# MOLD CLEAN-UP PROJECTS

## Post-remediation Criteria are Crucial to Success

As concerns about mold contamination indoors become more prevalent, the need for standards within the industry grows at an increasingly rapid pace. Not only is it crucial to have mold remediation standards, but post-remediation standards, as well. Non-standardized post-remediation inspections cause a number of problems, including project failure, confusion for the contractor, increased liability for the whole industry, limited comparisons between projects, and a breakdown in the public's confidence. Although the post-remediation evaluation process includes many parts, including sample collection and analysis procedures, this article focuses on the importance of logical and effective post-remediation sample interpretation from a macro approach. We will leave the discussion of collection and analysis methodology to a future paper.

Post-remediation evaluation is a critical component of any mold remediation project (AIHA 38). Oftentimes, due to the lack of concrete standards, the remediation work is done incorrectly or ineffectively. This can make the problem worse and the contamination widespread (ACGIH 15.2). If, for example, a proper decontamination unit is not correctly set up, the risk of contaminating clean areas increases dramatically. In other situations, there may be more than one mold source contributing to the problem. If all mold sources are not revealed and properly cleaned, mold will continue to be an issue even after remediation. A post-remediation evaluation process can identify shoddy remediation efforts or undiscovered mold sources that may continue to affect indoor air quality.

Despite the obvious need for generally accepted criteria to use as a comparison for post-remediation samples, no universally recognized document currently exists. In fact, many industry professionals have adopted the mistaken opinion that such criteria is impossible to develop as there are too many variables (ACGIH TLV 2) (Tiffany, Bader, and Pratt 523). While it is important to recognize and address multiple impacts, being difficult does not make a project impossible. As such, the first step in the process is identifying and categorizing the critical variables to be addressed in the development of a clearance criterion.

### Why Don't We Have Standard Post-remediation Procedures?

Take, for example, the number of different approaches and methodologies a hygienist or Indoor Environment Professional (IEP) can use to collect a sample. For surface samples, one might use swab, tape, bulk or dust collection methods to gather the sample. For air samples, gravitational sedimentation plates, air impact cassettes, spore trap on slides, collector sieves, liquid impingers,

or agar impaction methods could be used to collect the sample. Now consider the number of ways to analyze and interpret the sample data: cultured, non-cultured (polymerase chain reaction, PCR), chemical (to identify mycotoxins or microbial volatile organic compounds), and others. Furthermore, consider diverse geographic locations that have very different spore levels as a normal part of their environment. In addition, many professionals argue that any post-remediation criteria must also take into account the considerable range in individual susceptibilities to mold (ACGIH TLV 2). Last, and most important, there is a wide variability in the way in which contractors conduct remediation, often failing to combine effective work practices with proper isolation and containment, engineering controls, decontamination procedures, and effective air flow and pressure management. Consequently, the difficultly in creating clear, concise mold remediation criteria comes as no surprise.

## Past Efforts

Because mold spores are naturally occurring organisms and are found in all environments, it is very difficult to pin an exact number on exposure limits. Furthermore, selection of specific sampling locations has a direct impact on what spore levels might be found. While there is nearly universal agreement that mold growth indoors is unacceptable (Pinto and Janke 5-15), what, exactly, constitutes appropriate levels of mold spores in indoor air or dust is vigorously debated (Johanning 19).

A large body of relevant data exists for post-remediation sampling. Personal research, guidance documents, peer reviewed studies, and papers all contribute to the wide range of information available. Tables 1-1 and 1-2 are an attempt to organize by sample type and in chronological order much of the currently available data related to indoor mold levels. Most of the data on the tables consists of qualitative numbers concerning health issues, building and structure contents, and exposure limits (for both building/home occupants and workers). A wide range of questions is also addressed in the data, such as, what determines normal spore levels (backgrounds), what spore levels are indicative of an impacted environment, what levels are appropriate to determine if remediation is necessary, and what spore levels determine whether or not an area is clean (post-remediation). After collecting and reviewing the data sources in Tables 1-1 and 1-2, highlights were charted, categorized by analytical method, and a simple statistical analysis was applied to find the mean (average), median (center value), and mode (most frequent value) of the collective data.

Table 1-1 deals with cultured air samples, the most prevalent sample technique of all the data collected. However, non-cultured air sample analysis (Table 1-2) has been used frequently in the recent past and has gained considerable acceptance in the industry (Tiffany, Bader, and Pratt 527). The resultant data has increased the debate about which method is most appropriate. With non-cultured air samples, analysis can be done directly with a microscopic exam, the results are reported in counts per cubic meter of air, and the turnaround time is faster. One drawback to the

non-cultured samples is that the analysis is less detailed, producing identification only to the genus level. Cultured sample analysis, on the other hand, can identify to the species level, but has a longer processing time, media limitations, and difficult handling demands.

