POST REMEDIAL ASSESSMENT AND CLEARANCE CRITERIA FOR MOLD REMEDIATION PROJECTS

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June, 2004

Abstract
Post-remedial collection of 2,193 fungi samples were evaluated as a component of a three (3) tiered clearance criteria for mold remediations projects. Criterion #1 was the visual evaluation of remediated areas for the absence of fungal growth. Criterion #2 was the visual evaluation of surfaces in remediated areas for the absence of visible debris. Criterion #3 involved the evaluation of total fungal bioaerosol samples with a pre-defined post-remedial clearance criteria of $\leq$ 2,000 particles/m^3 of total fungi, with individual sub-categories composed of $\leq$666 particles/m^3 *Cladosporium*-like spores, $\leq$666 particles/m^3 *Aspergillus/Penicillium*-like spores, $\leq$666 particles/m^3 mixture of spores from other genera with no individual component comprising > 33% of this sub-category, and $\leq$ 22 particles/m^3 *Stachybotrys/Memnoniella*-like spores. Ninety-four (94%) of the population achieved clearance on the first assessment. One (1) percent of the initial failing population was related to fungal growth in the remedial area. Data obtained in this investigation support the modification of clearance criteria of *Stachybotrys/Memnoniella*-like spores to 88 particles/m^3. No specific health concerns were documented after the clearance of these areas; however, these guidelines are not intended to represent any specific medical or health related threshold regarding health. The authors conclude the three (3)-tiered clearance criteria provide a reasonable and obtainable clearance guideline, provided some latitude exists with respect to evaluating levels of all categories of fungal spores and the potential impact of an outdoor bias on a case-by-case basis.

Introduction

Recently, the impact of mold and mold-related remediation projects has received national attention [1-47]. Fungi can grow on many common building materials, such as sheetrock and paper, that have been exposed to excessive moisture. In general, the origin of fungal growth in indoor environments can be categorized into architectural and construction related events, the design, operation, and maintenance of air-conditioning systems, housekeeping and general maintenance issues, and catastrophic water intrusion events [48-53].

The goal of mold remediation is to return the work environment to that which is reflective of a "normal background levels" for these organisms[54-57]; however, the diversity of these organism and the analytical methods utilized to study them make it inherently difficult to determine the scope and range of fungal background levels. Numerous factors have the ability to impact the presence and concentrations of viable and non-viable particles of fungi in indoor environments. These may include the age and construction of the structure, geographical location, interior hygiene, air-conditioning system design, operation, maintenance, building processes, and other environmental contributors. Some documentation exists relative to the diversity and range of individual fungal populations and concentrations on surfaces within indoor environments [58-65]. Research has suggested that $\geq 10^6$ fungi/g of dust represents abnormal background and that further investigation is required [66-68]; however, the manner and means by which dust samples are collected and analyzed can significantly impact both the qualitative and quantitative expression of data. No standardized method is currently in place that defines a sampling and analytical process to render surface and/or dust samples comparable throughout the industry.

More has been documented relative to the standardization of methodologies relative to the collection of airborne concentrations and populations of fungi in indoor environments [70-84]. Most of these investigations have evaluated these environments using culturable bioaerosol techniques. A few studies have evaluated indoor fungal bioaerosols utilizing non-culturable methods. These studies suggest that indoor concentrations of fungi in normal air are between 10^3 –10^4 spores/m^3 [85]. The American Academy of Allergy, Asthma and Immunology (AAAAI) has identified categories that characterize outdoor concentrations of total (culturable and non-culturable) fungal bioaerosols[86]. The AAAAI suggests that 1–6,499 particles/m^3 represents "Low" levels, 6,500-12,999 particles/m^3 represents "Moderate" levels, 13,000-49,999 particles/m^3 represents "High" levels, and >50,000 particles/m^3 represent "Very High" levels. These studies do provide a general indication of spore concentration in our environment, and provide a basis of rational for normal and typical exposures for outdoor environments.

