of Fungal Growth:*

6.3.1 *Fungus grows on an appropriate substrate.* Fungal growth is associated with biodegradable building materials (for example, paper covered gypsum wallboard, wood, ceiling tiles). It will not grow on inorganic materials (for example, masonry, concrete, gypsum plaster, stone, glass, ceramic tiles, grout) except where dust, dirt, grease or oil is present. It usually appears on surfaces which are wet or were previously wet. Fungal growth may pre-exist on wood surfaces not subject to water damage on-site. For example, wood used for building materials often becomes stained during tree growth or milling

6.3.2 *Fungal growth may be detected by simple visual inspection.* Fungal growth may appear as raised, powdery deposits, rings or colored spots which may be black, gray, white, green, red, resembling cotton, velvet, leather, or powder. When rubbed, dried fungal growth tends to spread or smear as a powder.

6.3.3 *Discoloration is not necessarily fungal growth.* The following surface markings should not be categorized as suspect fungal growth: yellow/brown water stains, scuffs, soot, dye, dust, ghosting (dust deposits form an outline on a cool surface), efflorescence, adhesives, and other residues of occupancy, maintenance, or construction.

6.3.4 *Visual detection of fungal growth is not always definitive.* Where the origin of discoloration or staining is not clearly fungal or non-fungal to the investigator, the discoloration should be considered suspect fungal growth. In some cases, an ambiguous appearance may be resolved by comparing the suspect surface with the same material which has not been subjected to wetting to determine if the suspect color or texture was pre-existing. If essential to the assessment conclusions, the discoloration may be confirmed (see below).

6.3.5 *Visual detection of fungal growth may not always be possible even when exposed.* Very early stages of fungal growth may not be visible to the unaided eye. Visual detection of fungal growth may be difficult where substrate color is similar (for example, black on black) or where discoloration is covered by dust or debris.

6.3.6 *Fungal growth may be inaccessible or hidden.* Many surfaces in a building cannot be examined without considerable

damage, for example, the back or inside of wall cavities or plumbing chases. It is axiomatic that fungal growth cannot be visually detected on a surface that was not examined. Nearby fungal growth may be hypothesized if surface deposits are found to be consistent with settled material generated by fungal growth. In such a case, destructive examination may have to be added to the scope of work in order to find the fungal growth in situ.

6.3.7 *Visually suspect fungal growth may be confirmed.* Microscopical examination, culture or biochemical analysis (for example, enzyme activity-NAHA or ergosterol) can be used to confirm the presence of fungal material or fungal growth. Analytical findings of the presence of spores alone do not demonstrate growth because of the ubiquitous presence of spores in settled dust. Analytical methods differ in their ability to accurately identify fungal types (**6**, **7**, **11**, **12**, **3**, **13**).

6.4 *Building Moisture:*

6.4.1 *Moisture Characteristics*—An understanding of building moisture is generally necessary to help identify the underlying cause of fungal growth and estimate the extent. When evaluating moisture dynamics in a facility, the following potential pathways should be considered (**14**):

6.4.1.1 Rain leakage through the building envelope may involve simple penetration or be wind-driven. Leak points often occur at borders between materials (for example, damage, gaps, deficient flashing), which are generally visible to the naked eye.

6.4.1.2 Brick and concrete block are porous, affording a potential pathway for moisture in buildings.

6.4.1.3 Water flows to lower elevations by gravity.

6.4.1.4 Water may rise against gravity (wick) through a porous material by capillary action.

6.4.1.5 Air infiltration containing water in a gaseous phase occurs.

6.4.1.6 Water vapor migrates to areas of lower air or vapor pressurization (for example, may be driven by molecular diffusion, mechanical system or wind).

6.4.1.7 Evaporation of standing water may increase airborne moisture available to fungi.

6.4.1.8 Water leakage may remain hidden within wall, ceiling or floor systems.

6.4.2 *Common Moisture Problems* (A lack of moisture balance between wetting and drying of building assemblies):

6.4.2.1 *Construction-Related*—During the construction process, the following situations may contribute to fungal growth: (*1*) stockpiled materials which are open to the elements, (*2*) products installed with excessive moisture, (*3*) infiltration of rain or runoff into the unfinished structure (for example, while roof or drainage structures are incomplete), (*4*) structural materials installed over wet surfaces, (*5*) infiltration of hot, humid air before air conditioning is operational, (*6*) ineffective vapor retarder installation and/or crawl space ventilation, and (*7*) insufficient waterproofing of the foundation.