Upon examining the tables, some common deficiencies among past studies and their approach to post-remediation sampling were readily apparent: a small number of the approaches focus on post-remediation sampling, there is a heavy reliance on sampling, and a broad approach is lacking. In other words, most of the studies focus on trying to apply a single number to spore levels everywhere and anywhere, placing a heavy emphasis on sample results. These deficiencies convince us that, ultimately, the professionals within the mold industry need to realize that a variety of factors must be considered when conducting post-remediation clearance sampling.

Past recommendations for post-remediation values include suggestions for reviewing data by comparing types of fungal spores and their relative proportion in a sample (called a rank/order review), comparisons to out-of-doors levels, and requirements that no pathogenic organisms be detected in post-remediation sampling (ACGIH 7.4.2). To apply rank/order values to a mold remediation project, one would collect an air sample from out-of-doors and another sample from the remediated area within the building. The analysis results of each sample would then be compared, listing the spore types from the most common ones observed to the least common. In a healthy environment, the most common spore types identified within the structure should also be the most plentiful in the out-of-doors sample. Building on this, the indoor sample should reflect similar spore type occurrences at a reduced level. If, for example, an unusually high count of an uncommon spore type is found on the indoor sample that is not prevalent on the out-of-doors sample, it is feasible to conclude that there is an active mold source indoors. The rank/order method seems logical because it accommodates the issue of different geographic locations having different naturally occurring types of spores.

## Interpreting the Data

In examining the body of data available on cultured fungal air sample analysis summarized in Table 1-1, it is clear that the level of 1,000 colony forming units per cubic meter of air ($CFU/m^3$) is considered significant. This amount was most frequently mentioned (the mode) as the appropriate indicator of background levels of mold (Burge, OSHA, etc.). Indeed, a tight range of numbers emerged from the statistical analysis with 1,341 $CFU/m^3$ as the mean and 650 $CFU/m^3$ as the median. According to the collective data, results below 1,000 $CFU/m^3$ of common types of outdoor molds indicate no evidence of water intrusion and that no heath effects would be expected. However, target fungal types are discussed in many documents, with an overall agreement that further investigation should be conducted if fungal types do not mimic the variety seen in proximate outdoor samples. Many authors agree that significant consideration should be given to the presence of even small amounts of target organisms which have been found in

conjunction with water-damaged or contaminated buildings. In particular, many authors suggest that elevated levels of *Penicillium* and *Aspergillus* mold species are not only health concerns, but coincide with water-damaged building materials (AIHA Facts 9). In addition, many mold types that are associated with elevated levels of mycotoxins (*i.e.*, *Stachybotrys*, *Fusarium*, *Memnoniella*, etc.) are also tied to water-damaged buildings, even if they are detected only in small quantities (AIHA Facts 9).

As shown in Table 1-2, historical interpretations of "normal" (background) levels for non-cultured air samples ranged from 2,000 counts per cubic meter of air ($c/m^3$) as the mode, to 4,786 $c/m^3$ as the mean. 2,500 $c/m^3$ was the median value, and it's similarity to the mode give it increased validity as the dividing line between background levels and those found when contamination is present. Once again, many studies implied that no health effects are expected if fungal counts are at or below background levels as long as no target fungal types are present.

## Learning from History

Despite the controversy over acceptable levels and numbers, post-remediation guidelines that include numbers *are* feasible. However, numbers are only part of the solution; process and interpretation must also be part of the guidelines.

It is important to understand that initial post-remediation criteria will not be set in stone. Once any criteria gains substantial industry acceptance, it is prudent to expect that experience with those criteria will lead to future adjustments. Take, for example, historical issues concerning acceptable levels of asbestos, radon and lead. Initially, the exposure limits for these substances were controversial, but eventually the impacted industries adapted their work procedures to meet the criteria. As the acceptable control level became more commonplace, research was able to validate its effectiveness. Many substances that are considered contaminants in our buildings have gone through multiple cycles in which the acceptable level was adjusted based on continuing application and research. These same trends can be expected for the mold remediation industry.