The New York City Department of Health (NYCDH), the American Conference of Governmental Industrial Hygienists (ACGIH), the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Institute of Inspection, Cleaning and Restoration Certification (IICRC) and the Texas Department of Health currently provide guidelines for the remediation of fungi in indoor environments. The recommendations provided by these groups are not based on specific scientific data regarding airborne exposure or dissemination potentials. These groups recommend asbestos-like remedial responses that involve the use of containment structures and air filtration devises when large quantities of mold are deemed to be present; however, unlike asbestos remediation, none of the proposed guidelines specifically provide any type of clearance criteria that formally completes the remediation processes and serves as an initiating point for re-building, re-construction, or re-occupancy. Despite the general widespread prevalence of fungal remediation in indoor environments, only the absence of visible fungal growth exists as a criterion to determine if mold remediation processes have been successful. The purpose of this research is to define an arbitrary set of mold clearance criteria, evaluate the impact of these criteria when applied to mold remediation projects, and determine the appropriateness of utilizing the 3-tiered clearance criteria as an industry guideline for mold remediation clearance.

Methods

Mold remediation projects seeking clearance testing in contained mold remediation activities were allowed to configure air filtration devices to a re-circulating mode prior to performing the clearance assessment. A three (3) tiered clearance criteria was developed for this study. Criterion #1 was the visual evaluation of the contained work area for the absence of visible fungal growth. The presence of visible fungal growth within the contained work area would result in clearance failure. Residual staining as a result of fungal pigmentation and/or embedded hyphal fragments in framing materials were not considered to represent viable growth warranting further treatment. Criterion #2 was a visual evaluation of the surfaces within the contained work area and was only applied after passing Criteria #1. All interior surfaces in the contained working areas must be free of any visible dust or debris. Criterion #3 involved the collection of a total fungal bioaerosol sample and comparison to a pre-defined set of criteria.

Total fungal bioaerosol samples were collected utilizing a Zefon Air-O-Cell cassette linked to a vacuum pump calibrated at a flow rate of 15.0 liters per minute. Indoor samples were collected over a 10-minute period. Outdoor samples were collected over a 5-minute period. Sampling was performed within 1-5 days after the completion of the final containment clean up. Fungal containment and critical barrier systems ranged is sizes from approximately 8 m^3 to 32 m^3. No specific methods were utilized to agitate and/or disturb surfaces within the containment system prior to sample collection. Samples collected at the approximate center of the containment system. Other samples collected indoors were collected just proximate to the point of containment ingress and egress. No specific methods were utilized to agitate and/or disturb surfaces within the containment system prior to sample collection. A laboratory accredited

American Industrial Hygiene Association (AIHA) EMLAP program analyzed samples by direct microscopy. Residual traces of fungal bioparticulate were evaluated by light microscopy under 400X magnification. The microscopes utilized in the analyses had field diameters that ranged between 0.473 to 0.539 mm. Ten passes of each trace were read to result in the actual evaluation of 5.02 to 5.929 mm of each trace. This is equivalent to the analysis of 33 to 37% percent of each trace and resulting in a detection limit between 18-22 particles/m^3 based on a 150 liter sample. Morphological distinct fungal spores were assigned to a genus. Spherical fungal spores having a 1-3 micron diameter were identified as *Aspergillus/Penicillium*-like. All concentrations were reported in particles per cubic meter of air sampled (particles/m^3). A total particles/m^3 was provided for each collection site.

Clearance was established for air samples having $\leq$2,000 particles/m^3 of total particles of fungi, with $\leq$ 666 *Cladosporium*-like, $\leq$666 *Aspergillus/Penicillium*-like, $\leq$666 mixture of other genera with no individual component comprising > 33% of this sub-category, and $\leq$22 mixture *Stachybotrys/Memnoniella*-like spores. The basis of these "preliminary" clearance parameters was derived from an evaluation of over 4,000 samples collected from a variety of indoor and outdoor environments in the continental United States from 1989 to approximately 1998, as well as other published research regarding indoor and outdoor fungal bioaerosol concentrations and populations. These criteria have been utilized in numerous fungal remediation projects, including projects monitored or performed by the Texas Department of Health [87]. Brandy's suggests that there is no statistical significance between the 2,000 particles/m^3 and the application of the OSHA 50% regulatory standard to have reasonable certainty that employees are not over exposed to the low range level cited by the American Academy of Allergy, Asthma and Immunology[88]. Sampling for the projects occurred in areas where moisture related events resulting in the fungal growth had been corrected and building materials were reflective of normal and typical moisture content. Results from samples were evaluated as a whole and individually with respect to clearance criteria groups. Processing of the sample data included the statistical evaluation of range, average, median, standard deviation, and average deviation.

