PERSPECTIVES

Interpreting Airborne Fungal Spore Samples

Part 1: *Methods for Comparing Data*

by Joe Spurgeon, Ph.D., CIH

About the Author

Dr. Spurgeon, who is a Certified Industrial Hygienist, has extensive experience as an expert witness in mold litigation cases, and currently has a number of active cases in California and Texas. His experience includes both commercial and residential properties. His areas of expertise include microbial IAQ investigations, assessment strategies, sampling methods, and data analysis and interpretation. Dr. Spurgeon can be reached at cih@bi-air.com.

[*Author's Note: This is the first in a planned series of articles discussing the interpretation of airborne fungal spore samples. The article discusses four general methods for interpreting airborne data. Other articles in the series will discuss the use of databases, the use of multiple sample media, one or more case studies, how fungal spore concentrations can vary with time, and the effect of sampling time on the utility of the collected data. One of the objectives of this series of articles is to add to the reader's knowledge about interpreting sample results, allowing them to assume a more active role in assessing airborne data.*]

The topic of this article is a discussion of the various methods for assessing airborne fungal spore data when only a limited number of samples have been collected. The assumption is that a statistical analysis of the data cannot be performed, which is often true for residential investigations, and even many smaller commercial investigations. When only a small number of samples are available, interpreting the sample results for airborne fungal spores becomes more of an art than a science.

Therefore, the consultant has to rely heavily on their training, experience and professional judgment. There are only a limited number of methods the consultant can use in that environment. The methods I'm familiar with are: (1) reference samples, (2) control samples, (3) "expected values", and (4) statistical databases.

Reference Samples

Although outdoor samples are commonly referred to as control samples, they are more accurately referred to as reference samples. I shall define samples collected outdoors as reference samples. The most commonly used method for assessing the significance of the concentrations of airborne fungal spores is to compare indoor concentrations with outdoor concentrations.

The reason for this is that outdoor samples are generally easy to obtain and readily available — not that this is necessarily a preferred method. There are actually a variety of limitations that can affect the utility of outdoor samples as a reference for indoor concentrations, and several of these limitations are mentioned.

The rule applied by many consultants is: If the indoor concentration is less than the outdoor concentration, then the indoor environment is "acceptable". But, does this apply to only total spores, or to each spore type? It is not unusual for the concentration of "total spores" to be higher outdoors than indoors; but at the same time, for the concentration of a particular type of spore (Chaetomium, for example) to be higher indoors. The relative concentrations of each spore type should be compared, not just the concentrations of total spores.

What were the weather conditions when the outdoor samples were collected? Snow, rain, and high winds can result in low outdoor concentrations.

Were the windows and doors closed, and air cleaners off, for at least 8 hours prior to collecting the indoor samples? If not, the indoor spore count may be diluted by the outdoor air.

Did the consultant actively disturb the grass or shrubs near the outdoor sample? Walking on the grass while sampling is one way to make the outdoor sample appear to be "high."

How many outdoor samples were collected? Outdoor concentrations can change rapidly, so averaging two or more outdoor samples provides a better reference concentration. For example, collecting the outdoor samples as the first and last samples brackets the indoor samples.

What is the residence time of a fungal spore inside a building? This may not be especially important when sampling a single-family house, but it can be important for commercial buildings. In an office building with an area of one million square feet, the average residence time for an airborne spore may be on the order of three days. Should the outdoor samples be collected three days prior to the indoor samples?

Control Samples

A control sample is a sample that has been collected in a (supposedly) uncontaminated indoor environment that is comparable to the environment in the subject area or building. The use of control samples is one of the better methods for assessing the concentrations of airborne fungal spores, and I generally try to identify and sample control areas during a mold investigation.

Unfortunately, control samples are often difficult to obtain. Many property owners or managers are reluctant to volunteer their buildings as controls. What happens if the samples indicate a problem? Also, a control area is identified by first sampling and then evaluating the sample results. The consultant doesn't know if the selected area or building is suitable as a control area until after the samples have been analyzed.

Table 1a: Average Ratios for 22 Outdoor and 73 Indoor Samples: "Outdoor" Spores.

SPORE	Ascospores	Basidiospores	Cladosporium
Indoor to Outdoor Ratio	0.55	0.47	0.52

Table 1b: Average Ratios for 22 Outdoor and 73 Indoor Samples: "Indoor" Spores.

SPORE	Asp/Pen	Curvularia	Total Spores
Indoor to Outdoor Ratio	10.9	4.6	2.4

What are examples of control areas? In a two-story house with a mold problem on the first floor, for example, the second floor is often suitable as a control area. In a one-story house with a mold problem in the kitchen, the bedrooms can often be used as control areas. I try to collect at least two samples in assumed control areas during residential investigations.