## Seeing it from Our Perspective

It is not unusual for post-remediation sampling to fail to meet clearance criteria. Communication problems, along with failure to follow specifications, have a significant impact on post-remediation clearance. Since many industry guidance documents recommend that a mold remediation work area be left free of visible dust (Pinto and Janke 5-17), obvious visual problems are the first clue that something has not gone according to the specifications. For example, if visible dust is present within the containment, the isolated area has not been carefully cleaned and unacceptable levels of mold spores may still be present. There is no need to conduct

clearance testing if it is obvious the area is not clean. In addition to identifying visual mold growth, it is imperative to consider hidden mold that may be impacting the area. Work plans must consider multiple aspects of a remediation project, specifically the possibility of hidden mold. Documents written by both the EPA and the AIHA contain warnings about hidden mold in remediation projects (EPA 8) (AIHA 8). Without careful reference to documents such as these, crucial information could be missed, potentially causing a multitude of problems farther along in the project.

Improper setup of remediation projects also has a significant impact on post-remediation sampling results. Consider an isolation area without a decontamination chamber. Something that seems as trivial as a sheet or two of 6-mil plastic could cost the contractor several more days on the site (and substantial additional costs) after the post-remediation sampling failed due to an improper setup that caused recontamination of the project site. If care goes into creating and following remediation project specifications, small details can determine the success of a project. The easiest way to satisfy post-remediation evaluation criteria (Table 1-3) is to make the containment or work area a non-variable. If contractors approaching a remediation project consistently set up effective engineering controls such as isolation barriers and negative pressure enclosures, the surrounding environmental factors should not matter. Proper isolation of the work area will provide a uniform baseline between remediation projects regardless of the type of building.

Professionals in the mold industry want clarity. Contractors, building owners and occupants, insurance adjusters, and industrial hygienists are all directly impacted by the lack of clarity often found in regulations. As such, it is crucial that contractors understand the expected end point before beginning any remediation project. When all parties understand that remediated areas are to be dust-free and meet a predetermined criterion for levels of fungal material, the communication process between the contractor and the client is drastically improved. Having a clear end point also reduces surprises at the end of a project and helps contractors and consultants work together with the same goals in mind, ultimately cutting costs. Knowing the end point before beginning a project is also an important concept that must be considered when developing the industry's standard of care.

## General Recommendations for the Post-Remediation Sampling Process

It is important that contractors and independent hygienists take a macro approach to any job site before post-remediation sampling begins. Having a professional independent or third party consultant write specifications and aid in the inspection of the facility is usually a good idea (IICRC 4.2.1). In the event of legal action, having a third party consultant helps to ensure that actions taken during remediation are agreed upon and documented.

The post-remediation process should always start with a visual inspection. Small indicators such as dust and debris should immediately alert the inspector that the specifications were not followed. Understanding that post-remediation samples would most likely not meet clearance criteria due to the unclean condition of the site, conducting post-remediation sampling would be senseless.

To ensure that the data collected at a project site is valid, sampling and analytical techniques should be consistent. Using different techniques for post-remediation samples as compared to earlier project sampling may alter the results and ultimately cause additional problems, expenses, and frustration. Therefore, the same sample collection and analysis methods should be used at the beginning and the end of the project.

The final general recommendation is to remember that people's health is involved. If there are concerns about the project, err on the conservative side to protect the occupants of the building. On any remediation project the contractors' primary concern should be protecting themselves, the work crew, and the occupants of the building. It is also important to recognize that mold remediation occurs in a wide variety of situations. The recommendations included in this document are designed to be applied to normal residential and business environments. Structures with immunocompromised occupants, or other at risk populations, may need to apply more stringent standards to fungal contamination clean-up efforts.

## Putting it All Together

At some point all of the historical data and general concepts must be distilled into a workable process. Based on our ongoing research and extensive mold remediation project experience, we have developed Table 1-3, Post-Remediation Evaluation Criteria for Mold Contamination, based on non-cultured sampling. All the procedures have been laid out for a post-remediation evaluation in a six-step chart. To start, a visual inspection (step 1) is conducted prior to the collection of any samples. The visual inspection is conducted to determine if the project specifications were followed, the moisture source was identified and corrected, and that the work area is dust free (white glove test). Only after the area passes a visual inspection are non-cultured samples collected.

Initial interpretation of the sample data compares the total fungal spore concentration to the set number of 2,000 spore counts per cubic meter of air ($c/m^3$)(step 2). This number is derived from the supporting reference data in Table 1-2 in which the mode value is 2,000 $c/m^3$. As shown in the table, several studies agree that this value is typical of an environment that is not impacted by adverse interior fungal growth, in essence, a "normal fungal ecology". The data also shows that very low total counts are possible based on seasonal variability or location. Our experience is consistent with that expressed by many other authors: when comparing samples from various

areas the reliability of a gross comparison (*i.e.*, total fungal spores) drops off considerably at low spore concentrations. Therefore, an exemption from step 3 is provided for samples from inside the contained area that have a total spore concentration of less than 800 c/$m^3$.

