CHAPTER 4

Project Designs for the Abatement of Microbial Contamination

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INTRODUCTION

The significance of fungi and bacteria as indoor air quality (IAQ) parameters and their contribution to building-related illness is being increasingly recognized. However, a review of the existing literature indicates that there is little information and even less guidance available regarding decontamination of so-called "moldy" buildings. This chapter briefly reviews some current procedures for managing microbial contamination problems and then focuses on a case study involving assessment and elimination of mold growth in the wall cavities of a school. This is followed by results of monitoring conducted during and after remediation. Discussion includes general principles that may be applicable to the resolution of other IAQ problems caused by excess moisture in buildings.

Contaminated building surfaces present a source of IAQ problems that may be difficult to locate and even more difficult to resolve. Such contamination may be either chemical (e.g., pesticide misuse) or biological (e.g., excess mold growth). This chapter focuses on the latter.

When a building contamination problem is recognized, a complex assessment process may be necessary to map out affected areas along with primary and secondary sources. Objective identification of sources and exposure pathways is necessary for effective decontamination. Poorly planned abatement efforts may be ineffective, at best, or actually serve to increase occupant exposure.[1] Where

*Note: Work completed while primary authors were with Biospherics, Inc., Beltsville, Maryland.

Table 1. Simplified Microbial Assessment

Air Sampling Results	Visual or Historical Indicators of Sanitation Problems	Action?
Normal organisms background counts	No sanitation problems	No
Normal organisms background counts	Sanitation problems present	Yes
Opportunistic pathogens and/or elevated counts	Indicators of sanitation problems generally present	Yes

microbial contamination is an issue, an understanding of the factors that promote and prohibit growth is essential to remediation.

Excessive mold and/or bacterial concentrations in indoor air primarily impact the health of allergy-prone (atopic) individuals. Such persons may experience the relatively common symptoms of allergic rhinitis or asthma shortly after initial exposure.[2] Much less frequently, airborne microorganisms cause susceptible individuals to develop severe hypersensitivity illness or opportunistic infections.[1,3]

Microbial contamination in buildings can usually be traced back to either unsanitary mechanical equipment (e.g., growth in condensate pans) or excess moisture (e.g., flooding, leaks, condensation, and elevated humidity).[1,4] The extent of microbial growth depends on the type and amount of wet materials, duration of the moisture source, building ventilation, and the timing and type of cleanup. Where major building areas retain excess moisture for extended periods of time without proper disinfection, high hold and/or bacterial concentrations may be expected.

Initial assessment procedures for microbial contamination generally include inspection of the facility, interviews with occupants and maintenance personnel, and, if warranted, air sampling.[5] Air sample results are generally reported in terms of numbers and type of viable organisms. There is no concensus approach to the interpretation of airborne microbial samples. Various assessment schemes have been suggested including specific action levels[3] and consideration of indoor/outdoor relationships.[6] The authors assign microbial assessment results to one of three categories for the purpose of determining whether a microbial problem exists (see Table 1).

In the first category, only common, nonpathogenic organisms are present and their numbers are within the background range. In well maintained buildings, this is generally under 500 CFU/m³ (total fungi or total bacteria). In this case, there is no history of unresolved sanitation problems and a visual/odor inspection does not reveal significant indications of unsanitary conditions. No action is recommended.

In the second category, air sample results are also low and unremarkable, appearing to be negative. However, the building history or inspection indicates the potential for significant sanitation problems. Remedial measures are recommended here as a precaution. It is likely in such buildings that higher bioaerosol concentrations will occur at some point in the future if sanitation problems are not addressed.

The third category is where air sampling reveals counts above 500 CFU/m³ or the presence of opportunistic pathogens. Opportunistic pathogens (e.g., *Aspergillus niger*) can cause infection in persons with weakened immune systems.[7] Visual or historical indicators of sanitation problems are generally also present, but may not always be obvious. Some type of action, ranging from major abatement to further study, is recommended in such cases. The specific response selected is generally based on answers to the following questions:

- How high are microbial counts relative to normal background?
- How dominant are any opportunistic pathogens which are present?
- Are air sampling results consistent?
- What is the likelihood that elevated readings are due to an ongoing sanitation problem?
- Are building-related allergies actually being reported?
- Are immuno-compromised individuals likely to be present (e.g., patients with AIDS or undergoing cancer therapy)?

