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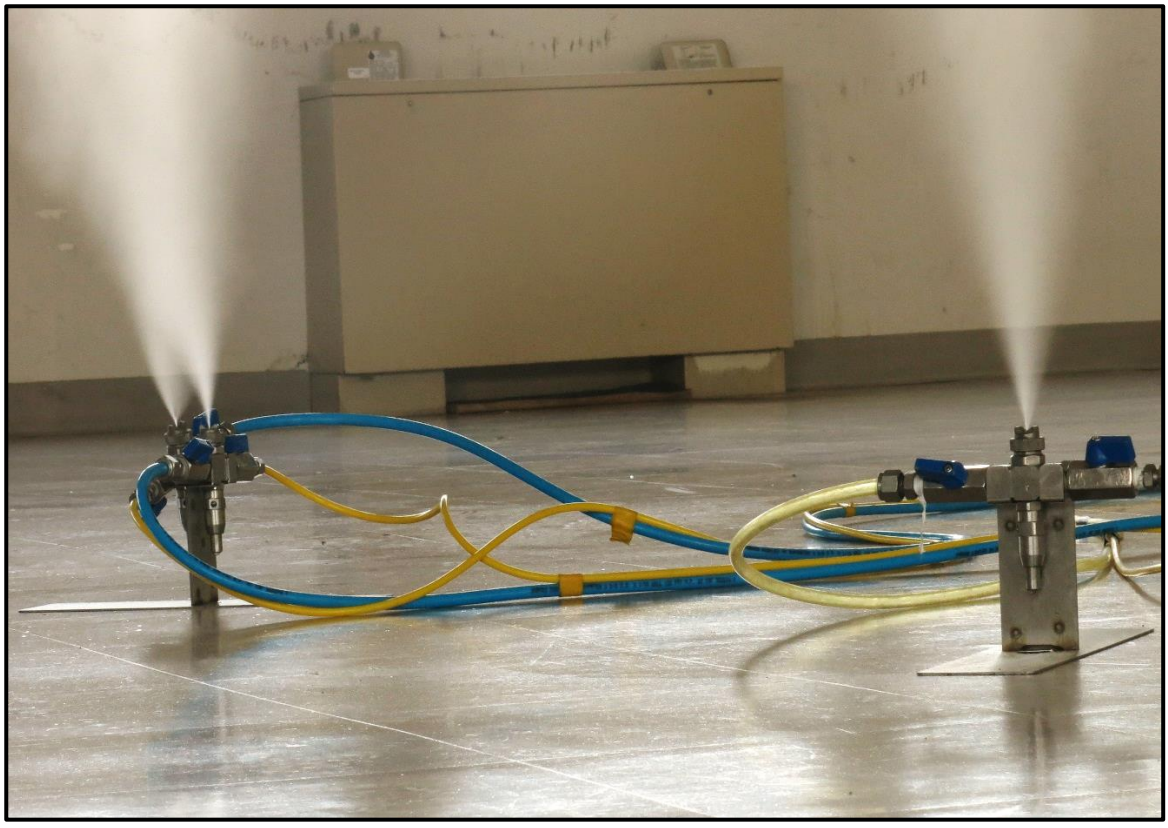
Performance Testing of a Novel Dry-Fog Mold Remediation and Prevention Process

Shane D. Hirschi and Dale L. Herron

DRAFT - October 2017



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Performance Testing of a Novel Dry-Fog Mold Remediation and Prevention Process

Shane D. Hirschi and Dale L. Herron

Construction Engineering Research Laboratory
U.S. Army Engineer Research and Development Center
2902 Newmark Drive
Champaign, IL 61822-1076

DRAFT Report

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Under ITTP, "Performance Testing of a Novel Dry-Fog Mold Remediation and Prevention Process"

Monitored by Construction Engineering Research Laboratory [FOR CRs ONLY]
U.S. Army Engineer Research and Development Center
2902 Newmark Drive, Champaign, IL 61822-XXXX

Abstract

Fort Campbell, Kentucky, and the U.S. Army's Engineer Research and Development Center partnered with the Army Office of the Assistant Chief of Staff for Installation Management's Installation Technology Transfer Program to demonstrate the effectiveness of a two-step dry-fog mold remediation process technology. The two-step dry-fog process introduces a gas/vapor with micron-sized particles that cover, penetrate and encompass mold spores in materials, spaces and places that current mold removal technologies are not able to penetrate.

The purpose of the project was to demonstrate the efficacy of mold spore removal and the potential for long-term mold prevention. Treating each test building took five to six hours and included: mobilization, "before" air and surface sampling, treatment application, "after" air and surface sampling, and demobilization.

Initial air samples taken prior to treatment from the dining facility and barracks locations indicated an average of hundreds of thousands mold spores per cubic meter while outdoor/background samples were in the thousands. Air samples to date, six months after treatment, have shown and continue to indicate effective treatment with mold spore counts remaining below outdoor/background levels.

Early project results were shared with Region IV of the Federal Emergency Management Agency (FEMA) and the Huntington District of the US Army's Corps of Engineers. Based on project results, the dry-fog technology could potentially support mold remediation needs resulting from ongoing military installation indoor air quality maintenance as well as more recent and future remediation requirements resulting from natural hazards.

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Preface

This study was conducted for the Assistant Chief of Staff for Installation Management (ACSIM) under an ITTP project titled “Performance Testing of a Novel Dry-Fog Mold Remediation and Prevention Process”. The technical monitor was Kelly Dilks-Moon (CEERD-CFN).

The work was performed by the Energy Branch (CF-E) of the Facilities Division (CF), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Andrew (Andy) J. Nelson was Chief, CEERD-CF-E; Donald K. Hicks was Chief, CEERD-CF; and Kurt Kinnevan, CEERD-CV-T was the Technical Director for Facilities. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguezel.

The authors would like to thank personnel from Fort Campbell, KY for their collaboration, knowledge, experience and field support.

COL Bryan S. Green was the Commander of ERDC, and Dr. David W. Pittman was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
microns	1.0 E-06	meters
mils	0.0254	millimeters
ounces (mass)	0.02834952	kilograms
ounces (U.S. fluid)	2.957353 E-05	cubic meters
pounds (force)	4.448222	newtons
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square yards	0.8361274	square meters
yards	0.9144	meters

1 Introduction

1.1 Background

Mold is a fungus that can grow on virtually any substance, provided moisture is present, damaging buildings and negatively affecting the health of building occupants. The preferred solution is to control and eliminate the source of moisture that precipitates the mold growth. However, this is an ever-changing problem with an unachievable long-term solution within most, if not all, "real world" operational settings due, in large part, to building personnel throughout the Department of Defense (DoD) adjusting system specific heating, ventilation and air conditioning (HVAC) set points to achieve their immediate comforts. Other physical controls such as windows, doors, etc. are opened or closed to satisfy current employee comforts without any regard to the impact on the larger "system" of controls. These adjustments inevitably create less than optimal operational conditions which frequently enhance the already prime onsite environmental conditions for mold growth. Deficient maintenance is also a reoccurring issue for all military installations and often contributes to optimal conditions for mold growth.

Fort Campbell, Kentucky, and the U.S. Army's Engineer Research and Development Center partnered with the Army Office of the Assistant Chief of Staff for Installation Management's Installation Technology Transfer Program to demonstrate the effectiveness of the two-step dry-fog mold remediation process technology developed by Pure Maintenance LLC, a commercial partner that owns the patented treatment technology. Two buildings at Fort Campbell were identified for the dry-fog demonstration; a vacant dining facility and a dormant barracks administration section that included classrooms, restrooms and office facilities.