The evaluation of the remediation process continues with a comparison of the total spore count inside the work area to the total spore count in the makeup air source, based on the location of the containment entry point (step 3). Subsequently, a rank/order comparison of the fungal types (to the genus level only) and concentrations, including hyphal fragments inside the work area, are compared to the types and amounts naturally occurring in the comparison sample (step 4). At this point, we also recommend that the levels of hyphal fragments be reviewed. *Hyphal fragment* is a term that many laboratories use to describe fragments of fungal organisms that are not spores. Since hyphal fragments generally do not have enough characteristics to allow them to be correlated with a specific genus of fungi, they are recorded as a separate item. Our experience indicates that when concentrations of hyphal fragments found inside are higher than those found out-of-doors, an indoor source of fungal growth is usually present. As such, we have included this secondary comparison in step 4.

The levels of fungal spores and hyphal fragments recovered in the work area sample(s) must be not more than 100 c/$m^3$ higher than the levels of corresponding fungal spores or hyphal fragments in the comparison sample. This limit is based on the principle that all analytical methods have a limit of detection that must accommodate the limitations of the equipment used in the laboratory and for sample collection. In an indoor environment with a normal fungal ecology the ranking of the spores types found inside the work area should reflect the ranking of the comparison sample. For example, if *Cladosporium* was the most common spore type identified in the comparison sample, one would expect to find *Cladosporium* as the top ranking spore type inside the work area, only at a significantly lower level.

At this point in the process, indicator fungal types are considered (step 5). Fungal types are designated as "indicator" if they are associated with water damage to building or indoor finish materials. Keep in mind that these fungi may also come from out-of-doors and make up a natural part of the existing flora. While several molds are discussed as potential indicators of water-damaged environments, *Aspergillus/Penicillium* types are mentioned frequently in the reference documents.

*Aspergillus* and *Penicillium* spores are lumped together when analysis is performed by direct microscopy because the spores are indistinguishable from one another. Oddly, this turns out to be a benefit for the post-remediation evaluation process. Certain species of both *Aspergillus* and *Penicillium* are early colonizers of water-damaged materials that grow quickly and disperse many spores. When these growth properties are matched with the negative health effects associated with these spores, their value as an indication of acceptable mold remediation

procedures is enhanced. Our experience at Wonder Makers Environmental with post-remediation criteria and the documents referenced in the tables have led us to conservative but achievable criteria that indicator fungal types (*e.g.*, *Aspergillus/Penicillium*) must be recovered at levels below 200 c/$m^3$.

The final step in evaluating a mold remediation project is to consider target organisms (step 6). Target organisms are identified by their characteristic need for high moisture content and/or water activity to grow, their ability to naturally produce toxins, and their common degradation of cellulose-containing materials. Spores from these target organisms are not typically found in clean indoor environments so the criterion for target organisms is zero tolerance. The presence of target organisms in a cleaned work area indicates ineffective remediation and can result in continued issues with the structure or ill-health effects for the occupants of the space.

Any time one of the steps in the evaluation process exceeds the criteria, the area must be recleaned and retested as many times and as thoroughly as needed to meet the criteria for that step before moving on to the next step. When the work area has met the criteria in all six steps, it is considered to be clean with a normal fungal ecology, and the project has been successfully completed.

## Industry Trends: Examples of Other Currently Suggested Post-Remediation Protocols

As the mold remediation industry grows, there is a growing recognition that a commonly accepted post remediation protocol is needed. In searching the literature we were pleased to find that other examples of post-remediation guidelines are being published and discussed. Two such examples are reprinted in Appendix A. While the details differ, it is reassuring that the industry seems to be moving in the same direction in terms of establishing criteria for post-remediation.

Appendix A is a proposed post-remediation guideline for spore trap samples from U.S. Micro-Solutions, Inc. Like our proposal, total spore counts are compared to an outdoor sample or, when they exist, to earlier air results. While both guidelines set a total spore count limit, U.S. Micro-Solutions proposes a more liberal limit of 3,000 c/$m^3$ as compared to our 2,000 c/$m^3$. Rather than a rank/order comparison, they add the condition that no one genera or spore type may exceed 75% of the total spore count. Their goal is a general decrease in the total spore count and a "marked" reduction in any predominant spore type. While both protocols indicate that no *Stachybotrys* conidia is acceptable on post-remediation samples, ours proposes an enlarged list of zero tolerance indicator/target organisms. Our list includes species that grow in environments similar to *Stachybotrys*, are early colonizers of water-damaged materials, and/or produce toxins.