Additional remedial actions were implemented within 24 hours for projects that did not obtain clearance. Specific remedial responses were a function of the failed clearance criteria. Projects failing clearance as a result of Criterion #1 required the additional removal of visible fungal growth followed by additional HEPA vacuuming and hygienic wipedown procedures within the containment structure. Projects failing clearance as a result of Criterion #2 required additional HEPA vacuuming and hygienic wipedown procedures within the containment structure. Projects failing clearance as a result of Criterion #3 required an additional 24-hours of air scrubbing with a HEPA filtration device. Re-sampling was performed within 1-5 days after the completion of the final containment clean up.

Results

A total of 572 remedial projects involving post remedial assessment and clearance testing were completed between January 2, 2003 and December 6, 2003 in Texas, Louisiana and Florida and involved the collection of 2,193 samples. Approximately 8% of this sample population was obtained in Florida, 1% of this sample population was obtained in Louisiana, and the remaining sample population obtained in Texas.

Outdoor Bioaerosol Concentration

A summary of outdoor fungal bioaerosols observed in this study is provided in Table 1.

Table 1

Outdoor Fungal Bioaerosols					
	Total	***Cladosporium***	***Aspergillus /Penicillium* -like**	**Mixed Others**	***Stachybotrys/ Memnoniella*-like**
Number of Data Points	1,228	1,122	258	1,076	1
% of Total	100	91	21	88	0.08
Average Part/m3	2,200	1,800	630	430	84
Median Part/m3	880	670	210	210	84
Range - Low- Part/m3	20	20	42	20	84
Range - High- Part/m3	147,000	144,000	18,700	11,000	84
Std. Deviation- Part/m3	5,560	5,300	1,500	830	
Average Deviation- Part/m3	2,200	1,900	660	400	

Outdoor fungal bioaerosols provided a basis by which the air in remediated indoor environments could be guaged as returning to background.

Indoor Bioaerosol Concentration-Control Samples Collected Outside of Containment

A total of 75 total fungal bioaerosol samples were collected at indoor areas just outside of the containment structures. Average total fungal bioaerosol concentrations outside the containment area were 200 particles/m^3 with a statistical median of 130 particles/m^3. The low/high ranges were 21 and 1,800 particles/m^3, respectively. Standard deviation of total fungal bioaerosol concentrations outside the containment area was 270 particles/m^3 with an average deviation of 160 particles/m^3.

Indoor Bioaerosol Concentrations- Samples Collected within Containment Areas

A summary of indoor control and containment fungal bioaerosols observed in this study is provided in Table 2 and Table 3.

Table 2

Indoor Containment and Control Fungal Bioaerosols		
	In Containment	**Outside of Containment (Indoor Control)**
Number of Data Points	831	1,100
Average Part/m3	100	200
Median Part/m3	42	130
Range-Low- Part/m3	20	21
Range-High- Part/m3	1,900	1,800
Std. Deviation- Part/m3	170	270
Average Deviation- Part/m3	100	160

Total bioaerosol sampling within and immediately adjacent to work areas revealed appropriate containment in negative air and air scrubbing air filtration devise configurations.

Table 3

Summary of Fungal Bioaerosol Initial Clearance Sampling			
	Sample Population	**% of Total**	**% of Sub-Set**
Total Population	832	100	
Projects Rejected due to Anomalous Data	1	0.12	
Passed 1st Clearance	780	93.75	
Failed 1st Clearance	51	6.25	
Categories of 1st Clearance Failures			
Visual	8	1	16
> 666 p/m3 A/P-like	14	1.7	27
> 24 p/m3 Stachy-Mem-like	17	2	33
>2000 p/m3 plus > 666 p/m3 A/P-like	10	1.2	20
>2000 p/m3 plus > 666 p/m3 A/P-like plus 24 p/m3 Stachy-Mem-like	2	0.2	4