This project is related to two prior studies/demonstrations performed separately in Fiscal Year 2009 (FY09)[1] and Fiscal Year 2010 (FY10)[2]. Both of these projects were funded out of the Installation Technology Transition Program (ITTP) and both were performed at Fort Polk, Louisiana. Brief Summaries of the FY09 and FY10 studies/demonstrations are provided below in Table 1 and Table 2 respectively.

Table 1. Prior Related Demonstration - 2009

Year of Study:	2009
Study:	**Demonstration of Mold Assessment and Removal Technologies at Fort Polk, Louisiana** ERDC/CERL Draft Technical Report *(L.D. Stephenson et al. 2009)*

Approach/Objective:	Determine the mold burden, eradicate mold, and mitigate its re-occurrence
Findings:	• Dry ice was successfully tested on concrete and concrete block surfaces, along with biocide protectants applied post-removal • Although dry ice was shown to be a successful multi-step mold removal process, a simple mold removal and long-term prevention strategy is desired

Table 2. Prior Related Demonstration - 2010

Year of Study:	2010
Study:	**Prevention of Toxic Molds in Army Facilities Using Surface-Applied Biocides** *(L.D. Stephenson, J.L. Lattimore, and K.M. Torrey 2011)*
Approach/Objective:	Evaluate the efficacy of a two-step mold removal process, which involves application of biocidal "eradicants" to remove mold from a variety of surfaces, followed by application of biocidal "protectants" to prevent recurrence of mold
Findings:	• Two best tests for quantifying potential for growth, existing mold, mold removal and long-term efficacy of protectants are: 1) viable swab test and 2) viable airborn spore count • Best performing eradicants were: Sporicidin® (a phenolic-based product) and Shockwave® (a quarternary ammonium chloride-based product) • Best performing antimicrobial protectants were Fosters 40-20 and IAQ 6000 • Full body coverage, rubber gloves, eye protection, and dust filter should be used during application of both eradicants and protectants • ASTM D5590 successfully predicted the long-term efficacy of protectants to mitigate re-occurrence of mold growth at Fort Polk. The 4-week accelerated test is suggested as a way to quantify relative efficacy among newly

	emerging protectants and can be used for screening purposes

Mold continues to be an ongoing problem for Army installations and contingency basing locations[3]. Current mold remediation technologies require intensive manpower and various levels of personal protective equipment (PPE) to be worn during the removal and prevention processes. Specific requirements are in Division 2 – Existing Conditions, Section 02 85 00.00 20 Mold Remediation of the Unified Facilities Guide Specifications (UFGS). There is some question within the mold treatment technology sector, as to whether the physical removal of the visible mold is enough to completely remove the mold spores and prevent regrowth. This can only be determined/verified through sample collection and analysis via an approved laboratory.

Interpreting laboratory results for mold can be difficult for a couple of reasons. One, there are no set maximum exposure limits (MELs) for airborne indoor mold concentrations. Setting limits would be difficult for multiple reasons such as variation in sampling techniques, sensitivity to microbial exposures across the human population, vast number of varying types of mold and other biological pollutants within the indoor environment, and limited data on the relationship between exposure and human response[4].

1.2 Objective

The objective of this ITTP demonstration is to perform independent performance testing of the novel dry-fog mold remediation and prevention process to determine the effectiveness of the treatment process at eliminating mold and preventing re-growth at military installations and contingency basing locations. More specifically, the technical objectives are to:

1. Demonstrate the dry-fog process (via the 2nd generation application system shown in Figure 1) in two buildings at Fort Campbell, KY.

2. Determine the efficacy and performance (via sampling and analysis) of the dry-fog process.

3. Verify initial remediation impact(s) and non-reoccurrence of mold/mildew over a test period of six months (via sampling and analysis).

Figure 1. Dry-fog application system

1.3 Approach

This project involves demonstrating and evaluating the short term and long term effects of a dry-fog technology. The following approach was used to demonstrate/validate this technology:

1. Identify two buildings suitable with existing mold problems at Fort Campbell that are suitable for use in the demonstration project.

2. Conduct pre-treatment air and surface sampling in the demonstration buildings to determine existing mold levels.

3. Treat the designated areas within the buildings using the dry fog process.

4. Sample immediately after treatment to determine the initial effects of the treatment process.

5. Perform additional sampling after 1 month, 3 months and 6 months following treatment to determine the long-term effects of the treatment.

6. Perform analysis to determine the efficacy of the dry fog treatment technology.

1.4 Method of Technology Transfer

The project team delivered the following items and activities during project execution.

- A Public Works Digest article[3] was submitted for publishing.
- The Huntington, West Virginia District of the Corp of Engineers and Region IV of FEMA were briefed on early project results via telecom.
- A USACE Engineering and Construction webinar was provided.
- A one-page project summary delivered to the PMO of OACSIM.
- A webinar with all 10 Regions and HQ of FEMA is pending.

2 Demonstration Process

The project team, made up of individuals from Fort Campbell, ERDC-CERL and Pure Maintenance LLC performed site validation, completed baseline/background sampling and analysis, executed the treatment process using the two-step dry fog technology and performed verification sampling and analysis to demonstrate the two-step dry-fog technology.

2.1 Site Validation

Prior to initiation of any onsite activities, the project team held a kick-off meeting via telecon to identify the potential facilities and associated infrastructure at Fort Campbell, KY. On March 9, 2017 a site visit was held to facilitate a walk-through of the two demonstration locations, Building 2261 (Dining Facility) and Building 6733 (Barracks). Figure 2 (google maps) shows their locations within the cantonment area of Fort Campbell. Both of these buildings were vacant and determined to be good candidates for the demonstration.

Figure 2. Fort Campbell cantonment area showing demonstration locations.

Building 2261 – is a vacant dining facility having an interior of 4000 ft² of which approximately 3700 ft² were treated. Figure 3 provides a view of the exterior of the facility. Figures 4 and 5 provide visual representation of the existing conditions inside the facility. Visual mold was present on most all surfaces to varying degrees.

Figure 3. Exterior of Building 2261 - dining facility

Figure 4. Kitchen area inside Building 2261

Figure 5. Dining area inside Building 2261

Building 6733 – is a vacant hammerhead style barracks facility having an interior of 38,000 ft² of which approximately 2800 ft² were treated. Figure 6 provides a view of the exterior of the facility. Only the administrative area of the first floor (i.e. classroom, offices and restrooms) were included in this demonstration. Figures 7 and 8 show the amounts of visible mold on the wall surfaces.

Figure 6. Exterior of Building 6733 – barracks

Figure 7. Classroom area inside Building 6733

Figure 8. Bathroom area inside Building 6733

These buildings were chosen because there were known high levels of mold and both buildings were vacant. Given the short, 8 month, demonstration period, vacant buildings made it easier to schedule for treatments and greatly simplify ingress and egress to the buildings. However, the absence of personnel and functioning HVAC systems made it difficult to ensure constant environmental/occupational conditions. Outside temperatures had an additional impact on the variables of interest within the two buildings.

2.2 Baseline/Background Sampling and Analysis

2.2.1 General Information

Mold analyses are typically reported in terms of marker molds, outdoor molds and hyphal fragments. Below is a brief description of each(ref).

- Marker molds – are uncommon mold types that aren't typically found in significant numbers outside. These mold types, associated with more serious health problems, are often the best indicator of indoor mold issues. The following are typical marker molds:

  - *Stachybotrys* - known as "black mold" is considered the most dangerous mold type and is typically found in low numbers, if at all in outdoor samples. This mold has been linked with infant death.

