SUGGESTED GUIDANCE FOR THE SELECTION AND USE OF RESPIRATORY PROTECTION DURING MOLD REMEDIATION

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INTRODUCTION

This document addresses the selection of proper respiratory protection for workers engaged in the remediation and restoration of indoor environments affected by extensive amplification of fungi (molds and yeasts) on building and finishing materials. Often the source contamination is extensive, resulting in the dissemination of massive numbers of airborne mold spores when areas of contamination are disturbed. Even though such remediation is performed with workers wearing respirators with seemingly adequate Protection Factors under conditions of physical containment and negative air flow, spore penetration of respirators is likely to occur, resulting in worker exposures and resultant respiratory health risks. Therefore, an understanding of microbial amplification and resultant levels of airborne mold spores, as well as types of available respirators and their assigned protection factors (APF), along with calculations of spore penetration, are required to make the proper respirator selection and adequately protect this increasing group of at-risk workers.

BACKGROUND

Fungal Ecology and Health Risk

Availability of moisture, the presence of organic substrates, and time are the factors necessary for the germination of mold spores. In uncontrolled situations, such as flooding, undetected or neglected roof and/or plumbing leaks, and high relative humidity resulting in condensation and films of surface moisture, germinated spores will grow and begin to amplify. Fungal amplification is typically characterized by the predominance of molds that are recognized as potentially allergenic, toxigenic, and/or opportunistic. Examples include *Aspergillus, Penicillium, Alternaria, Fusarium*, *Aureobasidium* and *Stachybotrys,* among others. These types of molds, in elevated concentrations and often in combination with other associated biological pollutants, such as bacterial endotoxins, B-1,3 glucans and various mycotoxins from fungi, present recognized human health risks. Such exposures appear analogous to those incurred in the agricultural industry.

The American Thoracic Society in its official report on *Respiratory Health Hazards in Agriculture* states that "Some of the most clinically significant bioaerosol-induced respiratory disease risks in agriculture are those associated with episodic exposures to very high concentrations of organisms" (ATS, 1998). Mold remediation workers can be at risk for both acute high level or chronic low level mold exposures, which may contribute to or exacerbate upper respiratory allergies and asthma, or lead to the development of debilitating conditions such as Organic Dust Toxic Syndrome (ODTS) and Hypersensitivity Pneumonitis (HP). This risk is compounded by the lack of any established and uniformly accepted human exposure limits or threshold limit values for airborne mold contamination. The latter includes mold spores and hyphal fragments and their potentially reactive substances, such as Beta-1, 3, glucans, ergosterol, and mycotoxins.

Need for Guidance

Presently there is uncertainty concerning the adequacy of personal protective equipment worn by workers performing mold clean-up activities, and it is not known what fraction of spores in a highly contaminated atmosphere penetrates the respirator filter or face seal (Flannigan et al, 2002). Current mold remediation guidance documents do not adequately address the selection of respiratory protection for mold remediation workers, relative to quantitative estimates of airborne mold concentrations during mold remediation, as well as expected resultant respirator penetration.

Neither the New York City Department of Health's Guidelines on Assessment and Remediation of Fungi in Indoor Environments, the U.S. EPA's Mold Remediation in Schools and Commercial Buildings, nor the ACGIH text on Bioaerosols: Assessment and Control make recommendations based on existing, published data from airborne mold measurements and/or estimates of potential airborne levels from quantitative surface contamination data. All three documents make general recommendations for respirator selection based upon extent of visible mold growth on substrates. Disregarding the extent of non-visible mold resulting from acute or chronic water damage, compromises both the selection of respiratory protection (and other associated PPE) and the determination of the appropriate physical containment required to protect the workers, the occupants, and the environment. Additionally, at this time, neither OSHA, NIOSH, nor ANSI provide guidance for the selection of respiratory protection for use in areas of high fungal and bacterial exposures based upon calculations of estimated airborne concentrations and resultant respirator penetration.

CRITICAL ELEMENTS

Assessing the Scope of Effort

The selection of respiratory protection is dependent upon the scope of the mold remediation effort. Therefore, the first and foremost element in determination of required containment and associated respiratory protection is an accurate assessment of the extent of the mold contamination. Such contamination is typically co-incident with the extent of water damage, and in that regard inspection and evaluation guidance can be found in the S500 Standard and Reference Guide for Professional Water Damage Restoration of the Institute of Inspection, Cleaning and Restoration Certification (IICRC, 1999).