6.25% of the projects failed the initial clearance sampling

Discussion

The goal of appropriate fungal remediation is to restore the environment to typical background levels; however, despite the general widespread prevalence of fungal remediation in indoor environments, only the absence of visible data fungal growth currently exists as a criterion to determine if mold remediation processes have been successful. Analytical criteria are needed to supplement visual observations as a means and method to determine when fungal remediation has been appropriately completed [89]. The Texas Department of Health Texas Mold Assessment and Remediation Rules cited in Publication #2-15 specifically regulate the collection of analytical data as a component of mold remediation clearance; however, no universally accepted numerical guidelines have been available to the industry to date. The American Industrial Hygiene Association has published post-remedial guidelines, however; these guidelines do not provide numerical criteria and recommend rank order and indoor-outdoor comparison. Furthermore, rank order and/or strict-indoor outdoor comparison would be largely inappropriate in environments having residual echoes of previously disturbed fungal growth [90], and furthermore, that attempting to adhere to such criteria represent unreasonable, variable, sometimes unobtainable clearance criteria that may result in the unwarranted failure of a fungal remedial project. The authors maintain that air sampling is an important aspect of a fungal remediation project. Visual observations can provide assurance that fungal growth sites have been appropriately removed; however, visual observations cannot provide assurance that the fungal spores that were aerosolized during the remediation process have been removed. Sampling was performed within 1-5 days after the completion of the final containment clean up. Post-clearance sampling to evaluate the long-term effect of remediation processes exceeded the scope of this research.

No specific methods were utilized to agitate and/or disturb surfaces within the containment system prior to sample collection. The authors recognize that such processes (leaf blowers, compressed air, etc.) have occasionally been utilized in clearance testing in the industry; however, the specific aspects of these processes extended beyond the scope of this research. The authors cite the current lack of baseline research that establishes the impact of such agitation processes in normal and remedial environments as limiting

factors with regard to its routine use in clearance testing. Additionally, the author's caution on the potential re-contamination of containment systems when devices such as leaf-blowers are consistently utilized as an agitating devise without appropriate decontamination between uses.

Ninety-four (94%) of the areas tested achieved clearance on the first assessment based on the proposed 3-tiered clearance system. Sixteen (16) percent of the failures, representing one (1) percent of the total sampling population, were related to the presence of visible fungal growth in the contained area at the time of the assessment. Given improved visual evaluations and responses prior to the clearance assessment, these studies indicate a first time clearance success rate approaching 95% are readily obtainable using these clearance criteria. These data suggest that the three (3)-tiered clearance criteria developed for these projects provide a reasonable and obtainable clearance guideline for mold remediation projects beyond the use of a visible assessment alone.

Six percent (6%) of the total sampling population failed the first attempt at the 3-tiered clearance criterion. 8 projects, representing 1% of the total sampling population and 16% of the initial failing-clearance population failed because visual fungal growth was detected in the contained work area. Despite the presence of visible fungal growth in the containment areas, 75% of this data sub-set revealed fungal bioaerosol concentrations that were within the pre-described aerosol criteria. This data suggests that aerosol criteria, standing alone, are not sufficient to utilize as a clearance criteria for mold remediation projects. These studies demonstrate that the presence of residual visible mold growth in a containment system may not result in bioaerosol levels that exceed a prescribed clearance criterion; however, the presence of visible mold dictates that additional remedial actions are warranted. Conversely, these studies also demonstrate that the absence of visible fungal growth in a containment system does not affirm that the fungal bioaerosol concentrations within that containment are typical and normal with respect to outdoor and indoor environments. These findings suggest that both visual inspection and aerosol testing are useful in determining when a fungal containment system can be disassembled.

The remaining 43 projects that failed the first attempt at clearance did so as a result of fungal concentrations that exceeded pre-described limits. The previously described sample set that was eliminated as anomalous data represented the only work area that failed clearance solely as a result of concentrations that exceeded 2,000 particles/m^3. These data suggest that, although possible, outdoor air bias does not appear to significantly impact containment systems, provided that HEPA air-filtration devices are operating in a re-circulation mode. Furthermore, an evaluation of bioaerosols concentrations just outside containment structures does not provide any evidence that the operation of HEPA air-filtration devices operating in a re-circulation mode result in any significant dispersion of fungal spores to non-work areas.

