AMPLIFICATION OF *PENICILLIUM CHRYSOGENUM* ON THREE HVAC DUCT MATERIALS

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ABSTRACT

Laboratory experiments were conducted to assess the amplification of *P. chrysogenum* on three types of ventilation duct materials (fibrous glass ductboard, galvanized steel, and insulated flexible duct). Newly purchased duct materials samples were tested, and only the flexible duct supported modest growth of *P. chrysogenum* at 97% RH. Wetting the clean duct samples with sterile water did not increase amplification of the *P. chrysogenum* over the level seen without the wetting. Soiling the samples with dust collected from residential heating and air-conditioning systems enhanced the susceptibility of all three duct materials to fungal growth. The results of these experiments suggest that dust accumulation and/or high humidity should be properly controlled in any HVAC duct to prevent the growth of *P. chrysogenum*.

INTRODUCTION

The heating, ventilating, and air-conditioning (HVAC) ducts of both residential and commercial buildings have been identified as sources of fungal colonization and amplification (1,2,3,4,5). Emissions from microbially contaminated HVAC systems have resulted in indoor air pollution problems and adverse health effects.

Three commonly used HVAC duct material types are fibrous glass ductboard, galvanized steel, and flexible duct. Fibrous glass ductboard is rigid insulation material manufactured from resin-bonded inorganic glass fibers. Both field data from building investigations (2, 6) and laboratory results (4) have shown that fibrous glass ductboard can be a source of fungi isolated from indoor air. In the building investigations, a layer of microbial growth was found on the air stream surface of the fibrous glass ductboard of HVAC systems. When disturbed by gentle pounding, the concentration of fungi increased by several orders of magnitude in the HVAC system air stream near the fibrous glass ductboard.

When a duct is made of a non-insulating material such as galvanized steel, fiberglass duct liners are often used to provide the needed thermal insulation and noise control. Controlled laboratory studies on fiberglass duct liners have shown that some products or lots within a specific product line may be more susceptible to fungal growth than others (7, 8). Morey and Williams (2) suggested that porous insulation materials lining HVAC systems should be avoided, and that fiberglass insulation should be applied to the outside of the main

air supply ducts to minimize the potential for microbial growth and subsequent release into the ventilation airstream. This would result in non-porous materials, such as galvanized steel duct and flexible duct, exposed to the airstream surface.

However, use of non-porous materials on the inner surface of ducts may not eliminate the potential for microbial growth. Pasanen et al. (9, 10) reported that fungal spores were able to germinate on galvanized steel duct if there is residue of lubricant oil or dust accumulation on it. Ahearn et al. (11) also detected fungal colonies on painted metal surfaces associated with HVAC systems. Therefore, fungal growth has been shown to occur on both porous and non-porous duct materials.

The objective of these studies was to quantitatively evaluate the fungal resistance of fibrous glass ductboard, galvanized steel, and flexible duct under controlled temperature, RH and dustiness conditions.

EXPERIMENTAL MATERIAL AND METHODS

The static chamber test method developed by Foarde et al. has been used to quantitatively evaluate the growth (as measured by sporulation) of a number of fungi on a variety of conditioned test materials at controlled RH and temperature. An overview of the method is presented below. Additional details of the experimental procedures on static chamber design, sample treatment, test microorganism selection, inoculum preparation, artificial soiling protocol, and test block inoculation have been reported (7, 8, 12,14).

Duct Materials Tested

Fibrous glass ductboard and insulated flexible ducts were purchased from local vendors. The fibrous glass ductboard is a rigid matrix 2.5 cm thick, composed of 60 to 100% fiberglass, and 10 to 30% phenol, polymer with formaldehyde, reaction products with hexamethylenetetramine (cured). It was purchased as 121.9 by 304.8 cm sheets. The external surface is covered by a scrim-reinforced aluminum foil (FSK) facing which acts as the air barrier/vapor retarder.