  - *Chaetomium* – this marker mold is not commonly found at significant levels indoors and is associated with health problems including fibromyalgia, MS, lymes disease and more.

- Outdoor molds – common outdoor molds are typically the molds that start growing outdoors and can still cause health issues when growing indoors. Health issues are usually related to cold, allergy, sinus, and respiratory issues. The following are typical outdoor molds:

  - Penicillium/Aspergillus – approximately 200 species in this genus and is the most common fungal genus in the U.S. commonly found in house dust, water damaged wall paper and sheet rock, wallpaper glue, fabrics moist chipboards, behind paint and in rotting food.

  - Cladosporium – approximately 28-40 species in this genus and is one of the top 3 most common genus in the U.S. found indoors on a variety of substrates.

  - Basidiospores – Extremely common mold genus in outdoor samples and originate from fungus in gardens, forests, and woodlands. Often found in dirt of indoor potted plants or dust.

- Hyphal Fragments – Hyphal Fragments are produced during mold reproduction and are often an indicator of active growth. Hyphal fragments can be found in small amounts outdoors and indoors in healthy environments. Indoor levels under 200, are generally considered "normal".

Analytical reporting, evaluations and discussions within this report will focus on the above prescribed marker molds, outdoor molds and hyphal fragments.

EMLab P&K produces U.S. Outdoor Average Mold Levels for various parts of the United States(ref). Tables 3-6 below illustrate those "typical" values for the months closest to those applicable to this demonstration as well as the location. Data is not available for Kentucky or Tennessee. Illinois was determined the most representable data set based on the geographic location of the demonstration.

Table 3. U.S. National Outdoor Average for April

Fungal Type	Low *(Dry Climate)* (#spores/m³)	Medium (#spores/m³)	High *(Humid Climate)* (#spores/m³)
Alternaria	13	27	53
Basidiospores	67	240	960
Chaetomium	13	13	27
Cladosporium	107	320	1013
Penicillium/Aspergillus Types	53	160	400
Stachybotrys	13	13	40

Table 4. U.S. National Outdoor Average for July

Fungal Type	Low *(Dry Climate)* (#spores/m³)	Medium (#spores/m³)	High *(Humid Climate)* (#spores/m³)
Alternaria	13	40	107
Basidiospores	107	427	3067
Chaetomium	13	13	27
Cladosporium	213	747	2120
Penicillium/Aspergillus Types	80	213	613
Stachybotrys	13	13	40

Table 5. U.S. National Outdoor Average for October

Fungal Type	Low *(Dry Climate)* (#spores/m³)	Medium (#spores/m³)	High *(Humid Climate)* (#spores/m³)
Alternaria	13	40	107
Basidiospores	133	627	3625
Chaetomium	13	13	27
Cladosporium	213	800	2720
Penicillium/Aspergillus Types	100	267	747
Stachybotrys	13	13	40

Table 6. Annual Outdoor Average for Illinois

Fungal Type	Low *(Dry Climate)* (#spores/m³)	Medium (#spores/m³)	High *(Humid Climate)* (#spores/m³)
Alternaria	13	53	187
Basidiospores	160	780	3220
Chaetomium	7	13	27

Cladosporium	120	693	2773
Penicillium/Aspergillus Types	53	133	400
Stachybotrys	13	13	53

2.2.2 Background Sampling for this Demonstration Project

Prior to application of the dry-fog technology in the demonstration buildings, background air samples and surface samples were taken in and outside each building as shown in Figure 9. Samples were taken at Building 2261 on 20 March 2017 and at Building 6733 on 21 March 2017. In Figure 9 below, the background/outdoor sample location at each building is shown as location #5 and location #17 respectively.

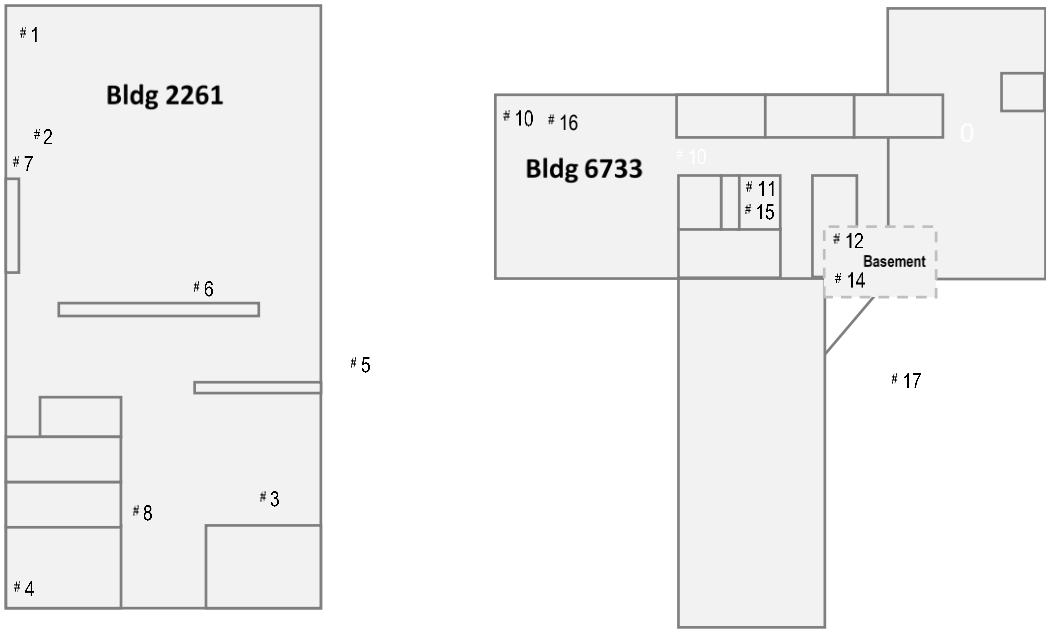

Figure 9. Sampling locations at Buildings 2261 and 6733 *(not to scale)*

Figure 10 shows the sample collection containers for both air and surface sampling. Air

Figure 10. Air and surface sampling equipment

sampling was conducted using a Zefon International Mold Sampling Pump P/Z- Lite-IAQ (see Figure 20). Sampling protocol for normal office space requires an air flow rate of 15 liters per minute (lpm) for a 5 minute period[9]. Zefon Air-O-Cell™ sample containers were used to capture the air samples. Surface samples were taken using the tape pull method.

2.2.3 Sample Analysis

Spore trap analysis and direct microscopic examination were performed for the samples collected at each location by EMLab P&K[10] (Lab ID #102297). Both of these methods are considered standard analyses when determining mold levels within the air and on surfaces of interest.

> Spore Trap Analysis – is used to determine the number of a particular mold spore type within a known volume of air at a specific location. Results are reported in number of spores per cubic meter (#/m^3). Positive results are an indication of airborne mold spores. Airborne mold spores contribute to an unhealthy environment and often lead to respiratory, or other illnesses.
>
> Direct Microscopic Examination – is used to determine specific types of mold spores present on the surface of any material at a particular location. Positive results are an indication of mold growth on the identified surface.

One of these two types of samples was performed on each sample collected during the demonstration. Results are provided is Section 3 of this report.

2.3 Two-Step Dry Fog Application

The dry-fog is a gas/vapor with micron sized particles able to cover, penetrate and encompass mold spores. The small size of the particles (6 – 8 microns)[7] enables treatment in materials and spaces that current mold removal technologies are not able to access. The first step of the two-step dry-fog process is the application of InstaPURE®. InstaPURE® is a powerful disinfectant that destroys mold spores and disinfects any surface it touches. The second step of the two-step process is the application of EverPURE®. EverPURE® is an anti-microbial barrier that destroys bacteria or viruses that come in contact with surfaces treated with EverPURE®. Both InstaPURE® and EverPURE® are Environmental Protection Agency (EPA) approved in all 50 states.

