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# ASSESSMENT OF FUNGAL *(PENICILLIUM CHRYSOGENUM)* GROWTH ON THREE HVAC DUCT MATERIALS

John C.S. Chang
Air Pollution Prevention and Control Division, National Risk Management Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711, USA

Karin K. Foarde and Douglas W. VanOsdell
Center for Engineering and Environmental Technology, Research Triangle Institute, Research Triangle Park, NC 27709-2194, USA

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Many building investigators have documented fungal biocontamination in heating, ventilating, and air-conditioning (HVAC) ducts. It has been suggested that emissions of spores and volatile organic compounds from the growing fungi may contribute to poor indoor air quality and result in adverse health effects. Laboratory experiments were conducted to evaluate the susceptibility of three types of ventilation duct materials (fibrous glass ductboard, galvanized steel, and insulated flexible duct) to fungal (*P. chrysogenum* ) growth. Each sample was inoculated with spores of *P. chrysogenum* and incubated in a static chamber controlled at 97% relative humidity (RH) and 21 °C for six weeks. Culturable spores on each sample were enumerated before and after incubation to determine the extent of fungal amplification. The results indicated that, of the newly purchased duct materials, only the flexible duct supported moderate growth of *P. chrysogenum*. No fungal growth was detected on the fibrous glass and galvanized steel. The number of culturable spores on galvanized steel even decreased during the test period. 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; however, at different levels of soiling. At a moderate level (0.4-0.7 mg $cm^{-2}$) of soiling, growth occurred on the fibrous glass ductboard and the flexible duct, but not the galvanized steel. At a markedly higher level (9-18 mg $cm^{-2}$) of soiling, growth was seen on the galvanized steel as well. 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 shown to be sources of fungal colonization and amplification (Reynolds et al. 1990; Morey and Williams 1991; Abdou and Sando 1994; Price et al. 1994; Batterman and Burge 1995). Emissions from the biologically contaminated HVAC systems have resulted in indoor air pollution problems and adverse health effects. Three of the commonly used HVAC ducts are fibrous glass ductboard, galvanized steel, and flexible duct.

Fibrous glass ductboard is made of rigid boards of insulation material manufactured from resin bonded inorganic glass fibers. Both field data (Morey and Williams 1990; 1991) and laboratory results (Price et al. 1994) have shown that fibrous glass ductboard can be a

source of fungi found in indoor air. In several building investigations, a microbial layer was found on the air stream surface of the fibrous glass ductboard of HVAC systems. The concentration of fungi increased by several orders of magnitude in the HVAC system air stream near the fibrous glass ductboard when it was disturbed by gentle pounding. It was suggested (Morey and Williams 1991) that the airborne particulate matter that passes through the inefficient filters found in most HVAC systems readily accumulates in or on the air-stream surface of the porous fibrous glass. The soiled fibrous glass ductboard may become a microbial amplification site when moisture is available.

When a duct is made of a non-insulating material such as galvanized steel, fiber glass duct liners are often applied to provide the needed thermal insulation and noise control. Foarde et al. (1995; 1996) showed that fiber glass duct liners, especially when soiled with dust, are susceptible to fungal growth. Morey and Williams (1991) suggested that the fiber glass duct liners should be applied to the outside of the main air supply ducts (which leaves the non-porous galvanized steel exposed to the airstream) to prevent the growth of microorganisms and their release into the ventilation airstream.

However, use of the non-porous material on the inner surface does not guarantee lack of microbial growth. Pasanen et al. (1993a; 1993b) reported that fungal spores were able to germinate on galvanized steel duct if there is a residue of lubricant oil or dust accumulation on it. Ahearn et al. (1991) also reported that fungal colonies were detected on painted metal surfaces associated with HVAC systems. Therefore, fungal growth may occur on both porous and non-porous duct materials. The duct conditions which lead to fungal amplification may be determined by interactions between microorganisms, duct materials, surface conditions, and the micro-environment inside the HVAC system.

In an effort to evaluate the fungal resistance of fibrous glass ductboard, galvanized steel, and flexible duct under different conditions, experiments were conducted using a recently developed static chamber test method (Foarde et al. 1994). Replicate small blocks of duct samples were inoculated with a fungus, *P. chrysogenum*, and incubated in 97% RH chambers. Before inoculation, one set was exposed to the high RH, a second set was wetted, and the third set was artificially soiled. This paper reports the experimental results and compares the fungal growth on the three duct materials tested under the different conditions.

