DISPERSAL OF SPORES FROM FUNGAL-CONTAMINATED DUCT MATERIAL

M P Buttner, P Cruz-Perez, P J Garrett, and L D Stetzenbach

Harry Reid Center for Environmental Studies, University of Nevada, Las Vegas, USA

ABSTRACT

Fungal-contaminated air handling systems have been implicated as a source for the dispersal of spores into the indoor environment, potentially serving as a route of exposure to building occupants. Because quantitative data are lacking, this study was conducted to measure the dispersal of spores from fungal colonies growing on three types of duct material: galvanized metal, rigid fibrous glass ductboard, and fiberglass duct liner. Duct materials were soiled, contaminated with a known concentration of *Penicillium chrysogenum* spores, and incubated in humidity chambers to provide a matrix of growing, sporulating fungal colonies. The contamination level following amplification was 10^9 CFU/duct section, with no significant difference between duct materials. For each experiment, a contaminated duct section was inserted into the air handling system of a bioaerosol research experimental room, and the air handling system was operated for three 5-minute cycles with an air flow rate of 4.2 m^3/min. The duct air velocity was approximately 2.8 m/sec. The airborne concentration of culturable *P. chrysogenum* spores (CFU/m^3), total *P. chrysogenum* spores (spores/m^3), and total *P. chrysogenum*-sized particles (particles/m^3) were measured in the room using Andersen single-stage impactor samplers, Burkard slide impactor samplers, and an aerodynamic particle sizer, respectively. The highest airborne concentrations were measured during the first operating cycle of the air handling system for all duct materials with decreasing airborne concentrations measured during the second and third cycles. There was no significant difference in spore dispersal from the three contaminated duct materials. These data demonstrate potential exposure for building occupants to fungal spores dispersed from contaminated duct material during normal air handling system operation.

INTRODUCTION

Air handling systems have been implicated as sources and routes of dispersal of microbial contamination with fungal contamination in air handling systems demonstrated in laboratory studies and field surveys of contaminated buildings[1]. However, no studies have quantitatively investigated the dispersal of spores from fungal colonies growing on air handling system materials. The following study was performed to provide data on the dispersal of spores into the air from fungal colonies resident on three types of duct material, galvanized metal, rigid fibrous glass, and fiberglass duct liner with contaminated sections inserted in air handling system duct.

METHODS

An experimental room measuring 4.0 m^2 by 2.2 m high, resembling a residential indoor environment and used in previous bioaerosol studies [2], was used as the study site for this

research. Galvanized sheet metal, rigid fibrous glass ductboard, and fiberglass liner duct materials were cut into straight sections measuring 19 cm x 61 cm. Each test section was coated uniformly with an autoclaved blend of finely sifted vacuum dust and vermiculite to provide a base for fungal growth. Spray suspensions of *Penicillium chrysogenum* spores were prepared in sterile potassium phosphate buffer amended with Tween 40 (Sigma Chemical Co, St. Louis, Missouri; 0.05% final concentration, pH 7.0). Duplicate pieces of each duct material were inoculated with spores and incubated in individual humidity chambers at 24EC for 13 days. Test sections were sampled and contamination assessed quantitatively immediately after inoculation and after a 13 day of incubation period. The contaminated duct was then installed downstream of the blower in a straight section of duct.

Andersen single-stage viable impactor samplers (Graseby Andersen, Atlanta, Georgia) operated at 28.3 liter/min. flow rate for 30 seconds to 2 minutes were used to measure airborne culturable *P. chrysogenum.* Total airborne *P. chrysogenum* spores were measured with the Burkard personal impactor sampler (Burkard Manufacturing Co., Ltd., Rickmansworth Hertfordshire, England) operated at the fixed flow rate of 10 liters/min. for 5 minutes. Measurements of total airborne particles in the *P. chrysogenum* spore size range (1.8-3.5 Φm diameter) were obtained using an aerodynamic particle sizer (APS; TSI Inc., St. Paul, Minnesota) operated for 5 minutes at an air flow rate of 5 liters/min. All air samplers were placed at 1 m height in the center of the room and activated from outside of the room.

Background concentrations of airborne culturable *P. chrysogenum* and *P. chrysogenum* spore-sized particles were measured in the room prior to insertion of the contaminated section into the duct system. After the contaminated section was inserted into the duct, the HVAC system was activated for 5 minutes and air samples were taken. The HVAC system was turned off for approximately 2-3 hours until measurements of spore-sized particles registered steady-state conditions. The HVAC was reactivated for 5 min. and a second cycle of air samples were collected. This was repeated for a third cycle following another settling period, however, no Burkard samples were collected for the third blower cycle.