The treatment system is completely mobile. It includes compressed air, spray nozzles and the dry-fog box as shown in Figure 11.

Figure 11. Equipment to apply the dry-fog treatment.

The dry-fog technology is housed inside the metal box shown in Figure 12. Independent control of the flow rates and pressures for the liquid and air, provides the patented ability to generate the dry-fog. The dry fog is made up of particles ranging from 6-8 microns in diameter. Mold spores generally vary from 10-30 microns in diameter. This small particle size provides a mechanism to treat areas inaccessible by liquid treatments. Knowing the dry fog is made up of particles much smaller than the mold spores, provides assurance that the fog is physically able to infiltrate all spaces and porous materials available to mold spores.

Figure 12. Dry-fog technology apparatus

Air compressors provide pressure to quickly distribute the dry fog. The dry fog disseminates rather readily covering 1000 square feet having 8 to 10 foot ceiling heights in approximately one hour (i.e. 10,000 cubic feet per hour (ft^3/hr)). This is accomplished with minimal manpower requirements. A single individual is able to completely treat, including mobilizing and demobilization, a 2000 square foot single story facility/space in approximately 3 hours. The larger the treatment volume, the longer the treatment time, for a given number of air compressors and spray nozzles.

Building 2261 took approximately five hours to treat. This included mobilization, surface and air sampling, and demobilization. Building 6733 took a total of approximately 4 hours to treat and accomplish the same tasks.

The dry-fog technology is relatively inexpensive when compared to current mold removal procedures and their labor intensive requirements. Costs for the treatment, given a one story building can be estimated at approximately $0.95/ft2. This estimate does not include travel costs by the vendor. Actual costs will be higher or lower depending on travel time, multi- versus single-story buildings, and special circumstances such as the geographical location, use(s) and layout of the building.

Material Specifications and Data Sheets for InstaPURE® and EverPURE® are provided in Appendix B. Given the chemical make-up of these liquids and the application process, i.e. the addition of deionized water and atmospheric air, there are not (and to date have not been) any adverse effects to humans or the contents within the treated buildings. Thousands of buildings, residential, commercial and industrial buildings have

been treated by the vendor, and others using their products, with no negative effects on any inhabitants or materials within treated buildings. As stated earlier in this section, both InstaPURE® and EverPURE® are approved by EPA for use in all 50 states.

The dry-fog technology is currently available via licensing from the vendor. The vendor provides start-up equipment, training (via in-person and online), and access to chemicals, local/national marketing materials and business development support.

The treatment is performed by introducing the dry-fog via spray nozzles (Figures 13 - 15).

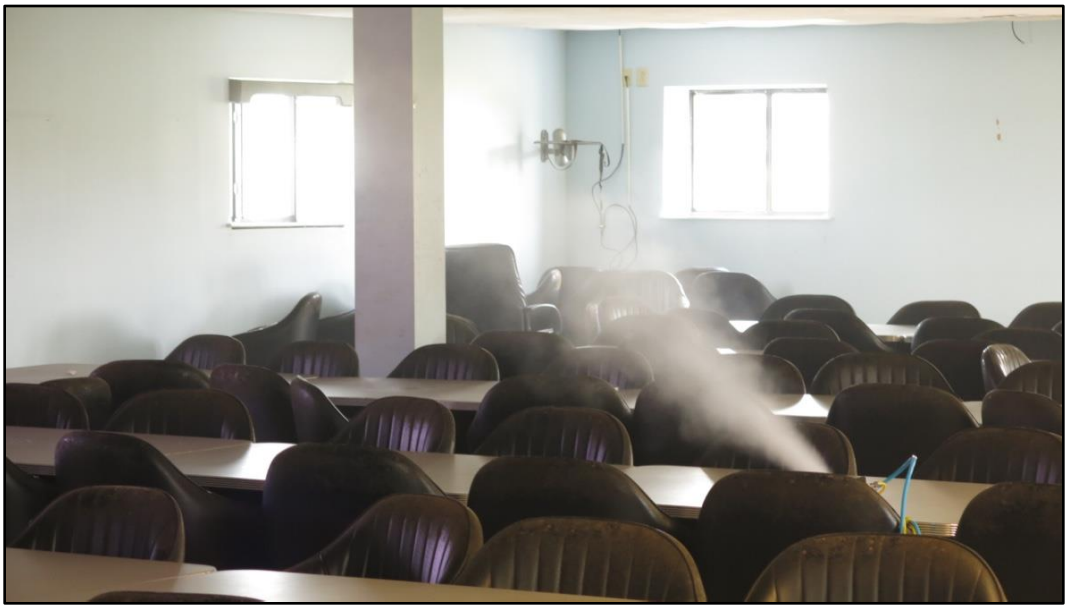

Figure 13. Dry-fog being applied via spray nozzle in Building 2261.

Figure 14. Dry-fog being applied to intake of HVAC ducting Building 2261.

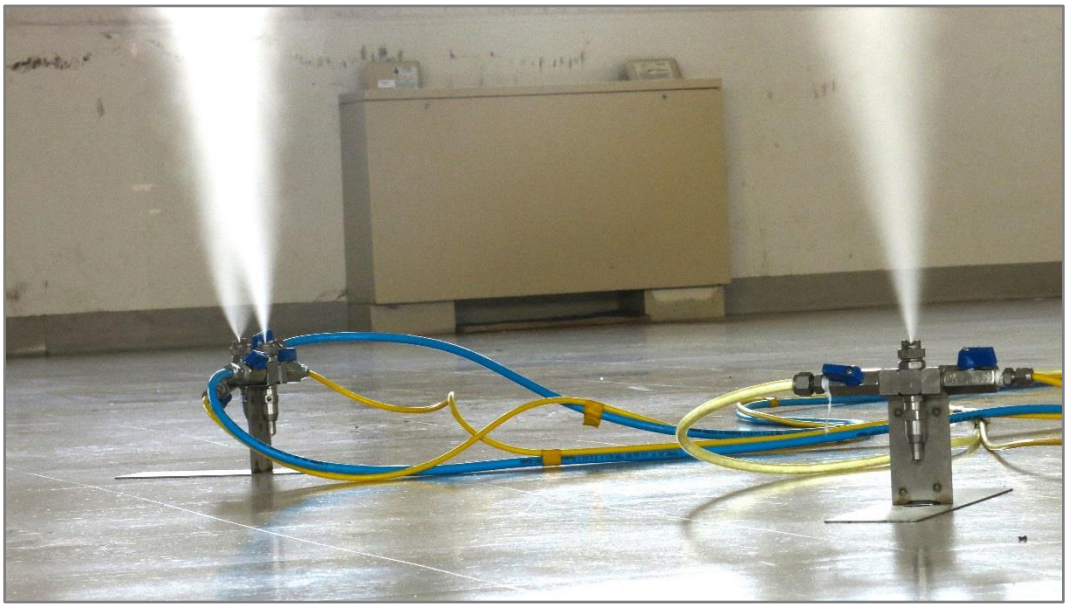

Figure 15. Dry-fog being applied via spray nozzles in Building 6733.

Figure 16 provides an example of minimalistic plastic barriers put in place to generate enough back pressure to provide positive pressure and ensure coverage when doing smaller areas within larger, more spacious rooms. Although it is not completely constrained, the dry-fog accumulates to provide treatment, as shown in Figure 17.