## EXPERIMENTAL MATERIAL AND METHODS

The static chamber test method developed by Foarde et al. (1994) was used to quantitatively evaluate the growth of a fungus on conditioned test materials at controlled RH and temperature. An overview of the method is presented below.

### *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% fiber glass, and 10 to 30% phenol, polymer with formaldehyde, reaction products with hexamethylenetetramine (cured). It was purchased as a 121.9 by 304.8 cm sheet. 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. The insulating middle layer is of light density fibrous glass insulation, and the inner core is a 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 a 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 conducted. The first three experiments were designed to evaluate the potential of fungal growth at 97% RH on: 1) newly purchased duct materials; 2) the same materials wetted with sterile water; and 3) samples soiled with moderate amounts of HVAC dust. A fourth experiment was designed to evaluate the impact of heavy soiling on the potential for fungal growth on newly purchased galvanized steel duct maintained in 90, 94, and 97% RH chambers.

Before each test, precut blocks (3.8 cm square) of the test materials were conditioned for 3 days at 54% RH and sterilized. The conditioned test materials were either directly inoculated with approximately $1 \times 10^5$ colony forming units (CFUs) of *P. chrysogenum* per sample block or treated (e.g., by wetting or soiling) and then inoculated. Sterilized but uninoculated blocks were used

