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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 (27)[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 and health practices and determine the applicability of regulatory limitations prior to use.*

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-Base 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

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

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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.

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 **(18, 28)**.

3.2.4 *fungus*, *n*—(pl. *fungi*) a kingdom of organisms including molds, mildews, mushrooms, yeasts and many parasites. These are important decomposers in ecosystems. Fungi are typically multi-cellular fungi with filamentous vegetative hyphae.

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" (**1**, **5**, **6**). 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.) (**7**, **8**, **9**, **28**).

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 (**5**, **6**).

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 (**5**, **6**, **12**, **16**, **28**, **29**).

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 (**4**):

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, (**1**, **4**); 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 (**4**).

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 (**2**, **4**).

6.4.2.9 See Ref (**26**) for detailed descriptions of typical building moisture problems.

7. Basic Fungal Growth Assessment

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.

7.1 *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.

7.2 *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.

7.2.1 *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.

7.2.2 *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.

7.2.3 *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

7.3 *Hypothesis Formulation and Testing*—A hypothesis is a tentative assumption tested for logical or empirical consistency (**19, 20**). 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.

7.3.1 *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.

7.3.2 *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.

7.3.3 *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.

7.3.4 *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.

7.4 *On-site Inspection*:

7.4.1 *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.

7.4.2 *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, (**5, 6, 28**)).

7.4.3 *Identification of Current Water Damage and Suspect Fungal Growth*—All surfaces within the inspection boundary should be systematically evaluated for indicators of moisture damage and fungal growth. Exposed surfaces (including building materials, furnishings, and contents) should be examined for past and ongoing damage including: (*1*) suspect fungal growth, (*2*) standing water (*3*) water stains, (*4*) dampness to touch, and (*5*) blistering, warping, de-lamination, or other deterioration.

7.4.4 *Identification of Potentials for Fungal Growth*—The inspection should identify moisture sources and moisture pathways, including: (*1*) sites where condensation may occur, (*2*) equipment or activities which may release water, (*3*) pathways for water movement and (*4*) areas where leakage is likely. Staining patterns are often useful in identifying moisture sources. Materials or areas susceptible to fungal growth which are likely to remain wet or are isolated from air circulation should be documented. Special attention should be given to areas adjacent to or below past water releases, determining if

general surfaces have dried and that moisture has not become trapped behind baseboards, attached furniture, etc.

7.4.5 *Presence of Odors*—Detection of musty odors should always be noted. Sources of such odors should be located. If the source is not apparent, intrusive investigation may be required.

7.4.6 *Classification of Inspection Observations*—Based on the above observations, classify each distinct area or area of interest within the inspection boundary (as detailed as applicable to the scope of work) as one of the following categories: (*1*) no apparent fungal growth and no apparent water damage; (*2*) water damage having no visually suspect or confirmed fungal growth, (*3*) visually suspect or confirmed fungal growth having no apparent water damage, and (*4*) water damage having visually suspect or confirmed fungal growth.

7.4.7 *Disturbance and Migration*—Where fungal growth has been disturbed without containment or enhanced cleaning procedures, settled dust should be noted on adjacent surfaces. Other surfaces with suspect fungal growth should be examined for signs of past or potential disturbance as indicated by erosion, contact marks, or adjacent debris. Such conditions suggest the possible dissemination of fungal spores into the air. Potential disturbance might be associated with scheduled maintenance, renovation, or occupant activities which could cause damage. Fungal growth located in an air stream (for example, in a duct or next to a diffuser) may also suggest a potential for release. Conversely, fungal growth inside structures or covered by furnishings may be protected from disturbance. Pathways for air movement are determined by relative air pressurization and may be observed with smoke tubes, helping to establish the potential for airborne fungi to be circulated into occupied areas. Spore migration from fungal growth inside wall cavities and other hidden sources may be negligible or significant, depending on the circumstances. Pathways may vary based on changes in HVAC operation or weather conditions.

7.4.8 *HVAC Inspection, if applicable per the scope of work*—The interiors of HVAC equipment in contact with ventilation air should be inspected for indicators of excessive moisture or suspect fungal growth. Such areas may include intake and return plenums, filters, coils, condensate pans, fans, housing insulation, and supply ducts immediately downstream from the coils (interior sanitation). HVAC surfaces subject to high humidity or inadequate filtration may be more susceptible to fungal growth. Exterior surfaces of ducts, chilled water pipes, diffusers, and grilles should also be inspected for evidence of condensation or suspect fungal growth (distinguishing this from dust, rust, soot, etc.). HVAC controls affecting humidification and dehumidification should be identified and located. Humidity control should be considered over the range of seasonal operations. All potentially significant moisture-related deficiencies in design, operation, or maintenance should be documented. The location and timing of negative pressure within the building, including air plenums, cavities and chases, may also be of interest in regard to moisture pathways (**19**, **20**, **23**).

