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An Opinion on Assessing the Health Effects of Mold

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INTRODUCTION

I am not a physician, so I am certainly not qualified to comment on whether or not there is an association between airborne concentrations of mold spores and potential health effects. However, I am qualified to comment on the quality of the data upon which such associations may reasonably be based. It is my opinion that if one is to conclude that health effects either are or are not associated with mold concentrations, those conclusions should be at least partially based on an analysis of defensible field data. Furthermore, if such conclusions are stated, they should include an honest assessment of the quality of the field data upon which those conclusions were based.

The US Environmental Protection Agency (EPA) considers the quality of field data to be of paramount importance. EPA has a multi-volume set of guidelines, referred to as Data Quality Objectives (DQO's), which their scientists are expected to follow when collecting field data. Both EPA management and scientists know that if the field data are collected incorrectly, the conclusions resulting from an analysis of those data may be indefensible. Surprisingly, the quality of the field data obtained during mold investigations has been of little interest within the indoor air quality community; and this may be especially true within the legal part of that community.

For example, the American College of Occupational and Environmental Medicine (ACOEM) published a guidance document for physicians on the health effects of indoor mold (Adverse Human Health Effects Associated with Molds in the Indoor Environment; 2002; www.acoem.org/guidelines). On page three of that document, ACOEM reached several conclusions, including:

"…indoor airborne levels of microorganisms are only weakly correlated with human disease or building-related symptoms…";
"Exposures associated with (organic dust toxic syndrome) … have ranged from 100,000 – 1,000,000 "microorganisms" per cubic meter of air …, extreme conditions not ordinarily encountered in the indoor … environment".

In comparison, the Institute of Medicine (IOM) in publishing *Damp Indoor Spaces and Health* (Institute of Medicine of the National Academies, National Academies Press, Wash, DC, 2004) reached the conclusion that associations between the concentrations of airborne mold and health effects may exist, but that not enough reliable data were available to ascertain if such an association actually did exist. The difference between these two positions is that ACOEM was willing to go where IOM feared to tread. Therefore, it's reasonable to examine the basis for the ACOEM conclusions; and the foundation for those conclusions includes the quality of the field data upon which they may have been based.

RISK ASSESSMENT

When an Indoor Environmental Professional (IEP) conducts a mold

investigation involving the potential exposure of occupants, those activities may be grouped into two broad categories. The first category of activities may be referred to as an exposure assessment. This requires the IEP to obtain the answers to at least two questions. First, are there "contaminants of concern" (mold, bacteria, allergens, etc.) present in the indoor environment? Second, can those contaminants potentially affect the occupants?

There are three possible outcomes to an exposure assessment. If the answer to either of these questions is positively "no", then there is no occupant exposure and the exposure assessment is complete. If the answer to both questions is positively "yes", then there is an occupant exposure and the exposure assessment is also complete. Unfortunately, in the real world, the actual result we get is often "uncertain". If the exposure assessment is uncertain, then the IEP may either continue to collect additional data or clearly indicate that the result is "uncertain". Since industrial hygiene (the recognition, evaluation and control of potential exposure hazards) often involves an assessment of human exposures, it must by necessity be a conservative science. If the exposure assessment remains "uncertain", then the IEP is directed by that conservatism towards assuming that an exposure exists until a negative assessment can be documented.

The second broad category of activities may be called a risk assessment. IEP's actually perform risk assessments all the time, but they often occur in the subconscious mind (otherwise called "professional judgment"). Anytime an IEP includes a recommendation in their report, they have probably performed a risk assessment to arrive at that recommendation. If there were no risk, why direct your client to spend possibly thousands of dollars on a mold remediation?

Risk may be thought of as a combination of the probability that an adverse outcome will occur and the potential severity of that outcome if it does occur. Examples of risk include the risk of water damage to the structure, risk of adverse health effects to the occupants, or legal risk to the property owner or the IEP. If there is an occupant exposure to airborne mold spores, for example, the IEP should then assess the exposure risk to the occupant; if for no other reason than to minimize legal risk to the IEP. I would guess that most IEP's are not licensed physicians, and therefore the typical IEP can not assess the health risk to an occupant exposed to indoor mold. However, IEP's are commonly expected to assess the exposure risk based on air sampling combined with other information.