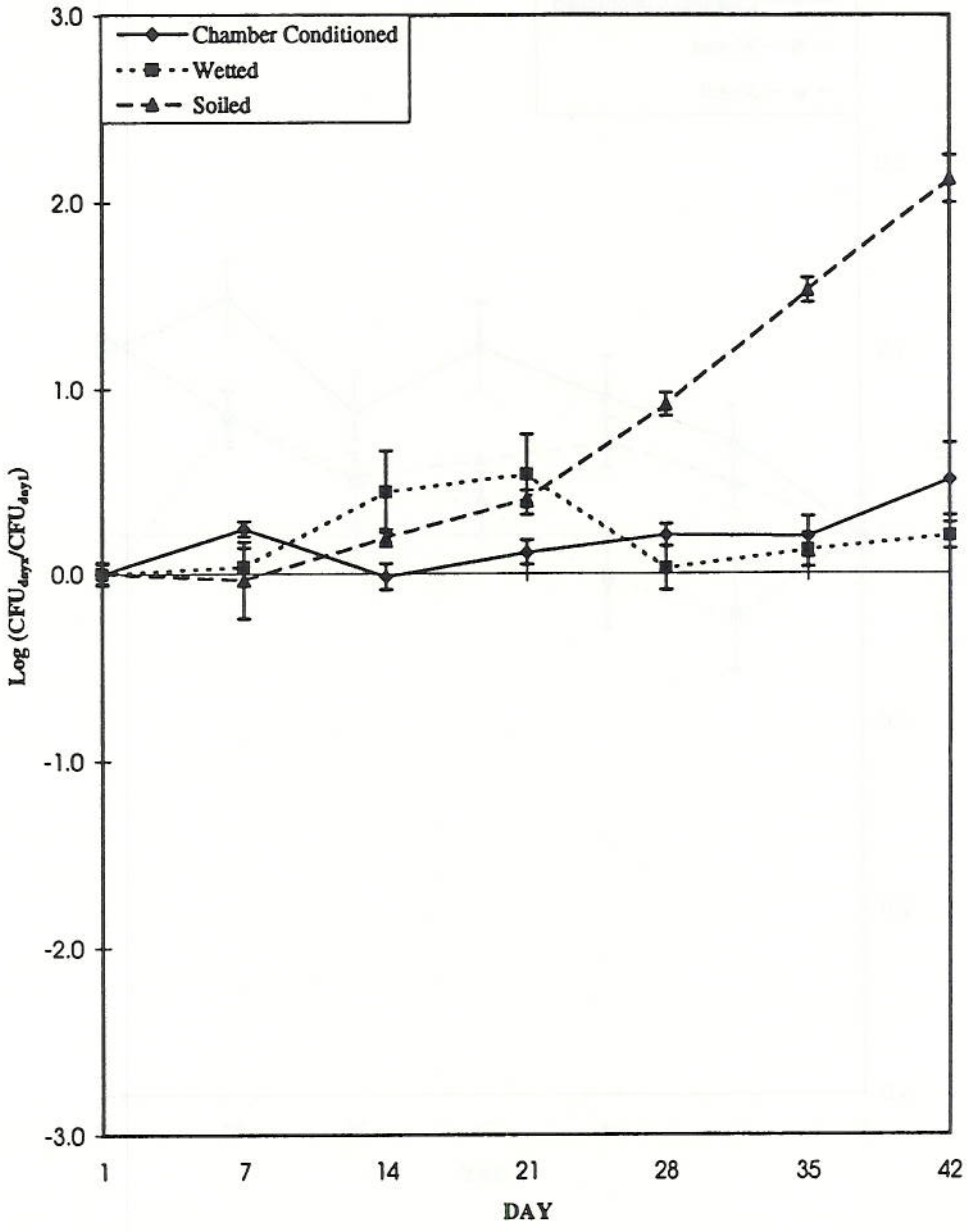


Fig. 1. Growth of *P. chrysogenum* on fibrous glass duct samples at 97% RH and 21 °C.

as controls. Both inoculated and uninoculated blocks were placed in static chambers. The static chambers (32 x 39 x 51 cm) were used as incubators to provide a controlled environment for the fungal growth tests. The chambers were placed 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 (ASTM E 104-85 1991) in each chamber.

To quantify the fungal growth, triplicate inoculated and duplicate uninoculated 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 submerged in phosphate-buffered saline with 0.1% Tween 80 and agitated to suspend the spores. The block/buffer suspension was diluted and plated on Sabouraud dextrose agar. Plates were incubated at room temperature for at least one week. CFUs were counted