P & K Microbiology Services have also developed an interpretation for fungal bioaerosol samples. Theirs is a twelve-step process, similar to ours in many aspects. Both set an acceptable total spore concentration, involve comparison samples (indoor to outdoor, complaint to non-complaint areas) and involve a rank/order comparison between samples. Many of the later steps in the P & K protocol are looking for indicator or "signature" fungi, similar to our indicator/target organisms in steps 5-6.

The main difference in the two protocols is that P & K rely on culturable air samples. Rather than a limit, they set an upper range of 150 to 250 CFU/$m^3$ for acceptable total spore counts. Their list of marker or "signature" fungi reflect cultured air sample results. We advocate using non-viable sampling which gives a broader look at what spores are in the environment and a quicker turnaround time for the client. Furthermore, the 12 step protocol can be a bit cumbersome. We feel our 6-step chart is more user friendly, and has the advantage of a clear pass/fail answer at each step.

## Key Points to Remember

Throughout the effort of collecting and reviewing the historical data, developing the post-remediation criteria, and then field testing the process, several over-arching concepts continued to appear.

*A lack of standardization creates problems.* Oftentimes projects fail due to incorrect or sub-par efforts to follow specifications. However, many projects are currently categorized as ineffective because there is no widely recognized verification protocol or criteria for comparison of post-remediation samples. As a result, the project becomes seemingly endless, costs skyrocket, and liability becomes an issue.

*Previous efforts have not focused on post-remediation as a separate subset of data*. This leaves the field wide open. Much of the research has been related to identifying background levels or levels that can be linked to specific health effects. Few studies have focused on identifying post-remediation criteria which verifies the effectiveness of the remediation and cleaning techniques; even if those criteria cannot be clearly linked to health risk. History has shown that oftentimes a "best guess" has to be made so that research can validate the effectiveness of a particular level or criterion. Separating post-remediation criteria from the debate over background levels or other confounding issues would allow the industry to advance while further scientific data is collected.

Developing post-remediation evaluation criteria for mold projects should be a process. Comparison numbers are only a small part of the big picture. *However, in the absence of regulations, it is critical that the end point be clearly detailed and communicated before the project begins*.

*Our recommendation for post-remediation criteria includes six steps*. Failure on any single step means the evaluation process must start over from step 1. Incorporation of visual criteria and interpretation of sample data is imperative to the success rate of remediation projects.

## Conclusion

Currently, there are many controversies surrounding indoor air quality, especially related to mold and its effects. Setting and using post-remediation evaluation criteria in all remediation projects is a surefire way to strengthen the industry and, in the long run, help define industry standards. Each mold remediation project should be viewed from a macro perspective, considering *all* related factors. The six-step Wonder Makers Post-Remediation Evaluation Criteria is a valuable and effective tool for verifying the success of a project.