7.4.9 *Remediated Fungal Growth*—Surfaces identified with fungal growth in the past but that have been effectively remediated need not be considered an ongoing source unless excessive moisture has recurred.

7.5 *Inspection Documentation*:

7.5.1 *Site Map*—A site/floor plan should be prepared showing each inspection classification, as determined in 7.4.6. The plan should be sufficiently detailed to allow each area of interest to the assessment to be unambiguously located.

7.5.2 *Documentation of Suspect Fungal Growth*—Wherever suspect or confirmed fungal growth is identified during the inspection, documentation should include: (*1*) extent (for example, approximate square footage of suspect growth), (*2*) severity (for example, relative darkness or continuity of stain), growth pattern (for example, light versus heavy growth and spotty versus continuous growth), and (*3*) clues to apparent cause (for example, exterior wall, condensation near a HVAC outlet, associated with water staining). Inaccessible areas suspected of harboring fungal growth should be designated for follow-up investigation, especially if near visually suspect fungal growth.

7.5.3 *Documentation of Moisture Damage*—In addition to documenting the location of moisture damage, as above, further documentation should include: (*1*) apparent sources of leaks and other moisture sources, and (*2*) apparent timing and duration (for example, whether the moisture has been resolved, active (currently wet) or the moisture source is likely to reoccur (for example, seasonal)).

7.5.4 *Visual Documentation*—Photographs or videotapes are often helpful in documenting building conditions. Captions should note location, timing, and context.

7.5.5 *Additional Detail*—Start and stop time of the survey could be considered a quality control measure in terms of time spent onsite and ability to witness potential intermittent issues.

7.5.6 *Documentation of Conclusions*:

7.5.6.1 *Hypothesis and Conclusions*—Detail all hypotheses formulated and investigated and whether they were supported by the observations/data, and any conclusions that thereby may be inferred from the investigation. Indicate whether the hypotheses were amended due to the investigation and how they were amended.

7.5.6.2 *Potential for Exposure*—If applicable per the scope of work, the potential for occupant or remedial worker exposure may be qualitatively assessed by considering: (*1*) the location and extent of fungal growth, (*2*) current moisture status (suggesting continuing growth), (*3*) areas where fungal growth has been disturbed without containment or enhanced cleaning, (*4*) potential air pathways (including HVAC zoning), and (*5*) whether the affected area has been enclosed or encapsulated using impermeable materials. However, a detailed discussion of exposure issues is outside of the scope of this guide.

7.5.6.3 *Response Measures*—Findings may be reviewed to develop strategies for addressing suspect fungal growth and other water damage (**23**, **24**, **25**). However, recommendations for response actions are outside the scope of this guide.

7.5.6.4 *Further Study Needed*—The investigator should determine if the initial investigation has been sufficient to fulfill the scope of work and thoroughly test the hypotheses. Additional tasks can be defined, where needed, to fill critical data gaps.

7.5.7 *Report*—The written presentation may include: (*1*) background information (for example, who performed the survey, for whom, and why, description of facility and relevant systems; historical documentation including a summary of previous reports), (*2*) methodology including the limitations of the methodology, (*3*) suspect fungal growth (for example, estimated square footage observed by location and/or substrate identified on floor plans), (*4*) moisture issues (sources, pathways, dynamics, observations, chronology), (*5*) non-fungal factors, if applicable, (*6*) conclusions about causation, timing, duration, etc., (*7*) recommendations for site management, moisture control and remediation, if applicable, and (*8*) photographs to illustrate conditions with captions that clearly note location and context. An initial report may be supplemented based on findings from subsequent, more detailed investigations.

8. Additional Procedures

Depending upon the extent and type of fungal and moisture problems observed during the on-site inspection, additional procedures may be helpful in delineating and documenting those problems.

8.1 *Moisture Diagnostics*—To perform an effective comprehensive building fungal assessment, the sources, pathways, and extent of building moisture problems should be determined. These, in turn, suggest where to look for fungal growth. Quantitative diagnostics may not be necessary where the source and extent of moisture are obvious, but more detailed procedures for moisture should be considered where water damage is widespread or multiple sources are present. Moisture tests may also be utilized to help document the cause and/or responsibility for excessive moisture. See Ref (**26**) for specific procedures on quantitative investigation of moisture issues.