The airborne concentrations using the Andersen samplers and APS measurements were corrected by subtracting the background levels. Andersen sampler data were corrected for coincidence using the positive hole correction method [2]. Data were log transformed prior to statistical analysis and one-way analysis of variance tests were used to compare data from different duct materials.

RESULTS

No significant difference was observed in the contamination level of the three duct materials before installation in the room HVAC system. The highest concentrations of airborne fungi were measured during the first air handling system cycle, regardless of the type of duct material or measurement method (Table 1). The greatest number of airborne fungi were dispersed from metal duct, followed by fiberglass duct liner and rigid fibrous glass duct, but these differences were not statistically significant.

Table 1. Concentrations released from fungal-contaminated duct materials into an experimental room. Data are expressed as the mean log/m^3 ± 1 standard error measured during each 5-minute operating cycle of the air handling system.

Measurement Method	Duct Material (n= 4 for each type)	Cycle of Air Handling System		
		1st cycle	2nd cycle	3rd cycle
culturable (CFU/m^3)	Metal	4.580 ± 0.117	3.399 ± 0.118	3.026 ± 0.216
	Rigid Fibrous Glass	4.058 ± 0.102	3.505 ± 0.097	3.237 ± 0.155
	Fiberglass Duct Liner	4.244 ± 0.168	3.449 ± 0.122	2.979 ± 0.144
total (spores/m^3)	Metal	5.919 ± 0.156	4.234 ± 0.180	not measured
	Rigid Fibrous Glass	5.322 ± 0.107	4.405 ± 0.125	not measured
	Fiberglass Duct Liner	5.464 ± 0.220	4.385 ± 0.019	not measured
particles (spore-sized particles/m^3)	Metal	4.759 ± 0.145	3.558 ± 0.277	2.889 ±0.244
	Rigid Fibrous Glass	4.228 ± 0.093	3.622 ± 0.097	3.075 ± 0.274
	Fiberglass Duct Liner	4.440 ± 0.165	3.495 ± 0.301	3.113 ± 0.185

DISCUSSION

This study demonstrated the dispersal of *P. chrysogenum* during routine operation of the HVAC system (duct velocity was 2.8 m/sec.) regardless of the type of duct material contaminated. These data agree with that reported by Pasanen *et al.*[3] who demonstrated in laboratory studies that *Cladosporium* spores were released from conidiophores in culture tubes at air velocities of 1 m/sec. and spores of *Aspergillus fumigatus* and *Penicillium* spores were released at 0.5 m/sec. air velocity.

The finding that the highest airborne concentrations were dispersed at the initial start up of the system and decreasing concentrations were measured during the two subsequent cycles of the HVAC system is similar to data obtained by Zoberi [4] who observed the release of *Trichothecium* spores during an initial gust of air followed by a rapid decrease of spore liberation with time.

Building inspections of filters, cooling coils, and ducting often demonstrate the presence of fungal growth and monitoring of room air often shows the presence of airborne fungal spores. This study provided a quantitative comparison of fungal-contaminated duct material with airborne fungal measurements in an experimental room during operation of a contaminated HVAC duct system. These studies will assist in developing design and maintenance recommendations for cleaning and maintenance of air handling components to alleviate potential exposure to building occupants.

ACKNOWLEDGMENTS

This research was funded in part by the US Environmental Protection Agency under cooperative agreement number CR-822640 to the Harry Reid Center for Environmental Studies, University of Nevada, Las Vegas and by the North American Insulation Manufacturers' Association (NAIMA). The views expressed are those of the authors and do not necessarily reflect the official views of the sponsor agencies.

REFERENCES

1. Stetzenbach, L D. 1997. Introduction to aerobiology. In *Manual of Environmental Microbiology*, C J Hurst, G Knudsen, M McInerney, M V Walter, and L D Stetzenbach, eds. ASM Press, Washington, DC, p. 619-628.

2. Buttner, M P and Stetzenbach, L D. 1993. Monitoring of fungal spores in an experimental indoor environment to evaluate sampling methods and the effects of human activity on air sampling. Appl. Environ. Microbiol. Vol. 59, pp. 219-226.

3. Pasanen, A L, Pasanen, P, Jantunen, M J and Kalliokoski, P. 1991. Significance of air humidity and air velocity for fungal spores release into the air. Atmos. Environ. Vol. 25A, pp. 459-462.

4. Zoberi, M H. 1961. Take-off of mould spores in relation to wind speed and humidity. Ann. Botany. Vol. 25, pp. 53-64.