DATA QUALITY

The most commonly used samplers for the collection of airborne mold spores are the slit-impaction samplers, such as the Air-O-Cell, Allergenco-D, Micro 5, etc. This type of sampler was originally developed as a qualitative tool, and used primarily for the enumeration of spore types present in the air. However, as indoor air quality surveys became popular, these samplers began to be used as quantitative tools, and they are now commonly used to report the concentrations of airborne spores.

In fact, most of the data relating to airborne concentrations of mold were probably collected using either multi-hole culturable samplers such as the N6 (also an impaction sampler), or slit-impaction spore samplers. Therefore, any attempt to associate health effects with concentrations of airborne mold has probably been based on data collected using these types of samplers – and this is the problem. In general, the sampling characteristics of these samplers have not been validated at high spore concentrations, which is exactly where adverse health effects would be most likely to occur.

What if the reported concentrations of airborne mold obtained using these samplers were not always accurate? What if the magnitude of these inaccuracies was variable rather than constant? [If they were constant, one could adjust the data to account for them] For example, what if a reported concentration of 5,000 spores/m^3 using these samplers corresponded to 11,000 spores/m^3 in one investigation and 700,000 spores/m^3 in another investigation? If this example reflected the quality of the field data collected during the typical mold investigation, could the conclusions reached by ACOEM possibly be valid?

The data in Table 1 were collected in the living room of a residential property. The six replicate samples were each collected for 5 minutes using the Bi-Air filter cassette (BA) and the Air-O-Cell slit-impaction cassette (AOC). The average reported *Aspergillus/ Penicillium* (*Asp/Pen*) spore concentrations were 5,400 spores/m^3 for the AOC and 11,300 spores/m3 for the BA; a BA-to-AOC ratio of 2.1. This difference was statistically significant based on an Analysis of Variance (ANOVA).

The data in Table 2 are for four replicate samples that were collected during a second residential project. The replicate samples were collected for 60 minutes using the BA and for 5 minutes using the

Table 1. Aspergillus/Penicillium (Asp/Pen) spore (spores/m^3) concentrations (spores/m^3) for six replicate samples collected in a well-mixed room with the BA and AOC samplers during a 66-minute period.

SAMPLER	BA	AOC
Samples	6	6
Minimum	8,000	3,400
Maximum	15,100	7,100
AVERAGE	11,300	5,350

AOC. The AOC samples were collected during the BA sampling period. Clusters of *Asp/Pen* spores were dominant in these samples, whereas single spores or small chains are more typical in field samples, as was the case for the data in Table 1.

The average concentration of *Asp/Pen* spores detected with the BA samples was 765,000 spores/m^3, which substantially exceeded the average concentration detected with the AOC samples of 36,800 spores/m^3. In this particular indoor environment, the average *Asp/Pen* concentration measured with the BA was 54-times that reported for the AOC. The ratios of BA to AOC concentrations ranged from a low of 14 to a high of 146. Significantly, all the BA concentrations were in the concentration range cited by ACOEM as being associated with adverse health effects, while all but one of the AOC concentrations were substantially below that range.

Chaetomium, a toxigenic fungus, was only detected in one of the AOC samples at the limit of detection, and would not have been reported as a significant contaminant in that particular indoor environment. However, *Chaetomium* was detected in all four BA samples in Table 2. The average *Chaetomium* concentration for the BA samples was 1,500 spores/m^3 with an average concentration of 15 spores/m^3 for the AOC samples. Therefore, the average *Chaetomium* concentration was 100 times greater for the BA samples compared to the AOC samples.

These examples raise a concern with the quality of the data upon which the ACOEM conclusions may have been based. In at least these two investigations, a reported concentration of 5,000 *Asp/Pen* spores/m^3 corresponded to 11,000 spores/m^3 in one investigation and 700,000 spores/m^3 in the second investigation. Therefore, the first conclusion by ACOEM that "…indoor airborne levels of microorganisms are only weakly correlated with human disease or building-related symptoms…" is at least questionable, and may in fact be incorrect.

During a period in which roughly 2,000 mold investigations were performed by the author, I believe potentially toxigenic effects due to mold exposures were encountered possibly three times (based on my opinions, since a medical diagnosis was not obtained in all the investigations). This is a rate of occurrence of roughly one in a thousand. In one sense these were indeed rare events. However, based on the "benzene ruling", where a cancer rate in excess of one in a million was found to be legally significant, this may be an astonishingly high rate of occurrence.