Total Fungal Bioaerosol Concentration

The arbitrary value of $\leq$2,000 particles/m^3 that has been proposed as a total fungal bioaerosol concentration is similar to the 2,200 particles/m^3 outdoor average observed in this study. Only one project in this study failed clearance based solely on indoor total fungal bioaerosol concentrations that exceeded 2,000 particles/m^3. This project revealed 1 x 10^5 concentrations of fungal spores in both outdoor and indoor samples. Outdoor concentrations most probably biased this indoor recovery. No other clearance project failed as a result of concentrations that exceeded 2,000 particles/m^3; however, the extreme variation that was observed in outdoor concentrations, in conjunction with the potential for outdoor bias, support a remedial strategy that utilized HEPA air-filtration devices (AFD) configured in the re-circulation mode until clearance is obtained. While, negative air containment systems may be more appropriate during the initial removal of fungal materials, reconfiguring the AFD to a re-circulation mode during the final wipe-down improves the containment and capture of aerosolized spores while minimizing the potential bias from areas outside of the containment structure. These data suggest that the continued use of the arbitrary value of $\leq$2000 particles/m^3 for total fungal bioaerosol concentrations would be acceptable, provided some latitude exists with respect to evaluating total levels of on a case by case basis. The authors suggests that it could be appropriate to pass a clearance if total concentrations exceeded 2,000 particles/m^3, provided that a specific outdoor bias can be verified.

Cladosporium Concentration
The arbitrary value of ≤666 particles/m^3 that has been proposed for concentrations of *Cladosporium* is lower than the 1,800 particles/m^3 outdoor average observed in this study; however, the median value of 670 is similar to the proposed clearance criterion of ≤666 particles/m^3. These data suggest that the continued use of the arbitrary value of ≤666 particles/m^3 would be acceptable, provided some latitude exists with respect to evaluating levels of *Cladosporium* on a case by case basis. The authors suggests that it could be appropriate to pass a clearance if *Cladosporium* concentrations exceeded 666 particles/m^3, provided that a specific outdoor bias can be verified.

Aspergillus/Penicillium-like *Concentration*
The arbitrary value of ≤666 particles/m^3 proposed for concentrations of *Aspergillus/Penicillium*-like spores is similar to the 630 particles/m^3 average observed in this study. These data suggest that the continued use of the arbitrary value of ≤666 particles/m^3 would be acceptable. The authors suggests that some latitude should exists with respect to evaluating levels of *Aspergillus/Penicillium*-like spores on a case by case basis and that it could be appropriate to pass a clearance if *Aspergillus/Penicillium*-like spores exceeded 666 particles/m^3, provided that a specific outdoor bias could be verified. The largest component that resulted in clearance failure in this study was the recovery of *Aspergillus/Penicillium*-like spores that exceeded the pre-defined clearance criteria of 666 particles/m^3. Fifty-one (51%) percent of the first-attempt clearance failures had *Aspergillus/Penicillium*-like spores that exceeded the pre-defined clearance criteria. Eighty-eight (88%) percent of second clearance failures were the result of *Aspergillus/Penicillium*-like spores that exceeded the pre-defined clearance criteria of 666 particles/m^3. The number and aerodynamic capacity of this group of fungal spores appears to be the most difficult for HEPA filtration units to control and capture, and would represent that portion of the fungal aerosol having the most potential of escaping containment. Reduction of clearance failure, as a result of *Aspergillus/Penicillium*-like spores levels that exceeded the pre-defined clearance criteria, can best be obtained by a thorough wipe-down with a damp rag with a detergent solution and HEPA vacuuming of all interior surfaces in the presence of an AFD in a re-circulation mode. Monitoring particle counts between 1-5 microns can provide an indicator as to when clearance testing can be performed with a improved probability of obtaining the defined clearance criterion.

Mixed Fungal Spore Concentration
The arbitrary value of ≤666 particles/m^3 proposed for concentrations of "mixed" fungal spores is greater than the 430 particles/m^3 average observed in this study. These observations suggest that some modification of the "mixed" category could occur, provided that the total of 2,000 particles/m^3 is not concurrently reduced; however, the arbitrary value of ≤666 particles/m^3 is within the standard deviation and average deviation of this sample set. Outdoor concentrations for this group exceeded 11,000 particles/m^3 and, theoretically, introduce the potential for outdoor bias. None of the projects in this study failed clearance as a result of the proposed clearance criteria. These data generally support the continued use of the ≤666 particles/m^3 for mixed fungal spores with no individual component comprising >33% of this sub-category, as a valid criterion. The authors suggests that some latitude should exists with respect to evaluating levels of mixed fungal spore concentrations on a case by case basis and that it could be appropriate to pass a clearance if "mixed fungal spore" exceeded 666 particles/m^3, provided that a specific outdoor bias could be verified.