6.4.2.2 *Envelope-Related*—Deficiencies related to construction defects such as improperly installed or missing flashing, weep holes, membranes, and gaps in finishes, sealants or air cavities may result in leaks including: (*1*) roof leaks, (*2*) window leaks, and (*3*) façade leaks (E2128, E331, E2270).

6.4.2.3 *Wind-Driven*—Where the above sources of moisture are wind-driven, damage may tend to concentrate on one side of the building or at different heights (E2128).

6.4.2.4 *Humidity-Related*—Fungal growth may occur when humidity is elevated over an extended period of time when: (*1*) there is excessive natural ventilation with humid air (for example, through open windows, structural penetrations, or crawlspace vents); (*2*) there is localized high humidity promoted by lack of air circulation; (*3*) there is condensation of humid air on cooled surfaces (for example, wall cavities may contain condensed moisture from outside in a hot climate or from inside in a cool climate which reaches its dew point on an assembly which supports fungal growth), (*4*) there is thermal bridging such as exterior walls by the floor; and (*5*) there is moisture movement from crawlspace soil that is not covered by an adequate vapor retarder (C755, (**5**, **14**); and see also HVAC-Related).

6.4.2.5 *Occupancy-Related*—Activities of the building occupants may impact moisture levels as follows: (*1*) laundry (for example, unvented clothes dryer), (*2*) failure to operate exhaust in shower, bath or cooking area, (*3*) cleaning (for example, excess water use or inadequate drying), (*4*) potted plants (for example, over-watering), (*5*) spills or overflows (for example, sink, tub), (*6*) wet contents (for example, damp laundry), (*7*) pools, spas or other water features, (*8*) fire suppression, and (*9*) maintenance (for example, failure to promptly resolve moisture-related incidents).

6.4.2.6 *Plumbing-Related*—Mechanical systems commonly contribute to fungal growth as follows: (*1*) pipe leaks, (*2*) drain backups, and (*3*) pipe condensation (for example, insulation deficiencies).

6.4.2.7 *Drainage-Related*—Water originating adjacent to or under the building may be significant when the following occur: (*1*) flooding from excessive rainfall or snow melt, (*2*) high water table, (*3*) inadequate drainage control, (*4*) moisture wicks through foundation causing basement dampness, (*5*) sump pump failure, and (*6*) blocked French drain (**14**).

6.4.2.8 *HVAC-Related*—Design, operation, and maintenance of building systems may impact moisture levels as follows: (*1*) inadequate condensate drainage (for example, drain pan overflows due to blockage); (*2*) moisture carries over beyond coils; (*3*) excessive humidification; (*4*) system fails to provide adequate humidity control due to design, malfunction, or unrepresentative controls or sensor location (for example, if the outside air exceeds capacity of the system to dehumidify, or if the outdoor air damper remains open to allow continual humid air influx, or if oversized cooling capacity limits the time when dehumidification can take place); and (*5*) moisture becomes entrained on filters or intake (**15**, **14**).

6.4.2.9 See Ref (**16**) for detailed descriptions of typical building moisture problems.

7. Basic Fungal Growth Assessment

7.1 The most important requirement of an assessment for fungal growth is an on-site inspection of the subject building or portion of the building as per the scope of work. The

professional performing the assessment may choose or emphasize or minimize any of the topics below during the assessment, as the scope of the project and its quality objectives dictate. Parts of an assessment may include: the collection of background information, the formulation of a hypothesis or hypotheses, an on-site inspection including moisture dynamics, an evaluation of the HVAC system, hypothesis testing, site documentation and written report.

