



**Evaluation and Control of Airborne Fungal Populations for Worker Protection
during the Deactivation of an Abandoned Process Facility (U)**

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1.0 Description

The Site Deactivation and Decommissioning Department (SDD) completed the deactivation and demolition of the 120,000 square foot 247-F complex at the Savannah River Site in 2006. The facility remained in an unoccupied state with no heating, ventilation, or air conditioning system for several years prior to 2003 when the deactivation project was initiated. Roof leaks were observed resulting in rainwater intrusion and water pooling. Visual indications of fungal growth were observed throughout the building on gypsum wallboard, floor tiles, cellulose ceiling tiles, wallpaper, office furniture, painted metal surfaces, and ventilation components. Heavy, musty odors (volatile organic compounds) were observed throughout the facility indicating the presence of additional fungal contamination in non-visible wall and ventilation areas. These conditions can be common in abandoned buildings, especially those with water intrusion and lack of ventilation controls, and can present a challenge in establishing worker protection controls during various phases of the project. The 247-F project addressed these hazards by applying engineering and administrative controls, work practices, and personal protective equipment based on the exposure potential of various categories of activities. Biomonitoring was conducted to verify the effectiveness of control measures and assess possible personnel exposures to airborne fungal contamination.

2.0 Issues

The deactivation of the 247-F facility included a complex set of hazards that included radiological contaminants, hazardous chemical residues, and abundant fungal growth. While the obvious fungal growth and strong associated fungal odors throughout the building created concerns among the deactivation workforce, the fungal hazard was more difficult to quantify than the other existing hazards. A documented strategy for quantifying, sampling, and controlling the fungal contamination was needed to ensure the hazard was mitigated.

Fungal spores, fungal toxins, and other associated microbial products can produce health risks to personnel performing work activities in conditions where fungal growth is present. Immediate health affects can occur upon exposure to large amounts of fungal toxins or upon exposure to fungal spores in allergic individuals. Chronic exposure affects can occur in workers assigned to long term deactivation projects which continually expose workers to fungal materials. This exposure can result in hypersensitivity over time. Typically when assessing a hazard, a comparison of measured or anticipated exposure is made to an established permissible exposure limit. Controls are implemented as needed to ensure exposures are less than these limits. However, no numerical limits had been established for airborne fungi due to the lack of historical epidemiological data and to the large variability in the impacts upon human health symptoms resulting from biological sources. Several organizations have recommended indoor air quality concentrations or established guidance for determining whether or not remediation efforts and control measures are effective in bringing a building with fungal contamination back to a state of safe general human occupancy. However, guidance had not been established for worker exposures during remediation activities. The 247-F project established a goal to maintain airborne spore count concentration levels and species in indoor work areas to those similar to outdoor conditions. Control measures were established on a graded approach based on the degree of potential airborne spore counts at a specified work location or during a discrete remediation activity.

Disruption of surface fungal growth can greatly increase exposure hazards since physical disruption creates airborne fungal spores and hyphae. Airborne distribution of fungal material during material handling and removal was a concern, and an effective means to enumerate airborne fungi during various phases of deactivation were needed. Traditionally, airborne fungal sampling is performed by use of an air sampler which impacts air onto a media filled Petri plate or by the use of an airborne spore capture system which allows direct microscopic spore enumeration. Impacting spores onto fungal growth media has the primary disadvantage of long lag time between sampling and results since results are dependent upon fungal colony growth on the growth media. Spore capture coupled with microscopic enumeration of spores allows short lag times between sampling and results, but these sample protocols can be difficult if debris is present in the air. The debris that is captured along with fungal spores makes it difficult to microscopically enumerate the spores. Sampling and quantifying fungal spores during the deactivation of the 247-F complex required a sampling and analysis system that could enumerate spores in the presence of large amounts of building debris while providing very short lag times between sampling and results.