8.1.1 *Air or Surface Moisture Content*—While qualitative observations of moisture indicators are sufficient for many investigations, quantitative tests can be considered for more detailed documentation or problem-solving. Such tests range from measurement of moisture in air or materials to mapping of air infiltration/exfiltration or simulation of moisture sources. While test strategies are site specific, some investigators generally measure air temperature and humidity at representative locations along with surface moisture at susceptible sites. Moisture tests may initially focus either on worst-case locations or on representative areas. Elevated moisture may not be detected in an area with dormant (dry) fungal growth.

8.1.2 *Material Moisture Content*—Moisture content in building materials can be estimated using a moisture meter (see D4442). Scanning-type moisture meters measure radio frequencies to detect areas with elevated moisture. Direct-reading type moisture meters measure electrical conductance between two metal pins inserted in the material. While the latter type is considered more accurate, scanning-type meters can screen a wider area without leaving pin holes. Interpretation of moisture readings may be based on comparison with readings made in dry areas of the facility being evaluated. Elevated moisture readings may indicate proximity to a water entry point or location of a water migration pathway. False positive readings may occur due to the presence of metal in building materials or ventilation system cooled air conveyance pathways.

8.2 *Air Infiltration and Distribution Study*—Tracer gas methods, such as in ASTM E1186, can identify points of air leakage (for example, where humid or cold outside air is introduced into the building) and can therefore indicate the potential migration of fungal spores within the building.

8.3 *Surface Temperature Study*—Surface temperature variations documented by infrared thermography can be used to help evaluate leakage, air distribution, and moisture (E1186).

8.4 *Water Penetration Study*—Building envelope components can be tested for leakage by simulating moisture sources (for example, spraying water from a hose under controlled pressure). Procedures for this are included in E1105-90, E331-86 and E547-86. This type of evaluation can also help identify moisture pathways and be used to verify corrective measures (E331, E547, E1105).

8.5 *Intrusive Inspection for Fungal growth*—Accessing covered surfaces or building envelope assemblies may be necessary where suspect fungal growth or moisture indicators are not visible or moisture pathways potentially impact materials susceptible to growth.

8.5.1 Hidden fungal growth may be concealed in wall or ceiling cavities, on the exterior side of wall sheathing, under carpets, or behind vinyl wall coverings, baseboards, or vinyl base cove, and behind attached furniture. Access to such locations may involve cutting either a small hole for a boroscope or a larger hole for direct viewing (for example, using an inspection mirror and flashlight). Similarly, a section of carpet, baseboard, or wall covering may be pulled back to reveal building materials. In each case, materials should be removed layer by layer to reveal any concealed conditions. Visible discoloration patterns may help confirm sources for repair and surfaces for remedial measures.

8.5.2 Access procedures should avoid exposing occupants to elevated levels of airborne fungi (for example, keep occupants out of the work room while cutting, place drop cloth below cut and clean the work area afterwards). Isolation of the work area from occupied areas may be necessary in some cases.

8.5.3 The presence of lead or asbestos-containing materials should be considered, noting building material types, reviewing past reports and, in some cases, testing to verify the content of materials before cutting into them. In accordance with OSHA and EPA, suspect materials (that is, not wood, glass, or metal) are assumed to contain asbestos until shown not to contain asbestos by qualified personnel. Additional control measures may be needed where such materials may be disturbed, and may be required by governmental regulations.

8.5.4 Where intrusive inspection would be necessary to draw conclusions, but access is not permitted by the building owner or other responsible person, this should be noted in the assessment report as a limitation of the assessment.

8.5.5 It may be necessary to consult or employ a tradesperson or expert to open or repair areas intrusively accessed to minimize damage. This decision should be made with professional judgment and is beyond the scope of this guide.

8.6 *Air or Surface Fungal Sampling*—The distribution of fungal colonization or of fungal particles on surfaces or in the air may vary widely. Additionally, there are currently no regulations concerning what constitutes safe levels of fungi on surfaces or in the air. Therefore, sampling, if performed at all, should be planned to test a specific hypothesis. If sampling is considered, a competent sampling strategy should be developed (see, for example, Ref (**27**), Chapter 10) to take into account site conditions, history, statistical significance for the number of samples taken, sampling and analytical uncertainties, and data interpretation.

9. Keywords

9.1 assessment; building inspection; condensation; flooding; fungal growth; HVAC systems; microbiology; moisture evaluation; mold; mycology; visual inspection; water leakages

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