Insulated flexible duct (50.8 cm diameter) is composed of three distinct layers. The outer layer, a fiber glass reinforced metalized film laminate, is a vapor barrier, followed by an insulating middle layer of light density fibrous glass insulation, and an inner core of spiral wire supporting the chlorinated polyethylene duct material itself. Only the inner core (airstream surface) material was used in the experiments presented in this paper.

The 26 gauge galvanized steel duct was purchased from an HVAC contractor as representative of the type most commonly used locally. The surface was unpainted and appeared to be oil-free.

Experimental Procedure

Four sets of experiments were performed. The first three were designed to evaluate the fungal resistance at 97% RH of: 1) newly purchased, chamber conditioned duct materials, 2) the same materials wetted with sterile water, and 3) samples of the same materials artificially soiled with moderate amounts of HVAC dust. A fourth experiment was designed to evaluate the impact of heavier soiling on newly purchased galvanized steel duct maintained in 90, 94, and 97% RH chambers.

Sterilized blocks (3.8 cm square) of the test materials were pre-conditioned for 3 days at the test RH (wetted blocks were not preconditioned) and then inoculated with approximately 1 x 10^5 colony forming units (CFUs) of *P. chrysogenum* per block. Artificial soiling, required for the third and fourth experiments, was performed before sterilization. Sterilized, uninoculated blocks were used as controls during each experiment.

The static chambers (32 x 39 x 51 cm) provided a well-controlled environment for growth. The chambers were kept in a relatively dark, temperature-controlled (21 ± 3°C),

HEPA (High Efficiency Particulate Absolute) - filtered room. Saturated salt solutions were used to maintain specific RHs in each chamber (13).

To quantify the fungal growth, triplicate blocks were removed from each chamber for analysis on days 0, 1, 7, 14, 21, 27, 35, and 42. Following removal, the sample blocks were placed in phosphate-buffered saline with 0.1% Tween 80 and agitated to suspend the spores. The block/buffer suspension was diluted and aliquots plated on Sabouraud dextrose agar. Plates were incubated at room temperature for at least 1 week. CFUs were counted shortly after visible growth was first noted and again as moderate growth became apparent.

RESULTS

Fibrous Glass Ductboard

Figure 1 shows the change in CFUs for the newly purchased fibrous glass ductboard between day 1 and day 42 under the different treatment conditions. Each data point gives the ratio of the mean CFUs on the test day (day x) to the mean CFUs on day 1. The error bars show the standard error of the ratio. As can be seen from Figure 1, essentially no growth was seen on the samples of newly-purchased, chamber conditioned fibrous glass ductboard maintained in the 97% RH static chambers (solid line) throughout the 6 weeks experiment. When wetted (dotted line), the CFU ratio may have increased slightly between day 7 and day 21 but fell to the base (day 1:day 1) level between day 21 and day 28 and showed little change thereafter. When the fibrous glass duct samples were soiled (dashed line) with 11 (± 2) mg of dust (per block), a steady increase in the CFU ratio was seen throughout the 6-week test period to a final amount two logs above the number measured on day 1.

Flexible Duct

Figure 2 shows the results for the same experiments with the flexible duct inner core under the same test conditions. A modest increase (about one order-of-magnitude) in the CFU ratio was measured on the samples of newly purchased, chamber conditioned flexible duct at 97% RH. When the flexible duct was wetted, the CFU ratio increased through day 35 for an overall increase of approximately one order-of-magnitude. However, by the sixth week there was a sudden decrease to below the base level in the number of spores isolated. After the samples were soiled with 6 (±1) mg of dust per block, steady growth between day 21 and day 42 resulted in a one order-of-magnitude increase in the CFU ratio by the end of the test.