More detailed characterization of airborne microorganisms may also play an important role in developing abatement strategy. For example, the presence of some microorganisms may serve as environmental source indicators (e.g., high concentrations of *Sporobolomyces* sp. suggest excess moisture). Other fungi present in high levels might indicate possible decay in wood structures.

Consideration of microbial abatement in the general literature focuses on replacement of contaminated porous materials and cleaning/disinfection of hard surfaces.[1,4] In proposed IAQ regulations governing state facilities in New Jersey, the following nonbinding recommendations are offered for microbial decontamination: workers wear respirators; materials removed carefully to minimize aerosolization; surfaces cleaned with HEPA vacuum (high efficiency removal of small particles such as spores) followed by dilute bleach or other biocide.[8] Beyond these basic corrective measures, there is little specific guidance on strategies for conducting major remediation projects. Success of such projects should be dependent on the following factors: (1) controlling occupant exposure during remedial work; (2) systematically sanitizing and protecting surfaces; and (3) demonstrating that microbial air quality has stabilized in the background range.

The following case study involves a school where moisture problems (leaks and condensation) developed in a four room modular addition. Wall and ceiling leaks were noted in conjunction with heavy rains. After several months, stained ceiling tiles were changed and outside walls were waterproofed. Each room (A, B, C, and D) was virtually identical and ventilated by a window fan-coil unit (no central HVAC). The authors were retained as air quality consultants after building-related illnesses were suspected. Data included in this paper was obtained over a 4-month period covering these events:

- Initial assessment (following corrective measures noted above)
- Second assessment (following disinfection of exposed surfaces)
- Preparation of abatement specifications
- Abatement monitoring (demolition of contaminated wall cavities)
- Clearance monitoring

METHODOLOGY

Air sampling was conducted following the general guidelines of the American Conference of Governmental Industrial Hygienists.[5] An N-6 stage Anderson impactor was used to collect 60-s air samples. Standard Methods Agar was used to culture bacteria while Sabouraud Dextrose Agar was used for fungi. Plates were incubated 3 to 5 d (25°C fungi; 35°C bacteria), followed by colony counts. When requested, organism types were also identified.

During abatement, containment pressurization was observed qualitatively with smoke tubes. Leakage of demolition dust from the containment was estimated with the use of a light scattering respirable dust monitor (ppm, inc.).

RESULTS

Assessment

The authors' initial assessment of the complaint area consisted of an inspection, interviews with school personnel, and limited air sampling.

For the 4 months preceding the original on-site study, there had been complaints of musty odor and aggravation of preexisting allergies. Airborne microbial levels were sampled in all four rooms. Fungal concentrations were consistently elevated (up to 1800 CFU/m^3), while airborne bacteria remained in the background range. All fungal samples were dominated by the mold *Cladosporium* sp., a common allergen not of major concern in regard to infections. The observed mold concentrations could be responsible for ongoing allergy complaints expressed by certain teachers in this one section of the school. Visual inspection was inconclusive, with obvious water leaks having been eliminated and no growth or stains observed on exposed surfaces. At this point, school personnel HEPA vacuumed and disinfected exposed surfaces as a preliminary measure while a more detailed response was under consideration.

The rooms were retested 4 d after cleaning. Airborne fungal levels were substantially reduced (maximum 600 CFU/m^3) and bacteria remained in the background range. A few days later, however, musty odors and allergy complaints reappeared, suggesting that the primary source had not been addressed. At this time, slight blistering of the walls was noted in a few locations and it was hypothesized that moisture inside the wall cavities was the primary source of microbial contamination. This was confirmed when a small hole was opened to the wall cavity. Visible growth and strong musty odors were readily apparent. Bulk samples of insulation and wallboard confirmed this to be a significant source with

bacterial levels in the 10^5 CFU/gm range (fungal readings were generally low). Further investigation revealed that an improperly installed ceiling vapor barrier had been allowing moisture to condense and drain into the wall cavities. The ongoing nature of the problem was confirmed 1 month later when the rooms were resampled and the peak airborne fungal count had risen about 50% to 950 CFU/m^3.