3.0 Measurements

Before deactivation activities began, surface samples were taken from building components to assess the fungal populations and the potential hazards that may be associated with those fungal populations. Microscopic examination of supply and return duct samples had evident fungal conidia, fruiting bodies, sporulating heads, mycelia, spores and hyphae. Some supply duct samples were predominately clumps of mycelial mats and/or clumps of spores, with numerous fungal reproductive structures. Microscopic evaluation of wall sticky tape samples indicated that the samples had predominantly *Stachybotrys chartarum* structures and spores with other fungal structures and spores present. Culturing of these surface samples on MEA (Malt Extract Agar) and CMA (Corn Meal Agar) showed the presence of *Stachybotrys chartarum*, *Aspergillus sydowii*, and *Aspergillus versicolor*, with a predominance of *Stachybotrys chartarum*

In the weeks before active deactivation activities began and during the early stages of this deactivation project, initial, background, outdoor, and active deactivation samples were taken with both Bi-Air cassettes at 1 l/min and 3.6 l/min and with Air-O-Cell cassettes at 15 l/min. Air-O-Cell utilizes an adhesive capture system which traps spores onto a clear slide which is then observed microscopically. Reliable reproducible spore counts could not be obtained with the Air-O-Cell cassettes while active work was being performed in the building. The high flow rate and the adhesive capture system resulted in excessive building debris on the cassette slide which interfered with identifying, observing, and counting fungal spores. Conversely, Bi-Air spore collection utilizes a filter cassette through which collected air is filtered so that spores are trapped in the filter media. The filter is then dissolved by acetone vaporization, and spores are enumerated and identified microscopically. In most cases, the low flow rates and the acetone vaporization process of the Bi-Air cassette system reduced the amount of building debris obscuring spores. Bi-Air samples were taken using both SKC Model 224-PCXR8 pumps (flow rate 1 l/min) and Gast Model 1531 pumps (flow rate 3.6 l/m). The 3.6 l/m flow rate was used in indoor areas only when there was little deactivation activity and low visible fungal growth. Fifteen, twenty, twenty five, thirty, fifty, or sixty minute duration samples were taken depending upon flow rate, sample location, and anticipated sample load due to work activities. The Bi-Air cassettes had the further advantage of the dual slit filter system which allowed the archiving of each sample so that

culturing of each air sample would be possible if needed. The Bi-Air sampling system was used for all subsequent air spore sampling.

Laboratory tests for sealant effectiveness indicated that Safe Encasement Systems Product SE-120 was effective in encapsulating fungal spores before deactivation work began. Before this encapsulating sealant was applied to work surfaces in the building, air spore samples were taken during episodes of active work (including removal of contaminated ceiling tiles and the tear down of fungal covered walls). Data from this work indicated that during active manual tear down activities, counts increased by an order of magnitude at the workers position and up to 20 ft from the workers position. Average airborne fungal counts in the building before active tear down activities were $1.3E+04$ spores/m³. Counts during and immediately after deactivation activities averaged $1.3E+05$ spores/m³. The high counts persisted in the area up to an hour after work ceased. After sealant application, airborne fungal spore counts during active work on fungal contaminated surfaces showed less than an order of magnitude increase over counts before the work activities began. These during and after work counts averaged $1.92 E+04$ spore/m³. This data indicated that encapsulating sealant application was an effective means to control spore release from disturbed building surfaces.

4.0 Benefits

The use of the Bi-Air sampling cassettes for air spore sampling was an effective way to obtain reliable spore count data in an air environment filled with building debris. Microscopic evaluation of the filter media allowed for rapid enumeration and as well as some speciation of fungal types based on spore morphology. The split sample cassette allowed for archiving of each air sample and for possible culture of the sample if required. The Bi-Air sampling process is simple, compact, portable, and cost effective. The use of the Bi-Air system for fungal sampling during deactivation ensured that rapid spore enumeration could be easily obtained with high air concentration of building debris and that culturable fungal samples would be available if required.

The application of the chosen sealant product prior to removal of building materials with fungal growth reduced the quantities of fungal particles released to the work environment during active work. The development and implementation of an aggressive strategy for mitigating airborne spore release during the 247-F project resulted in maintaining spore levels at manageable levels. The ten month air sampling plan validated the effectiveness of established control measures over a period of time. Data collected during discrete remediation activities was valuable in determining the extent and duration of spore dispersal during disturbance of significantly contaminated surfaces and was an important key in making respiratory protection decisions and establishment of control boundaries.

Due to the high visibility of fungal contamination in the facility and recent public media coverage of the subject, deactivation personnel were initially uneasy with the work environment. By informing employees of potential hazards, control measures, and the air monitoring program and data, employee understanding of potential fungal problems and appropriate control measures increased. To date, there have been no known comments from the workforce through supervisory or anonymous concerns programs. In addition, there are no known complaints of health consequences from the workforce that actively engaged in the deactivation and demolition of the facility.