One investigation involved three teenage boys in bed with cold/flu-like symptoms and having bloody discharges from their noses, which was assumed to be a possible cytotoxic effect (no medical diagnosis). Average airborne concentrations were 400 cfu/m^3 of *Stachybotrys chartarum* and 900 cfu/m^3 of *Aspergillus versicolor*.

A second investigation involved two female college freshmen. Their symptoms were many, but included loss of menses, significant hair loss, and both had been hospitalized for pneumonia. Indoor *Cladosporium* concentrations varied between 7,000 and 120,000 spores/m^3 and indoor *Asp/Pen* concentrations varied from 24,000 to a high of 4,000,000 spores/m^3 when shaking clothing hanging in a bedroom closet. *Aspergillus versicolor* was dominant in the culturable samples.

The second ACOEM conclusion was that "Exposures associated with (organic dust toxic syndrome) … have ranged from 100,000 – 1,000,000 "microorganisms" per cubic meter of air …, extreme conditions not ordinarily encountered in the indoor … environment". The BA concentrations in Table 2 were in the same concentration range that ACOEM considered to be important for adverse health effects to occur, whereas those collected with the AOC were not. In addition, significant symptoms occurred in the three teenage boys and the two female college freshmen at average concentrations well

Table 2. Asp/Pen and Chaetomium spore concentrations (spores/m^3) for four replicate BA and AOC samples collected in a residential property.

	Asp/Pen			*Chaetomium*	
ROOM	**BA**	**AOC**	**RATIO**	**BA**	**AOC**
Living Room	365,000	24,500	15	1,800	60
Kitchen	585,400	14,800	40	1,150	0
Bedroom	702,500	4,800	146	300	0
Bathroom	1,406,000	103,200	14	2,700	0
	0				
AVERAGE	765,000	36,800	54	1,500	15

below the concentration range cited by ACOEM.

The characterization of the concentrations detected by the BA as "extreme for indoor environments" was presumably based on data collected by slit-impaction and/or multi-hole samplers. Since *Asp/Pen* concentrations as high as 4,000,000 spores/m^3 have been detected with the BA in indoor environments, concentrations exceeding 100,000 spores/m^3 in the indoor environment, although not common, may not be as rare as predicted by ACOEM. Therefore, the ACOEM postulation of what constitutes extreme conditions in indoor environments would be more credible if it were also stated that (1) the data upon which this conclusion was based were collected with either slit-impaction and/or multi-hole samplers, and (2) the postulation is only as valid as the validity of the data upon which it is based. However, these clarifications were not discussed in the ACOEM position paper.

CONCLUSIONS

If one assumes an airborne concentration of at least 5,000 *Asp/Pen* spores/m^3 is sufficient to classify an indoor environment as contaminated, then the data in Tables 1 and 2 collected using slit-impaction samplers were adequate for performing an exposure assessment (determining if an exposure existed).

With a "cut-size" (50 percent collection efficiency) of about 1.9 to 2.7 microns, slit-impaction samplers generally retain no more than 50 percent of the *Asp/Pen* spores that are present in the environment. This retention rate is well documented in the peer-reviewed literature. However, as illustrated in Tables 1 and 2, the typical BA-to-AOC ratio of 2.1 was not constant, but varied substantially between projects. Because of the short sampling times and the low spore retention rates, these samplers tend to underestimate the average concentrations of contaminant spores. Unfortunately, the degree to which the average exposure has been underestimated for a particular project is usually indeterminate.

Slit- and multi-hole impaction samplers tend to provide the lower bound of exposure, and may substantially underestimate the average and maximum exposures. Therefore, they may not be suitable for performing risk assessments (assessing the potential risk to the occupant) where the average exposure, as well as the 95th percentile exposure, may be of concern.

Any attempt to assess an association between reported health effects and airborne spore concentrations must rely on currently available field data, some of which may be over 100-fold in error. Therefore, in my opinion, currently available databases of airborne mold concentrations may be useful for assessing occupant exposures, but their quality is not sufficient for either confirming or precluding the potential for occupant risk. Furthermore, because of the conservative nature of industrial hygiene, if the risk assessment is "uncertain" it is prudent that the potential for harm be acknowledged until some future date when that potential for harm can be disproved.

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