### REFERENCES

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## TABLE 1-1

| Date | Source [Reference] | Guidelines | | | Interpretation |
|---|---|---|---|---|---|
| | | Cultured Air Sample Analysis for Fungi (cfu/m$^3$*) | | | |
| | | Normal | Impacted | Remediated | |
| 1979 | Berk et al. [A] | <700 | >700** | | |
| 1979 | Gravesen (General) [B] | <3000 *Cladosporium*, <100 *Alternaria* - threshold for evoking allergic symptoms | 3000 *Cladosporium*, 100 *Alternaria* - threshold for evoking allergic symptoms | | |
| 1983 | Berstein et al. [B] | | 5000-10,000 | | |
| 1984 | Solomon et al. [A] | <1600 | >1600 | | |
| 1984 | Holmberg [A] | <2200 | >2200**, 10,000-15,000 - surface mold present | | |
| 1984 | Morey et al. [A] | <1000** | >1000 - need for investigation | | |
| 1986 | AIHA - Biohazard Reference Manual [A] | | | | No safe level of an uncontained pathogenic organism |
| 1986 | Morey et al. [B] | <10,000 total fungi or < 500 one species** | >10,000 total fungi or >500 one species - need for investigation or improvement | | |
| 1987 | Burge et al. [B] | | | | Indoor spore levels one-third of outdoor, same species spectrum recommended indoor limit, rank and order assessment |
| 1987 | Ohgke et al. [A] | <100** | >100 | | |
| 1988 | World Health Organization - IAQ: Biological Contaminants [A] | <150 mixture of species or <500 *Cladosporium* or other common phylloplanes | >50 of one species - investigate, >150 mix of species**, > 500 common phylloplanes** | | |
| 1988 | Canada Mortgage and Housing Corp. - Determination of Fungal Propagules in Indoor Air [A] | <200 if several species, <500 if mainly *Cladosporium* and *Alternaria* | >50 if one species, >200 if several species, >500 if mainly *Cladosporium* and *Alternaria* (investigate further for all) | | |
| 1988 | Hunter et al. (Homes) [B] | <5000** | >5000 level most often exceeded when surface mold present | | |
| 1988 | Miller et al. (Homes) [A] | <150 mixture of species or <300 common phylloplanes | >50 of one species of concern - investigate, >150 mix of species**, >300 common phylloplanes** | | Toxic/pathogenic unacceptable |
| 1989 | ACGIH - Guidelines for the Assessment of Bioaerosols [A] | <100 | >100** | | Indoor/outdoor ratio <1 is OK if similar taxa or complaint area/non-complaint area ratio >10 is unusual |
| 1989 | The Netherlands - Research Methods in Biological Indoor Air Pollution [A] | <10,000 total fungi or <500 of one species of a potentially pathogenic nature are a threat to health** | >10,000 total fungi or >500 of one species of a potentially pathogenic nature are a threat to health | | |
| 1989 | AIHA - The Practitioner's Approach to IAQ Investigations [A] | <1000** | >1000 | | High indoor/outdoor ratio indicates indoor amplifier, rank order assessment |
| 1990 | Burge [A] | <1000** | >1000 - investigate | | If indoor microbial aerosols qualitatively different from outdoors and indoor levels consistently more than double outdoor and exceeding 1000 cfu/m$^3$ should be investigated |
| 1990 | Reponen et al. (Homes not farms) [A] | <500 (winter only)** | >500 (winter only) | | Indoor/outdoor ratio >1 may indicate abnormal indoor level in summer |
| 1990 | Reynolds et al. [A] | <500** | >500 - indoor source indicated | | Significant indoor/outdoor differences indicate indoor source, speciation and rank ordering recommended |

| Date | Source [Reference] | Guidelines | | | Interpretation |
|---|---|---|---|---|---|
| | | Cultured Air Sample Analysis for Fungi (cfu/m$^3$*) | | | |
| | | Normal | Impacted | Remediated | |
| 1991 | Godish [A] | <1000** | >1000 | <100 "mold-free environment" | |
| 1991 | Nordic Council - Criteria Documents from the Expert Group [A] | 10-10,000 typical in "sick buildings" | 10-10,000 typical in ambient air | | |
| | | | | | |
| 1991 | Canada Mortgage and Housing Corp. - Testing of older houses for microbial pollutants [A] | <200 variety of species or <500 including *Alternaria* and *Cladosporium*** | >200 variety of species or >500 including *Alternaria* and *Cladosporium* - investigate | | |
| 1992 | Miller et. al. [A] | | | | Indoor mycoflora qualitatively similar to outdoors is OK or indoor mycoflora quantitatively lower than outdoors is OK |
| 1992 | OSHA - Technical Manual [A] | <1000** | >1000 | | |
| 1993 | Council of the European Community - Report #12: Biological Particles in Indoor Environment [A] | For houses: <50 (very low), <200 (low)** | <1000 (intermediate), <10,000 (high), >10,000 (very high)** | | |
| | | Non-industrial indoor: <25 (very low), <100 (low)** | <500 (intermediate), <2000 (high), >2000 (very high)** | | |
| 1993 | Yang et. al. [A] | <200 | >200** | | A critical analysis of results is required if pathogenic or toxigenic fungi are detected |
| 1993 | AIHA - The Industrial Hygienist's Guide to IAQ Investigations [A] | | | | Rank order assessment, indoor/outdoor comparison recommended |
| 1993 | National Health and Welfare, Canada - IAQ in Office Buildings: A Technical Guide [A] | <150 mixture of species, <500 if common tree/leaf fungi | >50 if one species - investigate, >150 mix of species**, >500 common tree/leaf fungi** | | Toxigenic/pathogenic unacceptable |
| 1994 | Cutter Information Corp. - IAQ Update: Biocontaminants in Indoor Environments [A] | <300 common fungi, <150 mixed fungi, <200 total fungi, <100 if immunocompromised population** | >300 common fungi, >150 mixed fungi, >200 total fungi, >100 unless immunocompromised population | | |
| 1994 | OSHA - Proposed IAQ Standard [A] | | | | Levels of bioaerosols in the indoors would reflect those outdoors, rank order assessment |
| 1994 | Healthy Buildings International [A] | <750 if species not infective or allergenic | >750 if species infective or allergenic** | | |
| 1995 | ACGIH - Air Sampling Instruments for Evaluation of Atmospheric Contaminants [A] | <100 (low)** | 100-1000 (intermediate)**, >1000 (high)** | | |
| 1995 | IAQ Association Inc. - IAQ standard #95-1 Recommended for Florida [A] | <300 common fungi, <150 mixed | >300 common, >150 mixed** | | |
| 1995 | Health Canada - Fungal Contamination in Public Buildings: A Guide to Recognition and Management [C] | <150 mix of species, <500 if *Cladosporium* or other tree/leaf fungi | <150 mix of species, <500 if *Cladosporium* or other tree/leaf fungi** | | |