On-site, pre-mold remediation inspection includes addressing water/moisture source(s), building history, extent of moisture intrusion, assessment of structural and finishing materials, evaluation of the HVAC system, basements, and crawlspaces, documentation of pre-existing conditions, and establishment of containment, remediation, and drying goals, among others. The IICRC S520 Mold Remediation Standard and Reference Guide provides additional detailed specifics on determination of the scope of mold remediation efforts. Inspection may require intrusive investigation, such as removal of a small section of wallboard to assess the extent of mold amplification in an exterior wall cavity. Professional judgment will determine the extent of containment and recommended respiratory protection required.

Source Contamination and Resultant Airborne Mold Concentrations

Concentrations of mold spores aerosolized during the remediation process are dependent upon the extent of amplification on substrate materials. Resultant remediation tasks, such as demolition, actively liberate massive numbers of spores into the air. Environments with significant water damage and strong mold amplification sites have been quantified. Examples of these concentrations from sampled substrates, along with predominant molds include: bulk samples of vinyl wall covering, $>10^4$ to $>10^7$ CFU/cm^2 (Aspergillus versicolor) and ceiling tiles, $>10^3$ to $>10^7$ CFU/cm^2 (Stachybotrys/Penicillium); vacuum collected settled dust on upper side of undamaged ceiling tile, 2.5 x 10^6 CFU/g (Aspergillus versicolor); swab collected dust on supply vent of unit ventilator, 1.7 x 10^4/cm^2 (Cladosporium); and sticky tape dust in fissure of stone veneer, 1.1 x 10^3 spores/cm^2 (Penicillium/Aspergillus) (Morey, 1993; Morey, 1994).

A number of case studies have related severely mold contaminated building materials to resultant airborne mold concentrations during demolition. Data collected during the remediation and repair of seven moldy buildings showed airborne concentrations of culturable fungi from 10^3 to >1.9 x 10^5 CFU/m^3 , with total spore counts by a microscopic method showing 10^5 to 10^6 spores/m^3 during demolition (Rautiala et al, 1996). Mold amplification on building materials eight days after a fire showed 10^7 CFU/g, with quiescent air sampling showing 10^4 spores/m^3, increasing to $>10^6$ spores/m^3 during demolition and subsequent clean-up (Rautiala et al, 2002). Likewise, in a mold remediation project in an arid climate, airborne mold levels within the containment area were 10^7 spores/m^3 and 10^5 CFU/m^3, with Penicillium and Aspergillus predominating, as compared with outdoor data showing 10^3 – 10^4 spores/m^3 with 10^2 – 10^3 CFU/m^3 and Cladosporium predominating (Hung et al, 2002).

Table 1 postulates minimum and maximum airborne mold concentrations in average sized residential rooms based upon areas of mold growth at minimum (10^6 spores/in^2) and maximum (10^7 spores/in^2) substrate concentrations. The calculated spore numbers assumes a 1% aerosolization from uniformly contaminated sources, and an even distribution of airborne spores throughout the room air spaces.

Table 1. Spores/m^3 During Remediation (Based on 1% Aerosolization)

Size of Mold Growth	Average bathroom 7 x 5 x 8 ~8 m^3		Average bedroom (12 x 15 x 8) ~41 m^3		Average living room (15 x 20 x 8) ~68 m^3	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
1 SF	180,000	1,800,000	35,121	351,219	21,176	211,764
10 SF	1,800,000	18,000,000	351,219	3,512,193	211,764	2,117,647
30 SF	5,400,000	54,000,000	1,053,659	10,536,585	635,294	6,352,941
100 SF	18,000,000	180,000,000	3,512,195	35,121,956	2,117,647	21,176,472