Stachybotrys/Memnoniella-like spore Concentration
The arbitrary value of ≤22 particles/m^3 of *Stachybotrys/Memnoniella*-like spores was not included as a component of the clearance criterion representing a return to typical background levels, but rather, specifically developed as over abundance of care relative to the initial assertions of the relationship of *Stachybotrys* exposure to acute-pulmonary hemorrhage in infants in 1993 and 1994. The Center of Disease Control's subsequent review of the research linking *Stachybotrys* to pulmonary hemorrhage concluded that insufficient evidence exists to support a causual relationship. This coupled with the lack of any current,

valid scientific data establishing an airborne relationship between spores, toxins and mycotoxicosis may negate the need for specific clearance criteria for this group of organisms. Limited data obtained in this study does suggest that concentrations of *Stachybotrys/Memnoniella*-like spores do occur in outdoor environments and at concentrations greater than 22 particles/m^3. Only a single outdoor airborne recovery of *Stachybotrys/Memnoniella*-like spores was observed in this study. Hence, the outdoor recovery of *Stachybotrys/Memnoniella*-like spores is considered rare when compared to the frequency of other more common groups such as *Cladosporium, Alternaria, Drechslera*, and basidiospores; however, this study indicates that when recovery does occur, concentrations in the order of 88 particles/m^3 can be observed. Studies performed by Dotson reported the frequency of outdoor recovery for *Stachybotrys*-like spores to be 4% of a 633 sampling population in the Houston, Texas area; however, when present, outdoor *Stachybotrys* concentrations ranged between 21-235 particles/m^3, averaged 57.7 particles/m^3 with a standard deviation of 49.8 particles/m^3 [91]. Anecdotal evidence suggests much higher levels of fungal spores from *Stachybotrys* and other toxic species may be required to induce toxigenic reactions [92-94]. Seventeen projects representing 2.0% of the total sampling population and 33% of the initial failing-clearance population failed because of *Stachybotrys/Memnoniella-like* spores at concentrations exceeding 22 particles/m^3. The absence of specific medical data regarding exposure to *Stachybotrys/Memnoniella*-like spores does not support the continued stringency for this category. This study concludes that proposed criterion for *Stachybotrys/Memnoniella*-like spores should be increased, if not completely abandoned until some specific need has been validated. Increasing *Stachybotrys/Memnoniella*-like spore clearance criteria to that concentration observed in the outdoor sample ($\leq$88 particles/m^3) would have reduced initial failure rates to 1% of the total sampling population and 15% of the initial failing-clearance population. Based on outdoor recoveries observed in this and other studies, the authors propose that the arbitrary clearance guidelines for *Stachybotrys/Memnoniella*-like spores be increased to $\leq$88 particles/m^3.

In general the data obtained in this study are consistent with other regional and national data. Recently, regional and national comparisons of mold spore concentrations in outdoors and indoor environments, as well as, non-water damaged homes and mold-contaminated buildings have been published [95-97]. The data reflected in these studies indicated that normal, clean environments have fungal spore concentrations and populations that are similar to the clearance guidelines that have been utilized in this research.

The author cautions that the use and establishment of any guideline or clearance criteria unintentionally insinuates some implied health threshold. The clearance criteria developed as a result of this research are not intended to represent any specific medical or health related threshold. No specific health concerns were documented to result from exposure to fungal bioaerosols after the clearance of these areas using the 3-tiered clearance criteria described herein. These clearance criteria have been utilized in projects involving populations of immuno-compromised individuals, with no adverse effects as a result of fungal bioaerosol exposure reported. Regardless, the authors caution that sensitivities and subsequent manifestation of negative health effects from exposure to fungal bioaerosols are unique, individually specific, and must often be evaluated on a case-by-case basis. These clearance guidelines are intended to represent what are considered to be typical concentrations and populations of fungal organisms in indoor environments and provide a reasonable and obtainable goal for post-remedial fungal remediation processes.