Abatement Specifications

The facility owner's representatives decided at this time to conduct a detailed abatement project with most of the school to remain occupied during the work. Specific goals were to be as follows:

1. Decontaminate wall cavities
2. Contain emissions during demolition
3. Protect cleaned areas from recontamination
4. Demonstrate that project air quality criteria have been met

With slight variations, precautions commonly used for asbestos removal provided a model for the project.[9] Basic demolition consisted of removing porous, contaminated material from the wall cavities including all gypsum board and insulation. Work areas were cleaned with a HEPA vacuum cleaner followed by disinfection. All work was to be conducted inside a plastic containment under negative pressure. Negative pressurization was achieved with an exhaust fan mounted in an exterior window. Unlike its asbestos counterpart, this exhaust was not filtered. Nonpathogenic spores discharged into outdoor environment were not considered to represent a health hazard.

Although there are several categories of chemicals that can be used as disinfectants.[10,11] Bleach was selected because it was effective against the target organisms, relatively nontoxic, and readily available. Dilutions of 1:5 or 1:10 bleach are commonly used in hospitals, laboratories, etc., for disinfection. Although bleach may be irritating if improperly used, other disinfectants may have more serious side effects (e.g., formaldehyde) or less effective (ammonium-containing disinfectants may actually encourage future microbial growth by leaving residual ammonium as a nutrient source).

Although school was in session during the project, all demolition work was conducted after business hours and buffer zones were designated around active work areas. Work progressed one classroom at a time, with a double layer of heavy plastic sheeting enclosing the demolition area (rear third of each room). Adjacent rooms were kept vacant.

There are no worker protection standards for exposure to nonpathogenic molds and bacteria. The contractor was encouraged to screen out workers with a history of allergies and to promote the use of air purifying respirators with HEPA filters. Disposable coveralls were also optional. Access and egress were through the outside window, making workers' clothing an unlikely route of contamination to unprotected portions of the school.

Following removal of all gypsum board and insulation from the rear wall, the following sequence was followed:

1. Bag gross debris
2. HEPA vacuum surfaces
3. Wipe down surfaces (after at least 1 h settling time) with 10% bleach solution, allowing 20 min contact time
4. Spray cracks and crevices with bleach solution
5. Encapsulate wall cavity (after bleach has dried) with a sealant containing an antimildew agent

These steps were intended to remove materials with excess microbial growth from the wall cavities, effectively kill any remaining organisms, and leave a residual biocide to maintain sanitary conditions. Meanwhile, the exhaust fan would be flushing airborne organisms from the containment. The authors suggested at least 24 h of flushing before clearance air testing in order to provide for a sufficient exchange of air following peak concentrations generated by demolition.

All major work activities were monitored by an on-site industrial hygienist. The containment was inspected regularly, with work to be stopped if barriers were breached or musty odor, haze, or excessive dust appeared on the outside. Microbial air sampling was conducted daily when work was ongoing. A respirable particulate monitor was used on some occasions to evaluate the effectiveness of the containment as a dust barrier. Any elevated readings outside the containment were to result in more stringent precautions and disinfection of affected areas.

A formal clearance procedure was established to be repeated in each classroom. First, cleanup had to be completed to the visual satisfaction of the industrial hygienist. Second, air samples for bacteria and fungi collected in the containment had to be either less than 500 CFU/m³ or lower than outside air concentrations (whichever standard is greater). Third, the entire classroom must pass a similar clearance test after the containment is removed and surrounding area cleaned. Detailed specifications for abatement can be found in Appendix A.

The building owner selected a general construction contractor to implement these specifications. Although a contractor more experienced in the handling of hazardous materials and disinfection would have been better suited to the task, the contractor selected had built the original structure which was still under warranty. The project consisted of four separate containments (classrooms A, B, C, and D). Although not intentionally a controlled experiment, conditions differed to some extent between the containments.

First Phase

The initial abatement period lasted 1 week, during which rooms A and B were contained, ceiling vapor barriers in rooms A and B were removed, two containments constructed, interior wall cavities accessed, cleaning and disinfection completed, and walls reconstructed. Major specification enforcement problems occurred due to failure to maintain negative pressure in the containments (improper ventilation) and the reconstruction of room B before it passed a clearance test.

During demolition in room A, fungal levels inside the containment rose to over 10,000 CFU/m³ while bacterial levels were also elevated. Substantial leakage occurred to buffer zones which had counts similar to the containment. The adjacent corridor remained at background levels.