| Date | Source [Reference] | Guidelines | | | Interpretation |
|---|---|---|---|---|---|
| | | Cultured Air Sample Analysis for Fungi (cfu/m$^3$*) | | | |
| | | Normal | Impacted | Remediated | |
| 1995 | NYC Department of Health - Guidelines on Assessment and Remediation of *S. atra* in Indoor Environments [A] | | 103-104 *S. atra* immediate evacuation | | Indoor/outdoor ratio indicates contamination |
| 1997 | Robertson [D] | <300 total fungi, <50 individual species (excepting *Cladosporium*) | >300 total fungi, >50 individual species (excepting *Cladosporium*) - further investigation | | |
| 1999 | Analytical Services, Inc. [I] | <550 | >550** | | |
| 1999 | Mycotech Biological, Inc. [J] | <300, <50 individual contributing excluding *Cladosporium* | >300 - further investigation | | |
| 2001 | Godish - Indoor Environmental Quality [E] | >300-<1000 | >1000 | | |
| 2001 | Clark, AIHA's The Synergist (Nov.) [F], Residential Buildings | <500 | 500-1000 (possible), >1000 (probable) | | |
| | Commercial Buildings | <250 | 250-1000 (possible), >1000 (probable) | | |
| 2002 | Mold Free [G] | <250 | >250 | | |
| 2003 | Auburn Environmental [H] | <1000 | >1000 | | |

* Colony forming units per cubic meter of air

** Interpreted levels – different descriptive language used by the study authors for these spore levels

| | | |
|---|---|---|
| **Mean** | **1341.666667** | **1476.394737** |
| **Median** | **650** | **700** |
| **Mode** | **1000** | **1000** |

## REFERENCES


[A] Rao, C.Y., Burge, H.A. and J.C.S. Chang. "Review of Quantitative Standards and Guidelines for Fungi in Indoor Air." *Journal of Air and Waste Management Association*. 46(1996): 899-908.

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[D] Robertson, L.D. "Monitoring Viable Fungal and Bacterial Bioaerosol Concentrations to Identify Acceptable Levels for Common Indoor Environments." *Indoor Built Environments*. 6(1997):295-300.

[E] Godish, T. *Indoor Environmental Quality*. Boco Raton: CRC Press LLC, 2001.

[F] Clark, G. "Assessment and Sampling Approaches for Indoor Microbiological Assessments." *American Industrial Hygiene Association (IAHA): The Synergist*. Nov. 2001.

[G] Mold Free: A division of Integrated Microbiological Services. http://www.1877moldfree.com/index.html.

[H] Auburn Environmental. Akron Ohio. http://www.auburn-environmental.com/.

[I] Analytical Services Inc. Huntsville AZ. http://www.asi-hsv.com.

[J] Mycotech Biological, Inc. Jewett TX. http://www.mycotechbiological.com/.

[K] Wonder Makers Environmental. Kalamazoo MI. http://www.wondermakers.com.