When investigating commercial properties, such as office buildings, the consultant is generally able to collect enough samples to identify control areas as an initial part of the investigation. This is an essential part of the investigation.

For what it's worth, my definition of a control area is a similar exposure area in which common environmental fungi are dominant and the geometric standard deviation of the airborne data is about 2 or less. This definition actually has a logical basis, and was derived from analyzing sample results from a number of commercial buildings.

Expected Values

In modern buildings with active mechanical ventilation systems, the indoor concentration of airborne spores is generally expected to be between 20 percent and 70 percent of the outdoor concentration, let's say with an average of about 50 percent. Therefore, if the airborne fungal spores detected indoors were all from the outdoors, their indoor concentration would be "expected" to be about half their outdoor concentration.

The data in Table 1 are the ratios of indoor concentrations of airborne fungal spores to the outdoor concentrations. The data were collected using the Bi-Air cassette and were collected in residential properties in Southern California. As indicated in Table 1a, the indoor concentrations of fungal spores typically associated with outdoor sources actually were about 50 percent of the outdoor concentrations.

Most of the houses where these samples were collected had some degree of a mold problem. As indicated in Table 1b, the indoor concentration of *Aspergillus/Penicillium* (*Asp/Pen*) type spores, rather than total spores, was the better indicator that a mold problem existed. The average indoor concentration of *Asp/Pen* type spores was more than 10 times the average outdoor concentration.

For example, let's assume the outdoor concentration of *Cladosporium* was 1,000 spores per cubic meter (spores/m^3) and the indoor concentration was 500 spores/m^3; or 50 percent of the outdoor concentration. Therefore, the furnace filter and physical

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"Most of the houses where these samples were collected had some degree of a mold problem."

Table 2: Concentrations of Airborne Fungal Spores in Texas and California (spores/m_).

PARAMETER	Asp/Pen (TX)	Asp/Pen (CA)	Total (TX)	Total (CA)
Number of Samples	9	40	14	51
Minimum	0	0	176	153
Maximum	2,672	2,640	7,893	7,311
Average	613	582	2,501	2,008
GM	262	365	1,555	1,469
GSD	4.96	2.75	2.85	2.37

structure of the building were able to prevent 50 percent of the airborne *Cladosporium* spores from reaching the indoor environment. One might expect a similar ratio for other outdoor spores.

Now let's assume the outdoor concentration of *Asp/Pen* type spores was 500 spores/m^3. If all the *Asp/Pen* type spores detected indoors came from the outdoors, what would be the concentration "expected" indoors? The "expected" concentration would be 50 percent of the outdoor concentration, or about 250 spores/m^3.

Let's further assume the measured indoor concentration of *Asp/Pen* type spores was 500 spores/m^3, the same as the outdoor concentration. Would this indicate a potential problem? The indoor and outdoor concentrations were the same, so many consultants would say the results did not indicate a problem. However, using the "expected value" of 250 spores/m^3 as the basis of comparison, then one has to ask where the additional 250 spores/m^3 came from if not from an indoor reservoir of *Asp/Pen* spores?

Statistical Databases

The concentrations of many airborne contaminants, including fungal spores, can be characterized by something called a lognormal distribution. A lognormal distribution is described by the geometric mean (GM) concentration and the geometric standard deviation (GSD). The parameters describing the distribution, once they have been calculated using a sufficient number of samples — generally 30 or more — are relatively stable (the calculated values don't change very much when new samples are added to the database).

The data in Table 2 are indoor airborne samples collected using the Air-O-Cell cassette. Fourteen samples were collected in Texas (TX) and 51 samples in Southern California (CA). Therefore, one would expect the parameters for the CA data to be less variable than the TX data.

The two distributions are remarkably similar, even though (1) the samples were collected by two different groups of consultants, and (2) from a humid region near Houston, Texas and a drier region in Southern California.

These data are from houses with a potential mold problem, the very same category of house that we sample as consultants. Second, the average airborne concentration of *Asp/Pen* type spores was about 600 spores/m^3 for both distributions, and the maximum concentration was about 2,650 spores/m^3.

A database cannot replace site-specific samples. However, referencing sample results to database parameters is certainly useful in assessing airborne data when only a few samples have been collected. For example, an *Asp/Pen* concentration of 300 spores/m^3 might be considered to be moderate compared to the average concentration of 600 spores/m^3 obtained in 40 houses. Similarly, an *Asp/Pen* concentration of 2,600 spores/m^3 might be classified as an extreme value compared to the maximum concentration of 2,650 spores/m^3 contained in the database.

Assess means "to determine the significance of." Can similar distributions for airborne fungal spores be used as a basis for assessing fungal spore concentrations in houses with potential mold problems? I believe the answer is yes.