5.0 Process Experience

The following includes a discussion of the various controls (engineering, work practices, personal protective clothing) used throughout the 247-F deactivation and demolition project to reduce personnel exposures and the spread of fungal contamination to other portions of the building. A summary of the sampling strategy implemented during these activities follows.

5.1 Engineering controls

- * Several immediate actions were taken when deactivation work began. Water intrusion was minimized by repairing the roof. Ceiling tiles and office furniture were removed using wet methods and promptly bagging and sealing waste prior to movement. Plastic sheeting was placed over wallboard surfaces where the integrity of the wall was compromised.
- * Areas with visible surface contamination were encapsulated with Safe Encasement Systems Product SE-120 using an airless paint sprayer. This product did not contain any hazardous ingredients or exhibit noticeable odors. There was minimal potential for the product to be reactive with the other chemical residues potentially present in the building or to be an irritant to personnel. This control measure was highly effective and was a rapid and straightforward technology requiring limited equipment and time. Prior to the selection of this product, commercial encapsulating sealants were tested on ceiling tiles for their ability to contain fungal growth on building materials and prevent release of spores during handling. After sealant treatment, the tiles were examined and scored for their effectiveness in controlling the release of airborne fungal material. Based on these tests, this product was selected.
- * An initial decision was made to not use disinfectants, sanitizers and biocides as a control measure due to their uncertain effectiveness and the chemical exposure hazards they may have introduced during their use. Spores may be released in greater quantities after an organism is killed or rendered inactive. Allergenicity and toxicity posed by bioagents are not eliminated when microorganisms are killed. Thus, fungal contamination must be removed or prevented from becoming airborne before allergic and toxic properties of the organisms are eliminated. Cleaning/sanitizing agents can also be irritants to workers and/or incompatible with other materials or chemicals they contact. Due to the effectiveness of the encapsulation methods, this decision was upheld throughout the project and no cleaning products were used with the exception of housekeeping in the change rooms and clean corridors.
- * Some exhaust was provided to the building by reversing the existing supply system. The existing exhaust duct exhibited evident levels of fungal contamination that would have been dispersed if air flow had been present. Cooled supplied air was also provided to work areas using portable systems. Small heating and cooling units were placed in the change rooms. Other forms of ventilation included local exhaust when disturbing surfaces with significant levels of visible contamination and leaving outside doors open to obtain natural ventilation as weather permitted.

- * In general, wallboard was not removed unless needed to deactivate process lines or to provide access for movement of large deactivated equipment. Portions of contaminated wallboard were removed using wet methods and plastic sheeting taped directly over the affected area to minimize spore dispersal. Tools were wiped down after use and floors that were not papered prior to work were mopped. Methods were similar to asbestos abatement without the use of double containment that would have been required for situations where the goal would have been to eliminate spore migration into completely uncontaminated areas.
- * During final demolition, heavy equipment was used to remove the debris and place into waste containers. Hydroseeders were used to spray water on portions of the building that were heavily contaminated with fungi.

5.2 Work practices/administrative controls

- * A facility entry briefing was required for workers and visitors and included the hazards and controls of the fungal contamination. The briefing, signed by employees, included a statement that immunocompromised workers should consult with medical prior to entry into the building.
- * Biohazard controls were included in all applicable work packages for the project.
- * Housekeeping and wet mopping was performed routinely in frequently accessed areas where protective clothing would not have been required. (e.g., change rooms, access corridors, storage areas, step off pads, personnel monitoring stations) To limit spore dispersal, neither dry sweeping nor blow-down cleaning methods were allowed in any portion of the facility.
- * One portion of the facility identified as an administrative wing was heavily contaminated with virtually every surface covered in a variety of fungal structures. Additional administrative controls were placed on entry and work in this location including additional work packages; access restricted by lock and key at all times, postings restricting entry, stay times limited to four hours.
- * Prior to any deactivation activities, a document was developed including the strategy for the management of molds. This document addressed the control measures and sampling strategy that would be in place throughout the duration of the project. The document was approved by the project industrial hygienist, industrial hygiene manager, the business unit safety and health manager, the biotechnology manager, the site medical director, and the 247-F project manager. This was a successful method for establishing and maintaining specific goals for controlling fungal hazards in lieu of a numerical regulatory permissible exposure limit.