Figure 16. Positive pressure at various points within Building 2261.

Figure 17. Dry-fog accumulation in kitchen area within Building 2261.

Indicator strips are placed at various locations within the treatment area to ensure coverage. The strips are initially white and turn black (Figure 18) as the dry-fog fills the air at a sufficient concentration to indicate full treatment. HVAC systems are operated long

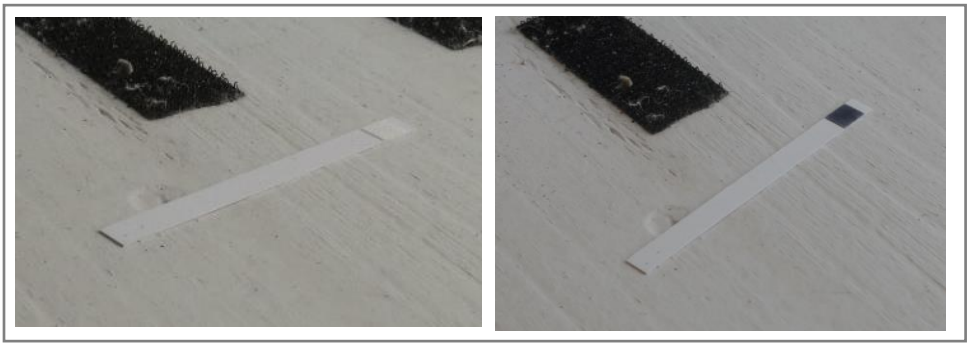

Figure 18. Indicator strips signify treatment (i.e. white to black).

enough to ensure complete coverage (i.e. multiple duct system volumes) throughout the duct work and associated filters/vents.

Note the "treatment" does not "remove" the black appearance of mold (Figure 19). However, mold spores can be eliminated and still appear as though they are there (i.e. the surface may still look as it did prior to treatment). It is essential that air and surface sampling are performed (before and after treatment) to provide quantitative measurements of the treatment's removal effectiveness.

Figure 19. Mold growing near duct vents in Building 2261

2.4 Verification Sampling and Analysis

Following the dry-fogging application, Pure Maintenance, LLC (with members of the project team present) conducted air and surface sampling (Figure 20). Continued sampling occurred at 1 month (25 April 2017), 3 months (22 June 2017) and 6 months (12 September 2017) following treatment. Results and analyses from these sampling events are discussed in Section 3 of this report.

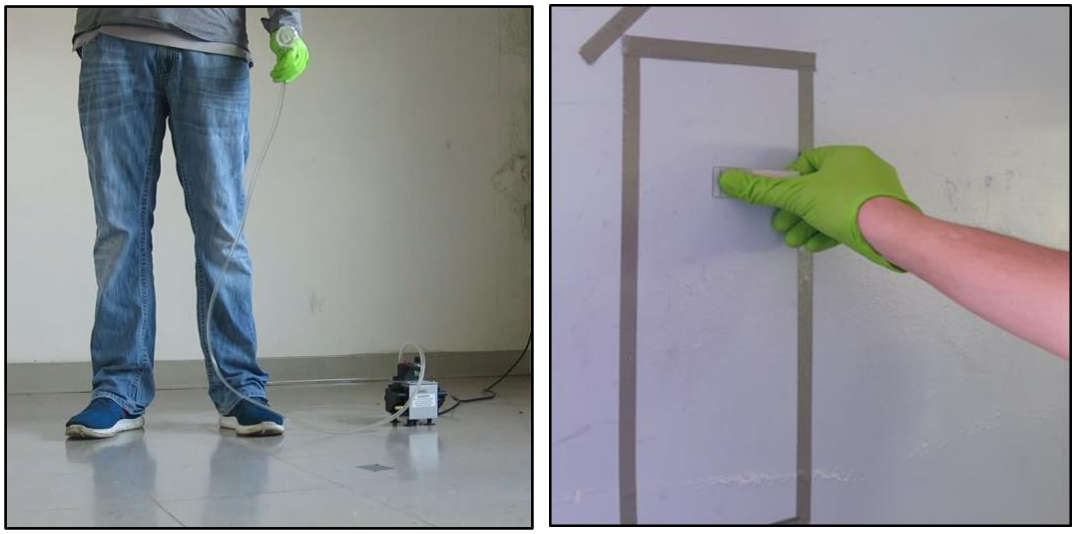

Figure 20. Air and surface sampling

3 Findings

3.1 Summary findings

The dry-fog treatment was successful in reducing and maintaining mold at below background levels over the duration of the 6 month demonstration period. Figures 21–23 and Table 7 provide results of air sampling and surface sampling at Building 2261. Figures 24-26 and Table 8 show results of air sampling and surface sampling at Building 6733. Sections 3.1 and 3.2 reveal detailed results specific to individual surface and air sampling locations within each building.

As shown in Figure 22, the total spore count weighted across all air sampling locations associated with Building 2261 decreased from 64,126 spores/m^3 prior to treatment, to 3,067 spores/m^3 at six months after treatment. Over this same time period, the outdoor/background total spore count increased from 590 spores/m^3 prior to treatment, up to 19,000 spores/m^3 at six months after treatment. Simply put, while the outdoor/background total spore count increased 3,120%, the indoor (i.e. treated space) total spore count decreased 95.21%.

In Figure 25, the total spore count weighted across all air sampling locations associate with Building 6733 decreased from 556,057 spores/m^3 prior to treatment, to 3,044 spores/m^3 at six months after treatment. Over this same time period, the outdoor/background total spore count increased from 3,100 spores/m^3 to 20,000 spores/m^3 at six months after treatment. As the outdoor total spore count increased 545.2 %, the indoor (i.e. treated space) total spore count decreased by 99.45%

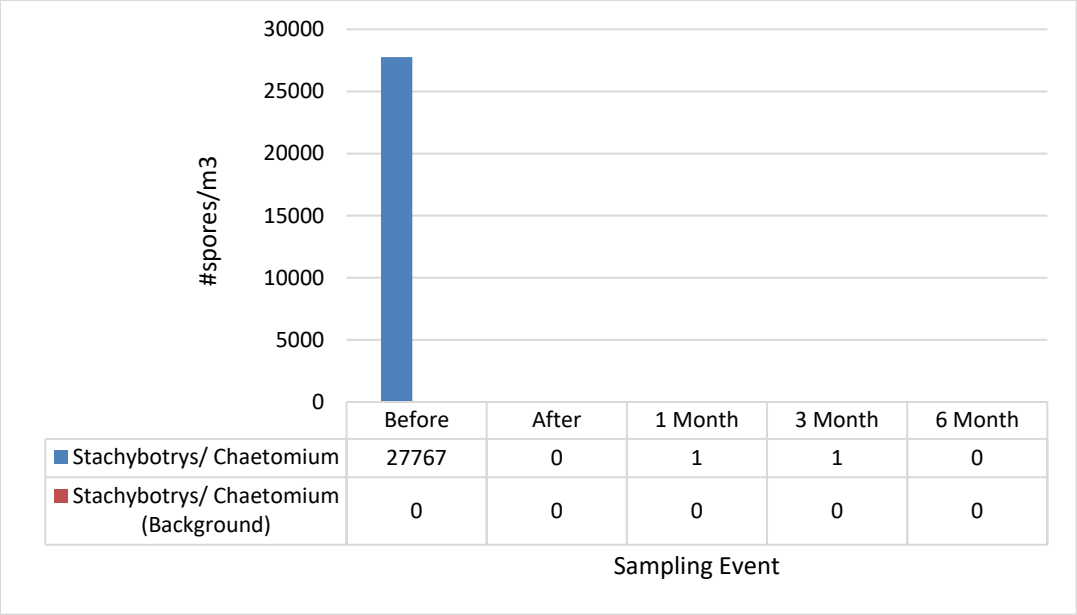

Figure 21. Bldg 2261 Stachybotrys/Chaetomium vs Stachybotrys/Chaetomium (background)