Minimum = 1,000,000 spores/in^2
Maximum = 10,000,000 spores/in^2

SF = square foot

Assigned Protection Factors and Respirator Classes

Respirators provide varying levels of protection, and so they are divided into classes, with each respirator class assigned a protection factor to help compare its protective capabilities with other respirator classes. An assigned protection factor (APF) is a unitless number, ideally determined statistically from a set of experimental or workplace data. It is the "minimum" level of protection anticipated for a substantial proportion (usually 95%) of properly fitted and trained respirator users. An APF is generated by dividing the airborne concentration of the contaminant outside the respirator by the airborne concentration of that agent inside the respirator wearer's facepiece, hood or helmet. Thus, if concentrations both outside and inside a respirator were equal, then the APF would be 1. An APF of 5 ideally infers that the respirator wearer was exposed to 1/5 (20%) of the airborne concentration that he or she would have been exposed to without a respirator, for an 80% reduction. An APF of 10 represents a 1/10 exposure and 90% reduction, while an APF of 50 represents a 1/50 exposure and 98% reduction, etc. APFs can range from 5 to 10,000. Most disposable respirators are at the low end of the scale, while self-contained breathing apparatuses (SCBA) operated in the pressure demand mode, are at the high end.

Typically, in selection of a respirator, airborne contaminant estimates (from monitoring) are compared to occupational exposure limits. Unfortunately, at the present time there are no Permissible Exposure Limits (PELs) or Threshold Limit Values (TLVs) for fungal contamination, and its resultant spores, products, and components of amplification and growth. Thus we must use currently available environmental data, such as those previously described, and examine the calculated potential for worker exposures relative to the different respirator classes and their associated protection factors. Such an assessment is presented in Table 2.

Table 2. Potential Mold Inhalation Exposures by Respirator Type

Spores/m^3 of workspace air	Spores/m^3 using Filtering Facepiece (APF 5)	Spores/m^3 using Half-face APR (APF 10)	Spores/m^3 using Full-face APR (APF 50)	Spores/m^3 using Full-face Powered APR (APF 1000) *
50,000	10,000	5,000	1,000	50
100,000	20,000	10,000	2,000	100
500,000	100,000	50,000	10,000	500
1,000,000	200,000	100,000	20,000	1,000
5,000,000	1,000,000	500,000	100,000	5,000
10,000,000	2,000,000	1,000,000	200,000	10,000

*According to 3M their powered air-purifying respirator (PAPR) has an assigned protection factor (APF) of 1000. According to NIOSH, PAPRs are rated the same as a full-face APR at an APF of 50.

NIOSH assigns the powered air-purifying respirator (PAPR) with half or full facepiece a protection factor of 50. This may be woefully inadequate under high exposure conditions, such as the demolition of extremely contaminated porous building materials. The American Thoracic Society has addressed such concern (ATS, 1998):

> *"A PAPR with a tight-fitting full facepiece has an assigned protection factor (APF) of 50. If concentrations reach 5 x 10^9 spores/m^3, an exposure sustained while wearing the PAPR may be as high as 10^8 spores/m^3. For adequate protection, a full face piece, supplied air or self-contained, positive pressure or pressure demand respirator would be needed. Such a device could reduce exposure by 10,000-fold (assuming the APF) to 5 x 10^5 spores/m^3. That is a far safer level, but it could still be hazardous, depending upon the inhaled spores and individual susceptibility."*

The NIOSH minimum recommendation for respiratory protection for workers remediating dusty areas contaminated with highly infectious Histoplasma capsulatum spores (from bird and bat manure) is a full-facepiece respirator (APF 50). Unless the results of quantitative tests suggest that a person wearing an air-purifying, full-facepiece respirator can achieve an outstanding facepiece seal, a powered air-purifying respirator (PAPR) with a full facepiece should be chosen for extremely dusty work. NIOSH takes a conservative approach in the absence of environmental sampling data and recommends a PAPR with a full facepiece should be the "…minimum respiratory protection worn by someone entering an enclosed area in which the amount of bat and bird manure contamination is unknown. A less protective respirator should be worn only when a site has been evaluated as having a low risk for inhalation exposure to material that might be contaminated with H. capsulatum" (Lenhart et al, 1997). This emphasizes the need for a similar conservative approach to protecting mold remediation workers where the extent of the hidden or non-visible mold is in question.