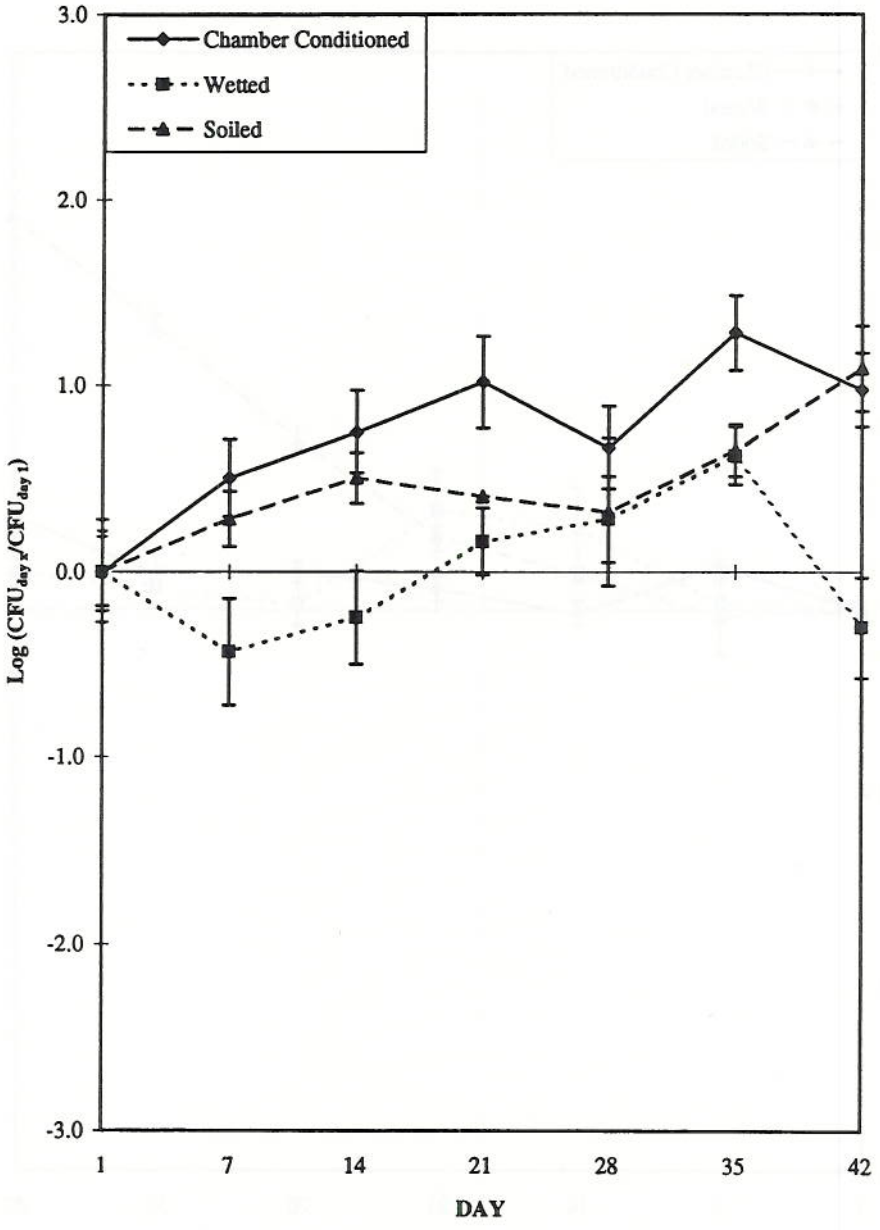


Fig. 2. Growth of *P. chrysogenum* on flexible duct samples at 97% RH and 21 °C.

shortly after visible growth was first noted and again as moderate growth became apparent.

Additional details of the experimental procedures on static chamber design, sample treatment, test microorganism selection, inoculum preparation, and test block inoculation have been reported before and can be found in referenced literatures (Chang et al. 1995; Foarde et al. 1995, 1996).

## RESULTS AND DISCUSSION

### *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 represents the ratio of the mean CFUs from day x to the mean CFUs from day 1. The error bars show the standard error of the ratio.