7.2 *Scope of Work*—Before attempting an inspection or assessment, a detailed scope of work should be agreed upon by the principals of the investigation (for example, building owner, manager, lawyer, consultant, investigator). Some scopes may be extremely limited (for example, find the extent of the fungal growth resulting from a single event water leak), to virtually unlimited (for example, investigate a case of employee malaise). Topics to be considered before agreeing to a scope of work include but are not limited to: (*1*) the buildings, building or part of a building to be assessed, (*2*) the nature of the problem, including complaints from occupants, if applicable, (*3*) budget, (*4*) building use and occupation (for example, unoccupied, business, residence, hospital, assisted living facility), (*5*) accessibility to the area(s) of concern, and (*6*) a clear statement of the limitations of the assessment. Occupant complaints, often assumed to be attributable to building fungal growth, may be caused in whole or in part by unrelated illness, non-fungal environmental factors, or may be psychosocial in nature. Odors may also originate from sources other than fungi. Where non-fungal factors may be significant, special consideration should be given to expanding or at least sharply delineating the scope of the assessment. The scope of work defines the problem and, just as importantly, which part of the basic assessment and which of the optional procedures, if any, are to be performed.

7.3 *Collecting Background Information*—Collecting background information may be essential for an assessment where the cause of fungal growth is not known or detailed in the scope of work.

7.3.1 *Documentation Review*—Knowledge of structural and mechanical design, historical concerns, and past activities addressing moisture-related issues are useful components of an assessment unlimited by the scope of work. Architectural and mechanical plans can be used in locating potential pathways for water movement, infiltration of humid air and surfaces subject to condensation. Review of HVAC design may indicate its capability to control humidity. Review of the drainage system design will indicate the ability to handle extraordinary precipitation events (E2128). Note how the original design use and occupancy differ from the current conditions.

7.3.2 *Operations and Maintenance*—Knowledge of historical and current facility operations may be useful. Information of interest may include climate history (available from the National Weather Service) and efforts to locate and repair moisture sources. With respect to leaks, maintenance personnel should be interviewed as to their frequency, apparent origin and conditions under which they occur. Service history of the facility may document patterns of leakage and areas impacted, highlighting these for follow-up inspection.

7.3.3 *Building Occupancy*—Building uses should be noted. Review of past occupant complaints and interviews with current occupants may aid in identifying temporal and spatial patterns related to moisture and fungal growth problems

7.4 *Hypothesis Formulation and Testing*—A hypothesis is a tentative assumption tested for logical or empirical consistency (**17**, **18**). Hypotheses may involve a specific area (for example, the cause of a discoloration) or the entire building (for example, the efficacy of the vapor retardation system). A hypothesis should consist of one simple statement. For example, "The tenant complains that the discoloration on a wallpaper is mold that resulted from a water leak" contains two statements. In this case, it would be advantageous for hypothesis testing to split this complaint into two hypotheses: (*1*) The discoloration on the wallpaper is fungal in nature, and (*2*) that same fungal growth was enabled by a water leak. Testing these two hypotheses would involve different observations or actions during the assessment.

7.4.1 *Formulation Before On-site Inspection*—Optimally, a hypothesis should be formulated before the on-site inspection based on the information provided while determining the scope of work, since the scope of work will be affected by the hypothesis being tested during the assessment.

7.4.2 *Formulation During On-site Inspection*—Alternatively, a hypothesis or hypotheses about fungal growth may be developed during the on-site inspection as suggested by the observations, or a new hypothesis may be adopted if the occurrence of fungal growth or water damage seen during the on-site inspection does not support the original hypothesis.

7.4.3 *Hypothesis Testing*—Observations or other information gathered during the assessment should be evaluated as to whether they support or negate the hypothesis or hypotheses. In the discoloration example above, if discolored areas of the wallpaper are found to contain fungal growth, and non-discolored areas are found to not contain fungal material, the data support the hypothesis that the discoloration is fungal in nature.

7.4.4 *Evidence Based Conclusions*—Data or conclusions regarding fungal growth should state whether they apply to the entire building or to a specified area. When there is no evidence to support the presence of fungal growth or its association with a complaint, this should be clearly stated.

7.5 *On-site Inspection:*

7.5.1 *Inspection Boundaries*—At a minimum, the inspection should include, within the scope of work, all areas of visible staining, discoloration, etc., areas potentially impacted by moisture problems of interest and the sites from which the moisture may originate. Studying a restricted area may compromise understanding of overall problems and result in an ineffective response. Ideally, the entire building should be evaluated for moisture and fungal indicators.

7.5.2 *Informed Inspection*—Within the inspection boundary, all surfaces should be inspected to the extent feasible, including above suspended ceilings and inside pipe chases, attics, and crawlspaces. The exterior of the building and adjacent grounds should also be inspected for moisture intrusion sites and air leaks (E2128, (**6**, **7**, **3**)).