An Interim Substitute for a Permissble Exposure Limit

The National Allergy Bureau™ (NAB™) is the section of the American Academy of Allergy, Asthma and Immunology's (AAAAI) Aeroallergen Network that is responsible for reporting current pollen and mold spore levels to the media. Table 3 shows NAB's current criteria for mold spores levels in the outdoor air, while Table 4 relates such levels to expected symptoms of exposed individuals.

Table 3. Mold Spore Levels (Burkard data)

Grains per Cubic Meter	Level
0-6500	Low (<50th percentile)
6500-13,000	Moderate (50th to 75th percentile)
13,000-50,000	High (75th to 99th percentile)
50,000 or more	Very High (>99th percentile)

Table 4. What This Means to Mold Spore Allergy Sufferers

Level	Those Who Will Likely Suffer Symptoms
Absent	No symptoms
Low	Only individuals extremely sensitive to mold spores
Moderate	Many individuals sensitive to mold spores
High	Most individuals with any sensitivity to mold spores
Very High	Almost all individuals with any sensitivity to mold spores. Extremely sensitive people could have severe symptoms.

NAB's position is that "Most individuals with sensitivities to mold spores" will likely suffer symptoms when spore levels exceed 13,000/m^3 of air. Other organizations have been more conservative in establishing levels that they consider as high. The Clark County Department of Air Quality Management (State of Nevada) website suggests that high is 2,500 to 25,000 spores/cubic meter of air. A private organization, The Asthma Center, suggests that levels from 1,000 to 2,500 are high with moderate to severe symptoms; from 2,500 to 7,000 are very high with moderate to severe symptoms and that 7,000 and above are extremely high with severe symptoms.

It is recognized that indoor mold problems can arise from outdoor mold spores infiltrating indoor environments and growing and amplifying in moist environments. Molds that are generally found in outdoor samples include *Alternaria, Botrytis*; *Cladosporium*, and various ascospores, basidiospores and smuts that are considered 'typical outdoor molds'. Table 5 presents a general categorization and characterization of environmental fungi typically found in outdoor and indoor environments (Macher 2002).

Table 5. Fungal Categories

Category Name	Fungi in Category	Characteristics
Leaf-surface (phylloplane) fungi	*Alternaria* spp. *Cladosporium* spp. *Epicoccum spp.*	Outdoor sources (growth on leaf surfaces); Indoor sources possible but less common than for the other fungal categories Presence in indoor air generally reflects outdoor air ventilation
Soil fungi	*Aspergillus* spp. *Penicillium* spp.	Outdoor sources (growth in soil) and possibly indoor sources Presence in indoor air generally reflects outdoor air ventilation and the contribution of indoor growth, if any
Water-requiring (hydrophilic) fungi	*Aspergillus fumigatus** *Botrytis* spp. *Fusarium* spp.* *Stachybotrys* spp.* Yeast *Sporobolomyces* spp. *Ulocladium* spp. Zygomycetes	Outdoor sources (growth on moist organic matter) and possibly indoor sources Presence in indoor air generally reflects outdoor air ventilation and the contribution of indoor growth, if any Higher prevalence or concentration indoors may indicate the presence of excess water
Potentially toxigenic fungi	Aspergillus flavus *Aspergillus fumigatus** Aspergillus versicolor *Fusarium* spp.* *Stachybotrys*	Outdoor and possibly indoor sources Presence in indoor air generally reflects outdoor air ventilation and the contribution of indoor growth, if any Presence indoors may indicate a concern for health of the occupants

	spp.*	
*Fungal groups included as both water-requiring toxigenic fungi: *Aspergillus fumigatus, Fusarium* spp., and *Stachybotrys* spp.		

When the indoor (or built) environment is subjected to a moisture problem or a prolonged water intrusion, a group of molds begin to amplify that are referred to as water indicator fungi. They include species of *Pencillium, Aspergillus, Ulocladium, Stachybotrys, Fusarium* and others. These molds, depending upon their nature, location and quantity, have been associated with adverse health effects in susceptible individuals. If levels of 'typical outdoor molds' in excess of 13,000 spores/m^3 are considered high, then it could be concluded that levels in excess of 13,000 spores/m^3 of molds categorized as 'water-requiring fungi' or 'potentially toxigenic fungi' would be of greater concern.