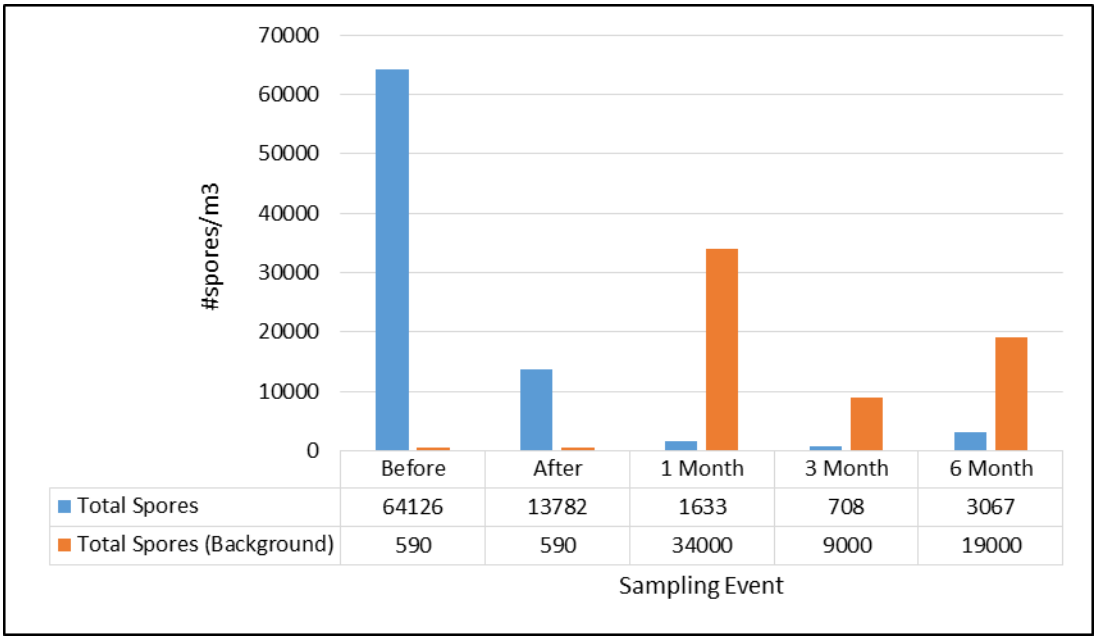

Figure 22. Bldg 2261 - Total Spores vs Total Spores (background)

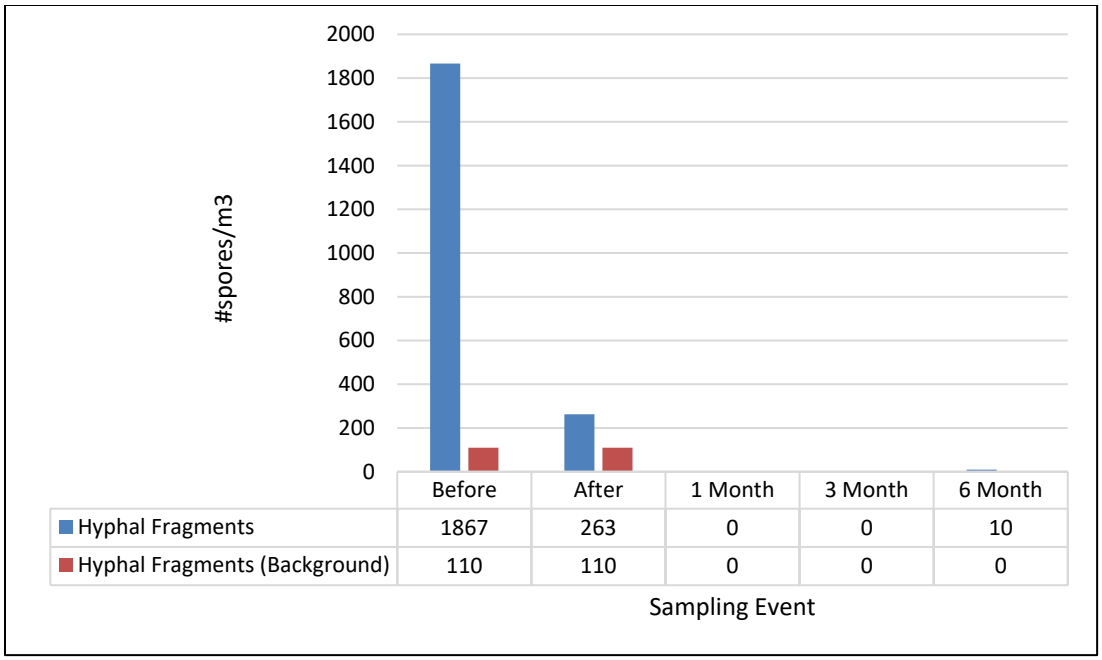

Figure 23. Bldg 2261 - Hyphal Fragments vs Hyphal Fragments (background)

Table 7. Surface sampling results in Building 2261

Fungal Type	Before	After	1 Month	3 Month	6 Month
Cladosporium	6+	<1	0	0	0
Penicillium/Aspergillus	0	0	0	0	0
Total	very few	very few	very few	0	0

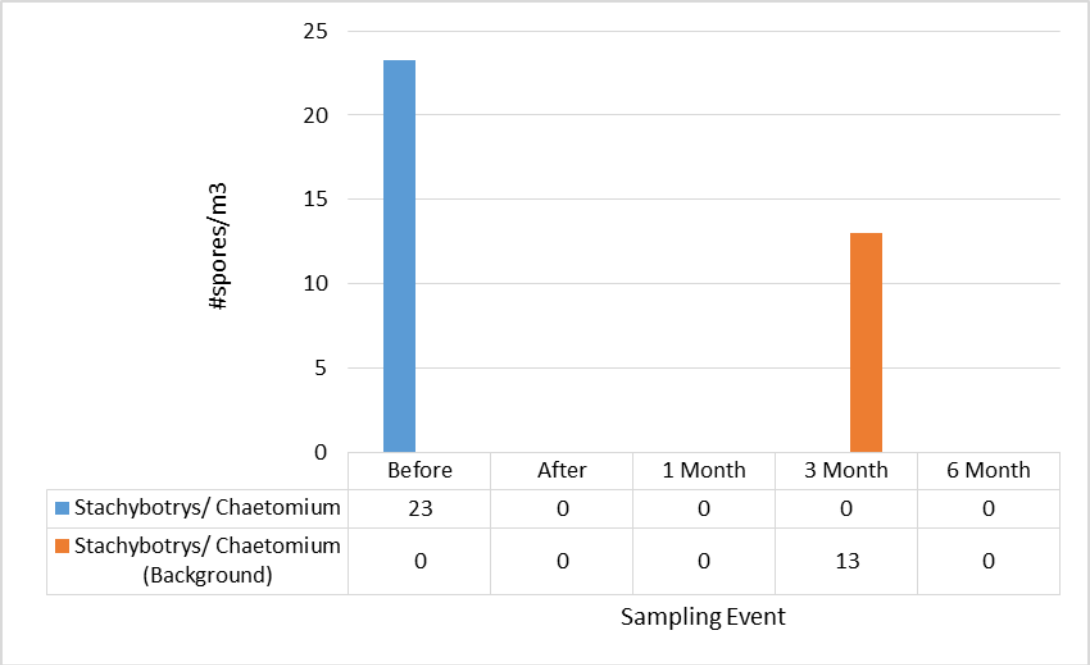

Figure 24. Bldg 6733 - Stachybotrys/Chaetomium vs Stachybotrys/Chaetomium (background)