Galvanized Steel Duct

Figure 3 shows the results for the same experiments with galvanized steel. The CFU ratio decreased (at least one order-of-magnitude) for all three experimental conditions - newly purchased chamber conditioned, wetted, and artificially soiled (10 ±1 mg HVAC dust per block). Furthermore, when the galvanized steel was wetted, a marked decrease in the CFU ratio was obtained. By 21 days, the CFU ratio on the wetted samples had decreased to near the minimum detection limit. Possibly, there was sufficient moisture for germination, but not subsequent sporulation.

Heavily Soiled Galvanized Steel

To further investigate the impact of soiling on fungal growth, additional experiments were conducted with more heavily soiled galvanized steel inoculated with *P. chrysogenum*. Samples of the same batch of newly purchased galvanized steel duct material were soiled with HVAC dust to levels at least 10 times the previous level of 10 (± 1) mg, to 132 (± 18), 177 (± 16), and 218 (± 68) mg/block, and placed in 90, 94, and 97% RH chambers, respectively. As seen in Figure 4, at all three RHs the CFU ratio increased steadily throughout the test period. After 6 weeks, the CFU ratios had increased approximately one order-of-magnitude regardless of RH.

DISCUSSION

Neither blocks of newly purchased fibrous glass ductboard nor galvanized steel maintained at 97% RH supported *P. chrysogenum* growth during the testing period. Modest fungal growth was seen on the flexible duct as demonstrated by an increase in culturable spores of about one order-of-magnitude. Wetting the newly purchased duct materials with sterilized water did not promote the growth of *P. chrysogenum* over the level seen with exposure to 97% RH. After artificial soiling with 6 - 11 mg HVAC dust/block, fungal growth (measured by an increase of at least one order-of-magnitude of culturable spores) was detected on the flexible duct and the fibrous glass ductboard but not the galvanized steel.

Although no amplification of *P. chrysogenum* was detected on the moderately soiled galvanized steel, on galvanized steel samples artificially soiled with at least 10 times more dust, modest growth (one order-of-magnitude increase in culturable spores) was measured. The moderately soiled samples (6 - 11 mg HVAC dust/ block) were visibly but lightly dusted to the naked eye and a noticeable amount of the test material remained visible. On the other hand, the more heavily soiled samples (132 -218 mg/block) were covered with a thin coating of dust and little if any of the galvanized steel was visible.

The difference between the degree of amplification measured on the moderately and heavily soiled galvanized steel, seen by comparing the data presented in Figures 3 and 4, is statistically significant. In addition, the increases in CFUs detected in these experiments on the non-porous materials are modest compared with the 3 to 4 log increases detected on fiberglass duct liner (8,7) for the same test conditions over the same 6 week time span. Data quantifying fungal emissions relative to surface growth is needed before the implications of these different amounts of growth can be understood.

With current HVAC design and operation, dust penetration into and accumulation on the duct surface is common. Humid conditions can be found around operating cooling coils, humidification zones, and when the outdoor air is humid or foggy outside, air intakes. Thus, conditions favorable to fungal growth occur in HVAC ducts for varying periods of time, depending on system operation. To minimize the possibility of fungal growth, a HVAC system should be designed to discourage the entry and accumulation of dust and moisture by better duct sealing and air filtration and should be operated to minimize the duration of the exposure to high RH conditions. Access to and cleanability of a HVAC system is also critical.

ACKNOWLEDGMENTS

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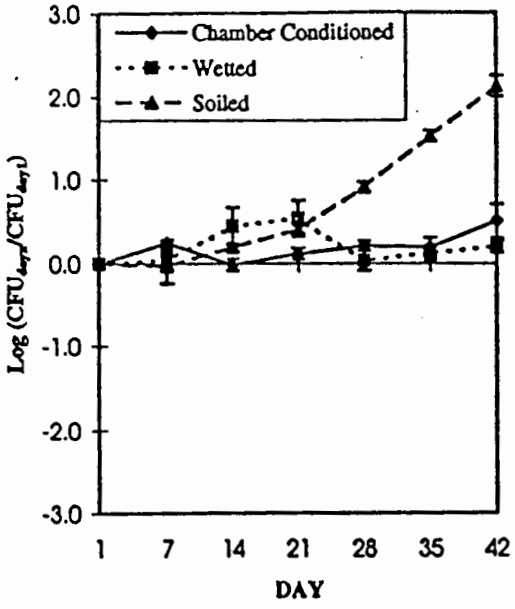