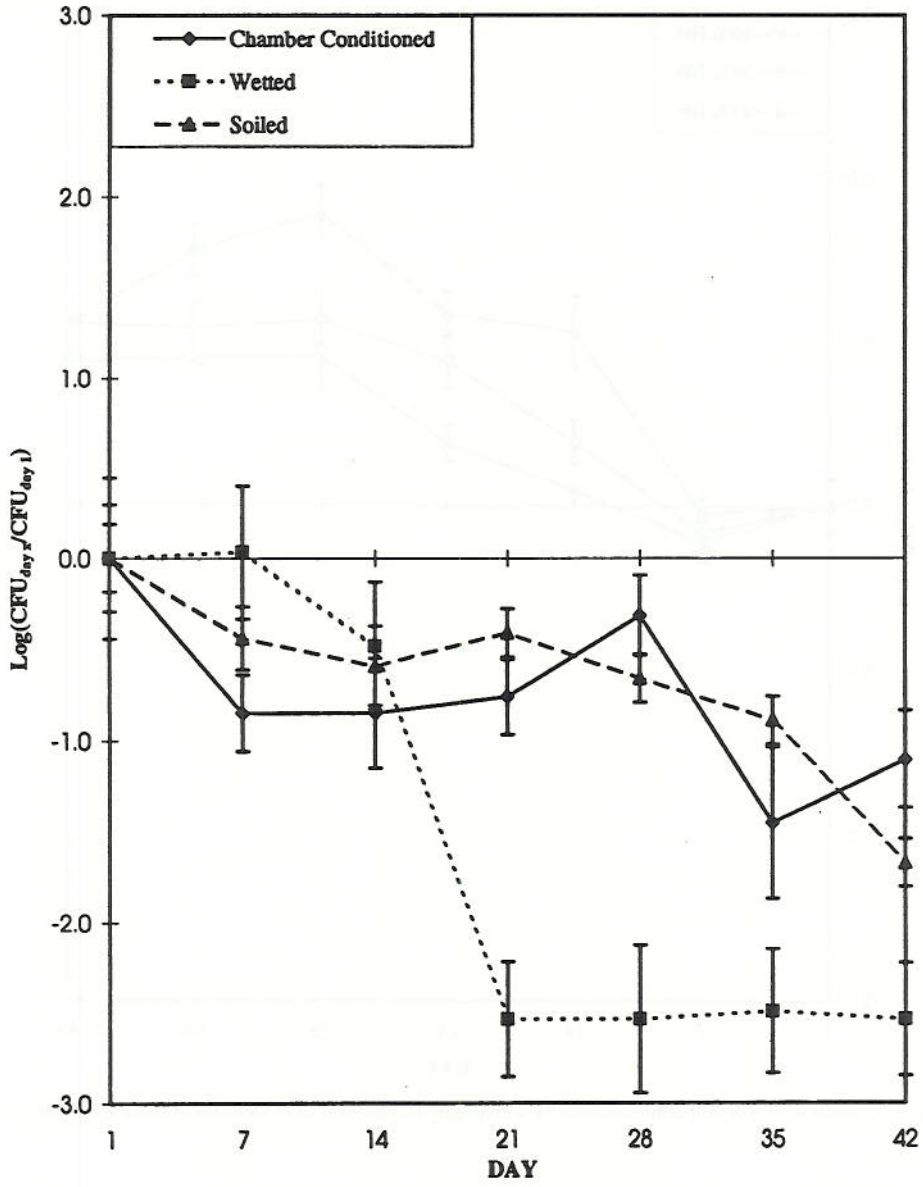


Fig. 3. Growth of *P. chrysogenum* on galvanized steel duct samples at 97% RH and 21 °C.

As shown in Fig. 1, essentially no growth was seen on the samples of new and conditioned fibrous glass duct-board maintained in the 97% RH static chambers, reflected by the little change in CFU ratio throughout the six-week experiment. When wetted, 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. However, when the fibrous glass samples were soiled with 0.76 (± 0.16) mg $cm^{-2}$ of dust, a steady increase in the CFU ratio was obtained throughout the test period. After 42 days, the fungal growth resulted in a two order-of-magnitude rise of the CFU ratio.

*Flexible duct*

Figure 2 shows the results for the same experiments with the flexible duct inner core as the test material. Similar results were seen for all three test conditions through day 35. A moderate increase (about one order-of-magnitude) in the CFU ratio was obtained with the samples of new and chamber conditioned flexible duct at 97% RH. The CFU ratio fluctuated after 21 days and showed no steady trend between day 21 and day 42. When the flexible duct was wetted, the CFU ratio decreased initially and then steadily increased through day 35 for an overall increase of approximately one order-of-magnitude. However, by the sixth week, there