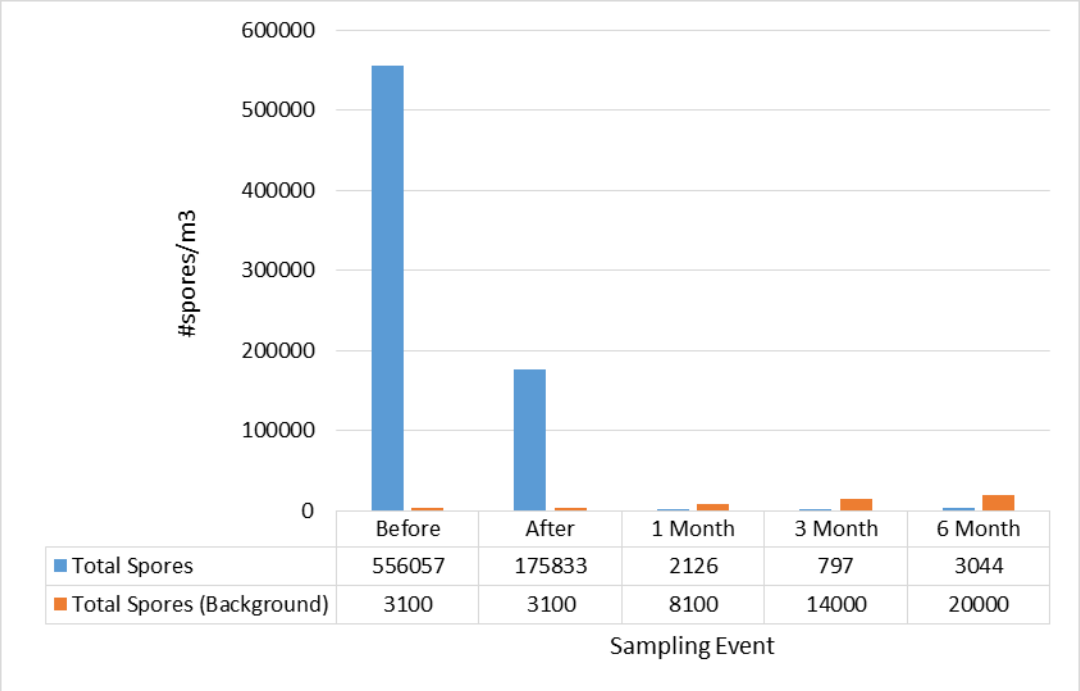

Figure 25. Bldg 6733 - Total Spores vs Total Spores (background)

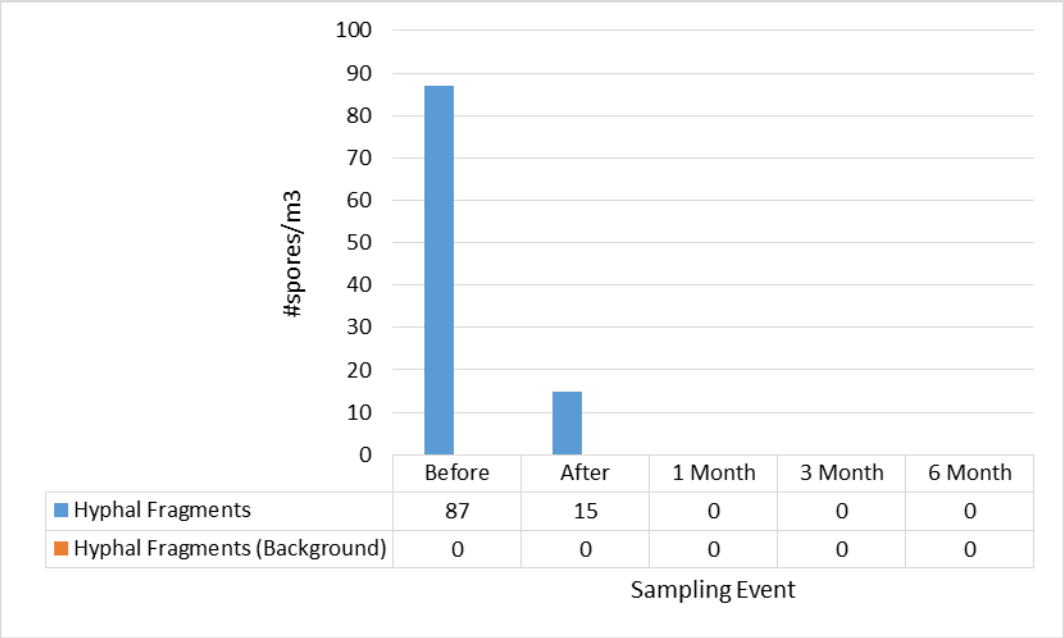

Figure 26. Bldg 6733 - Hyphal Fragments vs Hyphal Fragments (background)

Table 8. Surface sampling results in Building 6733

Fungal Type	Before	After	1 Month	3 Month	6 Month
Cladosporium	10+	<1+	0	0	0
Penicillium/Aspergillus	0	2+	0	0	0
Total	very few	very few	very few	0	very few

3.2 Dining Facility - Building 2261

3.2.1 Air Sampling

Results of the air sampling at Building 2261 are provided in Table 9 below. Each sampling location was allocated a representative number of square feet (ft^2) within the total square footage treated. A summation of the #spores/m^3 at each sampling location within the building, multiplied by the associated square feet for each sample, divided by the total number of square feet treated provides a weighted average of the sampling results. Thereby creating a single value for each fungal type for each building. The efficacy of the treatment is determined by comparing these values to the background levels at the time of each sampling. Values at or below background levels would indicate the treatment and/or removal was and continues to be effective.

Table 9. Air Sampling results fror Building 2261

ID	Associated Area (ft^2)	Fungal Type	Before	After	1 Month	3 Month	6 Month
#1	2268	Stachybotrys/ Chaetomium	0	0	0	0	0
		Total	19000	15000	1500	170	2800
		Hyphal Fragments	1300	430	0	0	0
#2	756	Stachybotrys/ Chaetomium	0	0	0	0	0
		Total	48000	12000	1400	480	4300
		Hyphal Fragments	2000	0	0	0	0
#3	486	Stachybotrys/ Chaetomium	0	0	0	0	0
		Total	110000	12000	2000	2800	2500
		Hyphal Fragments	2700	0	0	0	53
#4	198	Stachybotrys/ Chaetomium	520000	0	13	13	0
		Total	530000	11000	2000	2600	2800
		Hyphal Fragments	5800	0	0	0	53
#5	Outdoor/ Background	Stachybotrys/ Chaetomium	0	0	0	0	0
		Total	590	590	3400	9000	19000
		Hyphal Fragments	110	110	0	0	0

Samples #3 and #4 show an increase in hyphal fragments at the 6 month sampling event (highlighted in yellow). Even though the levels increased (from zero for the previous sampling events), they are still well below the levels prior to treatment. However, they are above the background level of zero. Ideally a future sampling round could potentially determine if this is an increasing trend, or an increase due to activity within the room where sample #4 was taken, and adjacent to the area represented by sample #3.