The authors recognize that the complete remediation process ultimately relies on the correction and/or prevention of future moisture-related events; however, the affect of such corrective and preventive responses often exceeds the scope of a typical remediation company. Hence, no specifics relative to moisture concentrations of building materials have been provided as a component of these clearance criteria. Modification of these clearance criteria to include the monitoring of building materials for appropriate moisture concentrations would be appropriate, provided the remediator has the sufficient scope and latitude in the project to address moisture-related issues.

Conclusions

The authors conclude that the three (3)-tiered clearance criteria developed for these projects provide a reasonable and obtainable clearance guideline beyond the use of a visible assessment alone; however, fungal bioaerosol data standing alone, are not sufficient to utilize as a clearance criteria for mold remediation projects. The arbitrary clearance values assigned to total, *Cladosporium*-like; *Aspergillus/Penicillium*-like, mixed, and *Stachybotrys/Memnoniella*-like spore are similar to the outdoor averages observed in this study. Data obtained in this investigation support the use of a modified arbitrary airborne clearance criterion for fungi that includes: $\leq$2,000 particles/m^3 of total particles of fungi, with $\leq$666 particles/m^3 *Cladosporium*-like, $\leq$666 particles/m^3 *Aspergillus/Penicillium*-like, $\leq$666 particles/m^3 mixture of other genera with no individual component comprising > 33% of this sub-category, and $\leq$88 particles/m^3 *Stachybotrys/Memnoniella*-like spores. The authors further conclude that outdoor and indoor control samples should be collected; however, analysis may not be required provided aerosol concentrations in work areas are within the recommended clearance criteria. Elimination of control outdoor and indoor sample analysis could significantly reduce overall cost associated with post-remedial assessment practices. The authors recommend the use of these post remedial assessment and clearance criteria would be acceptable, provided latitude exists with respect to evaluating levels that exceed the pre-defined bioaerosol criteria, provided that a specific outdoor bias could be verified. The authors further conclude that the operation of a HEPA air-filtration devices in a re-circulation mode does not result in the dispersment of fungal spores from the work area and that such modality reduces the potential impact of outdoors sources of fungal bioaerosols on clearance data.

Recommendations

The authors recommend the three (3)-tiered clearance criteria as a reasonable and obtainable clearance guideline for mold remediation projects beyond the use of a visible assessment alone; but that fungal bioaerosol data standing alone, are not sufficient to utilize as a clearance criteria for mold remediation projects. The authors recommend the continued use of these post remedial assessment and clearance criteria would be acceptable, provided some latitude exists with respect to evaluating levels of all fungal spores on a case by case basis provided that a specific outdoor bias could be verified. The author cautions that rank order and/or strict-indoor outdoor comparison would be largely inappropriate in environments having residual echoes of previously disturbed fungal growth. The authors further caution against the absolute numerical comparison of outdoor, indoor control, and work area samples and that such samples should be evaluated as a component of a diverse ecological system they represent.

The largest component that resulted in clearance failure in this study was the recovery of *Aspergillus/Penicillium*-like spores that exceeded the pre-defined clearance criteria of 666 particles/m^3. The authors recommend the preliminary monitoring of particle counts between 1-5 microns to provide an indication as to when clearance testing can be performed with a improved probability of satisfying this specific aspect of the defined clearance criterion.

The absence of specific medical data regarding exposure to *Stachybotrys/Memnoniella*-like spores does not support the continued stringency for this category. This study concludes that proposed criterion for *Stachybotrys/Memnoniella*-like spores should be increased, if not completely abandoned until some specific need has been validated. Based on outdoor recoveries observed in this and other studies, the authors propose that the arbitrary clearance guidelines for *Stachybotrys/Memnoniella*-like spores be increased to $\leq$88 particles/m^3.

The authors recommend a strategically approach to the use of HEPA air-filtration devices during mold remediation projects. At the onset of a project, configuration of the HEPA air-filtration device in a negative

air mode may be appropriate; however, the extreme variation of outdoor fungal bioaerosol concentrations, in conjunction with the potential for outdoor bias in a continuous negative air mode, supports a remedial strategy that utilizes HEPA air-filtration devices (AFD) configured in the re-circulation.

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