Figure 1. Growth of *P. chrysogenum* on fibrous glass duct samples at 97% RH and 21°C

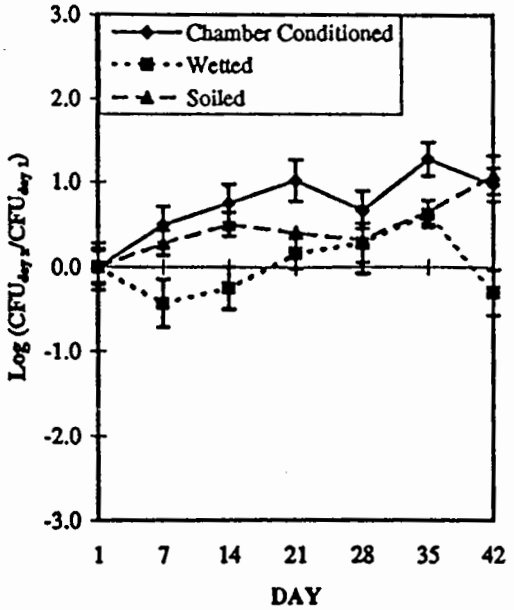

Figure 2. Growth of *P. chrysogenum* on flexible duct samples at 97% RH and 21°C

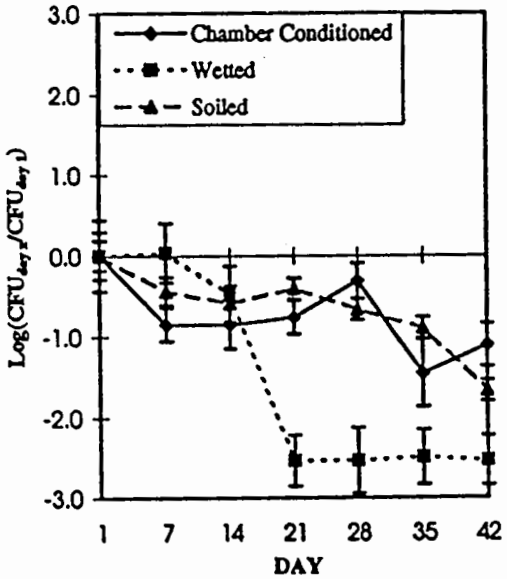

Figure 3. Growth of *P. chrysogenum* on galvanized steel duct samples at 97% RH and 21°C

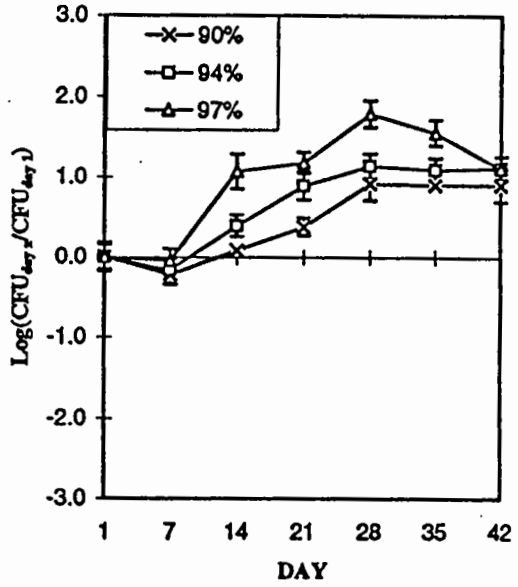

Figure 4. Growth of *P.chrysogenum* on heavily soiled galvanized steel duct samples at three RHs and 21°C