While performing the 3 month sampling event, team members encountered demolition activities in the room represented by sample #4. Figure 27 shows the debris and the meter reading showing one-hundred percent moisture content on the wall surface. The wall was damp to the touch and clearly saturated with water. The adjacent room, represented by sample #3 had recently began to leak from the ceiling, as shown encircled in Figure 28. These changes to the interior environmental/structural conditions are believed to have played a role in the increased total spore count. However, it should be noted that the background total spore count continued to increase beginning with the 1 month sampling event through the 6 month sampling event, where background was between four and seven times greater than the indoor sample results.

Figure 27. Wall surface moisture content of 100% near sample location #4.

Figure 28. Leakage from ceiling piping or roofing

3.2.2 Surface Sampling

Results of the surface sampling at Building 2261 are provided in Table 10 below. Initially all surfaces indicated the presence of mold. Immediately after treatment only a "very few" total spore count was present at sample locations #6 and #7. Sample location #8 showed ≤ 1+. No surface mold was detected at any surface sample location for the 3 month sampling event. Mold levels at all sample locations remained zero thru the 6 month sampling event.

Table 10. Surface sampling results for Building 2261

ID	Fungal Type	Before	After	1 Month	3 Month	6 Month
#6	Cladosporium	2+	0	0	0	0
	Penicillium/ Aspergillus	0	0	0	0	0
	Total	very few	very few	0	0	0
#7	Cladosporium	2+	0	0	0	0
	Penicillium/ Aspergillus	0	0	0	0	0
	Total	very few	very few	0	0	0
#8	Cladosporium	2+	<1+	0	0	0
	Penicillium/ Aspergillus	0	0	0	0	0
	Total	very few	very few	very few	0	0

3.3 Barracks - Building 6733

3.3.1 Air Sampling

Results of the air sampling at Building 6733 are provided in Table 11 below. Each sampling location was allocated a representative number of square feet (ft^2) within the total square footage treated. A summation of the #spores/m^3 at each sampling location within the building, multiplied by the associated square feet for each sample, divided by the total number of square feet treated provides a weighted average of the sampling results. Thereby creating a single value for each fungal type for each building. The efficacy of the treatment is determined by comparing these values to the background levels at the time of each sampling. Values at or below background levels would indicate the treatment and/or removal was and continues to be effective.

Table 11. Air sampling results for Building 6733

ID	Associated Area (ft^2)	Fungal Type	Before	After	1 Month	3 Month	6 Month
#10	1458	Stachybotrys/ Chaetomium	0	0	0	0	0
		Total	110000	210000	1200	430	93

		Hyphal Fragments	0	0	0	0	0
#11	768	Stachybotrys/ Chaetomium	0	0	0	0	0
		Total	1400000	100000	1100	480	210
		Hyphal Fragments	150	0	0	0	0
#12	648	Stachybotrys/ Chaetomium	80	0	0	0	0
		Total	3400	13000	3300	1200	10000
		Hyphal Fragments	110	53	0	0	0
#17	Outdoor/ Back-ground	Stachybotrys/ Chaetomium	0	0	0	0	0
		Total	3100	3100	8100	14000	20000
		Hyphal Fragments	0	0	0	0	0

It should be noted that between the 3 month and 6 month sampling events, the Fort Campbell personnel and/or contractor personnel began to renovate the building. Ingress and egress of these personnel surely had some effect on the existing conditions. However, no monitoring or oversight was in place to account for these differing site conditions. This may explain the drastic increase of total spores for the 6 month sampling event (1200 spores/m3 to 10,000 spores/m3) at location #12 (basement of the administrative area) in Building 6733. This represents a 733% increase while the background spore count only increased by 42.9%. Despite this drastic increase, indoor levels were only 50% of the background level suggesting continued treatment.

3.3.2 Surface Sampling

Results of the surface sampling at Building 6733 are provided in Table 12 below. Initially all surfaces indicated the presence of mold, specifically cladosporium. One month after treatment only a "very few" total spore count was present at sample locations #14 and #16. Three months following treatment, "very few" were reported for location #14 and no mold spores were present at locations #15 and #16. Levels appear to be rising between the 3 month and 6 month sampling events. During this time, the building's interior moved from an uninhabited space to a space undergoing renovation. This change in environment combined with added occupancy and ongoing renovation activities created varying conditions that could have triggered an increased total spore count.

Table 12. Surface sampling results for building 6733

ID	Fungal Type	Before	After	1 Month	3 Month	6 Month
#14	Cladosporium	2+	0	0	0	0
	Penicillium/ Aspergillus	0	0	0	0	0
	Total	very few	very few	very few	very few	very few
#15	Cladosporium	4+	0	0	0	0

	Penicillium/ Aspergillus	0	2+	0	0	0
	Total	0	very few	0	0	very few
#16	Cladosporium	4+	<1+	0	0	0
	Penicillium/ Aspergillus	0	0	0	0	0
	Total	0	very few	very few	0	few

Continued monitoring and sampling could have provided greater insight as to whether or not this trend would continue. Unfortunately continued monitoring and sampling was not possible under the funded scope of work due to an expiring period of performance.

4 Conclusions and Recommendations

Typically mold is removed and remediated due to its visual appearance (i.e. it looks bad). Unfortunately common practices for mold removal only address the visual presence of mold and is assumed removed or remediated when it is no longer visible. Air and surface sampling are required to ensure complete removal. Without indoor air quality regulations/limitations for mold spores, it is difficult to enforce and/or provide rationale to justify mold treatment based on indoor air quality.

Based on the sampling results from this demonstration, the dry-fog technology proved to be capable of rapidly annihilating the mold spores. The dry-fog technology's second step (EVERpure™) continued to reduce mold spore levels over time. While total spore counts outdoors increased throughout the demonstration, indoor levels continued to decrease, with minor exceptions. There is some question, given the increased values for hyphal fragments at locations #3 and #4 in Building 2261 during the 6 month sampling event, as to the technology's treatment effectiveness beyond 6 months.

However, the dry-fog technology provides rapid and quantifiable improvements to indoor air quality. It also drastically reduces exposure of Army building occupants and maintenance workers to harmful chemicals resulting from current mold remediation practices.

Current estimates for application of the dry-fog technology are approximately $1.00/ft^2$. Actual costs would deviate from this estimate dependent upon location and proximity to the vendor. Obtaining the capability of applying the treatment organically (i.e. in-house) would provide additional cost savings.

Implementing the dry-fog technology at Army installations would be relatively straight forward, i.e. the equipment could be purchased and training of its use would be conducted by the vendor owning the technology. Ongoing in-house training could be used to disseminate additional treatment systems across Army installations. Treatment systems could be purchased for use at each installation or regionally and then shared across installations having neighboring geographic locations.

It is recommended that additional demonstration(s) for 12 to 24 months be completed. Ideally the demonstration(s) would be in buildings where the indoor environment and building usage would remain constant throughout the demonstration period. It is also recommended that the dry-fog technology be demonstrated at new construction sites where it could potentially serve as a preventative measure.

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Appendix A

<<< All laboratory analytical reports will be included in this Appendix prior to final editing. The analytical reports are in .pdf format (as received from EMLab P&K) and will be included/attached when the FINAL version of the document is created in .pdf format. >>>

Appendix B

<<< Material Safety Data Sheets for INSTAPure and EVERPure are in .pdf format. The MSDS's will be provided via this Appendix. They will be included/attached when the FINAL version of the document is created in .pdf format, prior to final editing. >>>