5.3 Personal Protective Clothing

- * Respiratory protection was based on the activity performed, the amount of visible surface contamination present, and spore counts obtained during air monitoring.
- * Full face air purifying respirators with HEPA cartridges were required based on the size of the remediation area, the potential to generate dust, and the visible concentration of the fungi. This

included performing removal activities on surfaces with visible contamination in excess of 30 square feet. (e.g. wallboard or ceiling tile removal) This area was based on a "large isolated area" as specified in the remediation recommendations in the New York City Department of Health, "*Guidelines on Assessment and Remediation of Fungi in Indoor Environments..*" Full face respirators were also required when accessing exhaust ductwork that was heavily dust/spore laden and when emptying vacuum cleaners or replacing HEPA filters on local exhaust or ventilation systems. Based on air monitoring data performed for discreet activities, a period of 24 hours was required for an area to return to pre-work conditions after remediation had been completed. This data was also used to establish a twenty foot barricade around the work area during removal activities..

- * Full face air purifying respirators with HEPA/organic combination cartridges were used to enter the heavily contaminated administrative wing. Spores were dispersed while walking on carpeting and the offensive odor from the volatile organic compounds (VOCs) emitted from the mold was filtered with the organic cartridges.
- * Disposable coveralls with attached hood and booties and disposable gloves were required any time a full face respirator was required. Hard hats and non-slip shoe covers worn into heavily contaminated areas were not re-used outside the area with fungal growth.
- * Disposable N-95 filtering facepieces were prescribed in certain portions of the building based on spore counts obtained during air monitoring. The "dustmasks" filtered spores present in the affected areas and contained a charcoal layer to reduce the odor of emitted VOCs. Postings were present in the facility stating if a "dustmask" was required or not in designated areas. Visitors were issued the facepieces on a voluntary basis while individuals assigned to the facility were required to wear them due to their potential for chronic exposures. These individuals were required to comply with OSHA 29 CFR 1910.134 requirements for medical surveillance, training, and fit testing. Fit testing practices were difficult to implement and the facepieces were uncomfortable to many wearers. Facepieces were not generally re-used after an entry due to personal preference and comfort, thus becoming an expense in excess of that originally anticipated. It is recommended that the use of these facepieces be limited in use and minimize the areas where they are prescribed. With a lack of any airborne spore data at the onset of the project, this minimization of the use of this personal protective device was difficult.

5.4 Sampling

A sampling plan was developed to initially characterize the hazards in the facility, investigate the extent of dispersal during discrete remediation activities, to verify respiratory protection decisions, and routinely verify the effectiveness of controls.

- * Speciation performed initially on visible amplification. This information was maintained on file for any future potential medical investigations.
- * Surface samples were obtained to distinguish between fungal contamination and other surface contamination such as dust or lint. These samples were not speciated. Sampling methods were such that field industrial hygiene could obtain the samples for analysis by

biotechnology personnel. This was often a time critical investigation required for establishing immediate work controls.

- * Air sampling was performed during several discrete activities involving the removal of contaminated ceiling tiles or wallboard >30 ft². This data was used to establish respiratory protection decisions and to determine the extent of spore dispersal in area and magnitude.

- * Routine sampling was performed approximately every week for 10 months. Routine locations were established in non-active work areas such as change rooms, step off pads, and access corridors. Other sampling locations were determined based on active work areas. An outdoor sample was taken on each day of routine sampling as a comparison. Housekeeping efforts and work controls were increased if samples in non-active work areas exceeded an order of magnitude over the outdoor samples or if spores in the samples were physically different from the outdoor spore samples. Engineering controls were re-evaluated for active work areas where samples were an order of magnitude over outdoor spore samples. Routine samples were also used to establish posted areas for filtering facepiece respirators.

5.5 Additional Recommendations

The shut down of HVAC systems during preliminary deactivation of a building should be reconsidered if at all possible in order to prevent similar undesirable building conditions from occurring. Initial cost savings may be exceeded in the long run due to additional controls needed to address hazards from fungal growth to deactivation personnel. If the HVAC system must be shut down, all measures should be taken to prevent water intrusion from occurring. Also, as many nutrient providing substrates as possible should be removed from deactivated buildings before a lack of moisture control supports amplification. (i.e., ceiling tiles, carpeting, office furniture, wallboard)