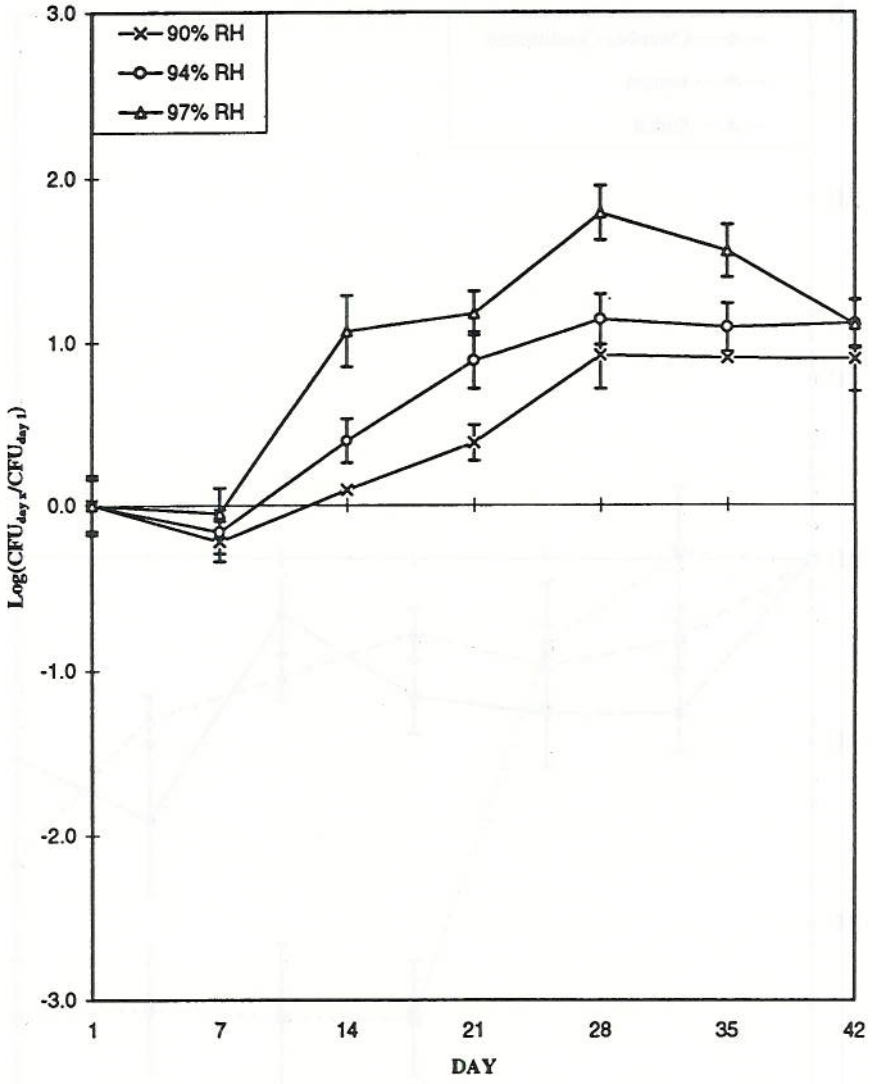


Fig. 4. Growth of *P. chrysogenum* on heavily soiled galvanized steel duct samples at three RHs and 21 °C.

was a sudden decrease to below the base level in the spores isolated. After the samples were soiled with 0.43 (± 0.05) mg cm$^{-2}$ of dust, 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 experimental results with galvanized steel as the test material. The CFU ratio decreased moderately (one order-of-magnitude) when the new and conditioned galvanized steel duct was maintained in the 97% RH chamber. 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. After the galvanized steel was soiled, the CFU ratio fluctuated in a narrow range around the day 1 level and decreased steadily (over 1.5 orders-of-magnitude) throughout the six-week test period. No fungal growth was detected on samples of galvanized steel duct at the three conditions tested. Overall, decreases ranging from steady to marked were seen even after soiling with 0.7 (± 0.1) mg cm$^{-2}$ of HVAC dust. These results are quite different from the fibrous glass duct and flexible duct results shown in Figs. 1 and 2.

### *Heavily soiled galvanized steel*

To further investigate the impact of soiling on fungal growth, additional experiments were conducted with heavily soiled galvanized steel as the test material. Samples of new galvanized steel duct material were soiled with HVAC dust at levels of 8.91 (± 1.05), 12.57

(± 1.14), and 18.72 (± 1.54) mg $cm^{-2}$, inoculated with *P. chrysogenum*, and placed in 90, 94, and 97% RH chambers, respectively. As shown in Fig. 4, the CFU ratio increased steadily throughout the test period.

Generally, there was little difference between the results seen for the samples maintained at the three different RHs. After six weeks, the CFU ratios had increased approximately one order-of-magnitude regardless of RH. These results indicate that sufficient moisture and nutrients were probably present for *P. chrysogenum* growth on samples in all the chambers.

## CONCLUSIONS

Three types of commonly used HVAC duct materials were tested in static chambers to evaluate their susceptibility to fungal growth. Neither samples of newly purchased fibrous glass ductboard nor galvanized steel maintained at 97% RH supported *P. chrysogenum* growth during the testing period. Fungal growth was seen on the flexible duct as demonstrated by an increase in culturable spores by about one order-of-magnitude on samples kept at 97% RH and 21 °C for six weeks. 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. But after artificial soiling with the equivalent of approximately 0.4 to 0.7 mg $cm^{-2}$ HVAC dust, fungal growth as measured by an increase of culturable spores of more than one order-of-magnitude was detected on the flexible duct and the fibrous glass ductboard but not the galvanized steel.

On galvanized steel samples soiled with significantly more dust, approximately 9-18 mg $cm^{-2}$, moderate growth (one order-of-magnitude increase in culturable spores) was seen. It would be interesting to determine the impact of the intervening amounts of dust. The moderately soiled samples (0.4 to 0.7 mg $cm^{-2}$ HVAC dust) were visibly but lightly dusted to the naked eye and a noticeable amount of the test material remained visible. The heavily soiled samples (9-18 mg $cm^{-2}$) were covered with a thin coating of dust and little if any of the galvanized steel was visible.

Conditions favorable for fungal growth in HVAC ducts exist because, with current HVAC design and operation, dust penetration into and accumulation on the duct surface is almost inevitable. Humid conditions can be found around cooling coils, humidification zones, and sometimes outside air intakes when the outdoor air is humid or foggy. 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 seal and air filtration. Access to and cleanability of an HVAC system are also critical.

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