If, for the sake of discussion, it can be agreed that 10,000 spores/m^3 (which would include spores of health concern) is the highest concentration that a worker should be exposed to during the mold remediation process, then we can substitute that number for a PEL (perhaps better referred to as a SubPEL) in the respirator selection process.

Approach to Worker Protection

Table 6 illustrates suggested minimum respirator requirements based upon a SubPEL of 10,000 spores/m^3 of air. While this number may be used as a general guideline for establishing effective respiratory protection, it should be noted that the number is a generalization and not specific as it relates to genera or species. Therefore, depending upon the quantity and types of spores present as well as the length of time that a worker is exposed to the environment, some might suffer adverse reactions at much lower levels.

Additionally, if it is assumed that mold remediation workers should not be exposed to concentrations greater that 10,000 spores per cubic meter of air for short term excursions into contaminated areas, and if one selects a respirator that has an APF that would accomplish that goal, it becomes apparent that in most cases the minimum respiratory protection that should be employed during remediation is a full face air purifying respirator with appropriate cartridges.

Also, if levels inside containment are predominately toxigenic species, the SubPEL may be reduced to a suitable lower level (e.g. 2, 000 to 6,000 spores/m^3). To reduce the exposure to a lower exposure limit may require the use of powered air purifying respirators (PAPR) or self-contained breathing apparatus (SCBA) in conjunction with more stringent engineering controls and work practices that reduces the dispersal of spores from the substrate. In order to assess actual airborne mold levels generated, an Indoor Environmental Professional (IEP) must be engaged to conduct or oversee quantitative airborne spore monitoring.

Table 6. Respiratory Protection – Suggested Minimum Requirements			
Spores/m^3 in	**Minimum Assigned**	**Spores/m^3 in**	**Minimum Assigned**

ambient air	Protection Factor	ambient air	Protection Factor
50,000	5[1]	600,000	1,000[4*]
100,000	10[2]	800,000	
200,000	50[3]	1,000,000	
300,000		5,000,000	
400,000		10,000,000	
500,000		>10,000,000	10,000[5]

1: Filtering facepiece
2: Half-face APR
3: Full-face APR
4: Fullface PAPR*
5: Supplied-air, SCBA or quantitative fit test

*According to 3M their powered air-purifying respirator (PAPR) has an assigned protection factor (APF) of 1000. According to NIOSH PAPRs are rated the same as a full-face APR at an APF of 50.

Relevance to OSHA

While OSHA does not specifically regulate workplace exposure to molds at this time, current OSHA rules relative to recognized but unregulated hazards apply. According to Federal Register # 63:1152-1300 Respiratory Protection - Final Rule: “In addition, the general duty clause (§ 5(a)(1)) of the OSH Act may require employers to protect their employees from substances that are not regulated but that are known to be hazardous at the exposure levels encountered in the workplace…. Moreover, as also noted above, this rulemaking does not address the hierarchy of exposure controls in paragraph (a)(1). Thus, employers may not rely on respirators to control exposures when feasible engineering controls are available and are sufficient to reduce exposures.”

OSHA further states that “99 citations have been issued for violations of paragraph (a)(2) in conjunction with a citation of the General Duty Clause (i.e., § 5(a)(1) of the Act). These citations concerned various situations involving the failure of the employer: (1) To control exposures in emergencies; (2) to control exposure to unknown concentrations of a toxic substance; (3) to control exposure to a contaminant that was clearly a recognized hazard even though no OSHA PEL existed; Personal exposure monitoring is the "gold standard" for determining employee exposures because it is the most reliable approach for assessing how much and what type of respiratory protection is required in a given circumstance.”

SUMMARY AND CONCLUSION

In summary, reported high airborne concentrations of mold spores during remediation activities places significant emphasis on appropriate respirator selection in order to reduce potential penetration, thereby reducing worker exposure and resultant health risk. If there is a concern with respect to the use of more expensive respiratory protection methods, based upon the approach we have described, then airborne mold spore concentrations must be maximally reduced by adoption of appropriate engineering controls and work practices.

In that regard, we encourage mold remediators to optimize the reduction of airborne mold concentrations and hence potential worker exposures during remediation activities through combined attention to effective engineering controls, prudent work practices, and appropriate respirator selection. The effectiveness of such an approach may be assured through environmental monitoring conducted by a qualified Indoor Environmental Professional.

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