## TABLE 1-2

| Date | Source [Reference] | Guidelines | | |
|---|---|---|---|---|
| | | Non-Cultured Air Sample Analysis for Fungi (spores/m³) | | |
| | | Normal | Impacted | Remediated |
| 1988 | Lacey et al. [A] | 1000-10,000 | | |
| 1993 | Russian Federation - MAC of Harmful Substances [A] | 1000-10,000 cells/m³ | >10,000 cells/m³* | |
| 1999 | Mycotech Biological, Inc. [J] | <2000 | >2000 - further investigation | |
| 2001 | Godish - Indoor Environmental Quality [E] | >3000-<10,000 | >10,000 | 1000-3000 |
| 2001 | Clark [F], Residential buildings | <5000 | 5000-10,000 (possible), >10,000 (probable) | |
| | Commercial buildings | <2500 | 2500-10,000 (possible), >10,000 (probable) | |
| 2003 | Wonder Makers Environmental [K] | <2,000 mixed types, <1,000 *Aspergillus, Penicillium,* <500 outdoor types | >2000 | |
| 2003 | Auburn Environmental [H] | <2000 | >2000* | |

* Interpreted level

| | |
|---|---|
| **Mean** | **4786** |
| **Median** | **2500** |
| **Mode** | **2000** |
| **Standard Deviation** | **3718** |
| | |
| **Mean** | **4785.714286** |
| **Standard Error** | **1405.165398** |
| **Median** | **2500** |
| **Mode** | **2000** |
| **Standard Deviation** | **3717.718194** |
| **Sample Variance** | **13821428.57** |
| **Kurtosis** | **-1.280292985** |
| **Skewness** | **0.938866018** |
| **Range** | **8000** |
| **Minimum** | **2000** |
| **Maximum** | **10000** |
| **Sum** | **33500** |
| **Count** | **7** |

**REFERENCES**


[A] Rao, C.Y., Burge, H.A. and J.C.S. Chang. "Review of Quantitative Standards and Guidelines for Fungi in Indoor Air." *Journal of Air and Waste Management Association*. 46(1996): 899-908.

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[J] Mycotech Biological, Inc. Jewett TX. http://www.mycotechbiological.com/.

[K] Wonder Makers Environmental. Kalamazoo MI. http://www.wondermakers.com.

**TABLE 1-3**

| Post-Remediation Evaluation Criteria |
|---|
| **Step 1. Visual Inspection**<br>By submission of samples client has indicated that specifications were followed, moisture source was identified and corrected, contents and debris were removed, all visible mold was removed, and work area is white-glove dust free. |
| **Step 2. Total Spore Concentration**<br>Total concentration of fungal material on work area sample is below 2,000 c/$m^3$. If less than 800 c/$m^3$, go to criterion 4. |
| **Step 3. Comparison to Make-up Air Source**<br>Total concentration of fungal material on work area sample is below comparison sample. |
| **Step 4. Rank / Order Comparison**<br>The level of each fungal type and hyphae recovered on the work area sample is less than 100 c/$m^3$ above the comparison sample levels. |
| **Step 5. Indicator Organisms**<br>*Aspergillus/Penicillium*-like spores on the work area sample are below 200 c/$m^3$. |
| **Step 6. Target Organisms**<br>The work area sample recovered no target fungal types (*Stachybotrys*, *Fusarium*, *Trichoderma**, *Memnoniella*, *Chaetomium)*. |

**APPENDIX A**

**Spore Trap Samples (Previously Affected Area)**

A spore trap sample will be collected in the area(s) of concern. These samples should show no *Stachybotrys* conidia. The total spore count should be below background (outdoor) air (certain exceptions apply to this guideline, particularly when outdoor spore counts can be negatively impacted by snowfall and other factors). On total spore counts over 3,000 no one genera or grouping may exceed 75% of the total spore count. Where prior air results exist, the total spore counts should be reduced by 70% where unusually high spore counts (greater than 10,000 spores per cubic meter) have existed in the past. Otherwise, a general reduction in total spore count is favorable with a marked reduction in any predominant spore type. Older buildings, with poor HVAC filtration or heavy outside air infiltration may be evaluated at the discretion of the site visitor. (Total sample volume should be 75 liters on Air-O-Cell cassettes, 25 liters on Micro5 cassettes or 60 liters on Cyclex-D cassettes.) Areas corresponding to air samples not meeting these guidelines will be recommended for further remedial action.

U.S. Micro-Solutions, Inc., Greensburg, PA, www.usmicro-solutions.com

## About the Authors

***Michael A. Pinto*** *currently serves as Chief Executive Officer of Wonder Makers Environmental, Inc. His educational background includes a Bachelor of Science degree in philosophy and a Masters Degree in public administration. Michael holds numerous other certifications including Certified Safety Professional (CSP) and Certified Mold Professional (CMP). He has more than 30 years of safety and environmental experience from jobs in the private sector, the non-profit arena, and regulatory agencies, and is the author of five books, including Fungal Contamination: A Comprehensive Guide for Remediation, over 150 published articles, and 18 commercial training programs. Mr. Pinto can be reached at map@wondermakers.com.*

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