The first containment passed the clearance test (containment level less than outside air) 2 d after it was disinfected. Simultaneous sampling in the room A buffer zone still showed marginal contamination.

Testing during demolition in room B showed leakage into the outer room area was substantial. Particulate measurements in the outer room were also relatively high. Room B failed clearance 2 d later with fungal counts being higher than outside air. Also, the room B buffer zone remained contaminated. In violation of the specification, the contractor reconstructed the wall in room B while these laboratory results were pending. During the preceding work, the plastic barrier remained in place while all demolition and disinfection tasks were completed. Negative pressure was not maintained because of several deficiencies. These included the exhaust fan being two small and leaking around the edges (short circuiting), makeup air not being drawn through much of the containment, and the fan not running continuously (it was shut down following each work shift). These factors may have all contributed to the leakage noted. Failure to pass the initial clearance test in room B may have been due to an insufficient time between last disturbance and sampling (less than 24 h for air flushing). Incomplete disinfection may have also contributed.

Second Phase

Due to the technical and enforcement problems cited above, abatement activity stopped for 3 weeks. It was determined that the wall in room B would have to be reopened and disinfected a second time. Abatement would then proceed to rooms C and D under continuous negative pressure. A larger fan was to be installed in each containment, sealed into the window frame and operated around the clock from start of demolition to clearance. Demolition was to be permitted only when there was a negative pressure as indicated by the plastic barriers being drawn into the work area. Detailed smoke tube testing was also conducted to verify air movement through the containment.

With heating units off and the onset of winter weather, condensation began to form on surfaces in the work rooms. Space heaters were added to control this new moisture source. Beams that had become wet were disinfected as a precaution.

During the second demolition of the room B wall, containment levels again became elevated. Buffer zone concentrations were somewhat lower than they had been before for fungi but higher for bacteria indicating that some leakage was still taking place. Adjacent corridor readings were low.

Room B passed the clearance test 24 h later, and the buffer zone returned to background levels. However, readings in the outside corridor were now higher.

Custodial sweeping had occurred a few minutes before the air test and may have been the source of this elevated sample.

Abatement of room C proceeded without incident. Inside levels were high during demolition with some leakage to the buffer zone indicated. Corridor levels were also elevated, although this may have again coincided with elevated dust from recent sweeping. The following day, levels returned to background and the containment cleared.

Rooms C and D cleared 1 d after demolition, with the buffer zone and corridor returning to background levels. All four classrooms were retested for final clearance after reconstruction, removal of the containment, and final cleaning. All areas, including the corridor, showed background levels of fungi and bacteria in the final samples.

One possible cause of leakage during the second round of demolition was worker access to the containment. Workers entered through an outside window, which was observed to short-circuit the fan and eliminate the negative pressure. When the access window was opened, significant containment leakage may have occurred into the classroom.

Data Summary

The progression of airborne fungal and bacterial concentrations as they occurred in each classroom over the course of this project is presented in Figures 1 to 4. Fungi levels consistently remained higher than bacteria. Classroom A provides an example of how airborne fungi changed over time. The original assessment (samples during allergy complaints) recorded a level of 1800 CFU/m³. This temporarily dropped to 250 CFU/m³ following initial (superficial) cleaning, then rose back to 880 CFU/m³ a few weeks later. At the height of demolition, the containment exceeded 10,000 CFU/m³ (maximum limit of detection). The initial clearance level inside the containment following disinfection dropped to 670 CFU/m³. Final clearance of the room after cleanup was 35 CFU/m³ (see Figure 1).

Containment leakage occurring during the project is illustrated in Figures 5 through 7. As mentioned previously, background counts under sanitary building conditions can generally be expected to remain in the background range (below 500 CFU/m³). During demolition in containment B, fungal counts were very high, exceeding 10,600 CFU/m³. At the same time, sampling in the buffer zone (unprotected outer portion of classroom C) reached 5300 CFU/m³. This is elevated for an interior environment with the only apparent source being containment leakage. After 1 to 2 d, all buffer zones where such contamination was documented had returned to the background range (350 CFU/m³). Sampling results from the corridor (adjacent to the upper zones) are summarized in Table 2. Readings generally remained low. Elevated concentrations appeared to be related to local custodial activity rather than the abatement.

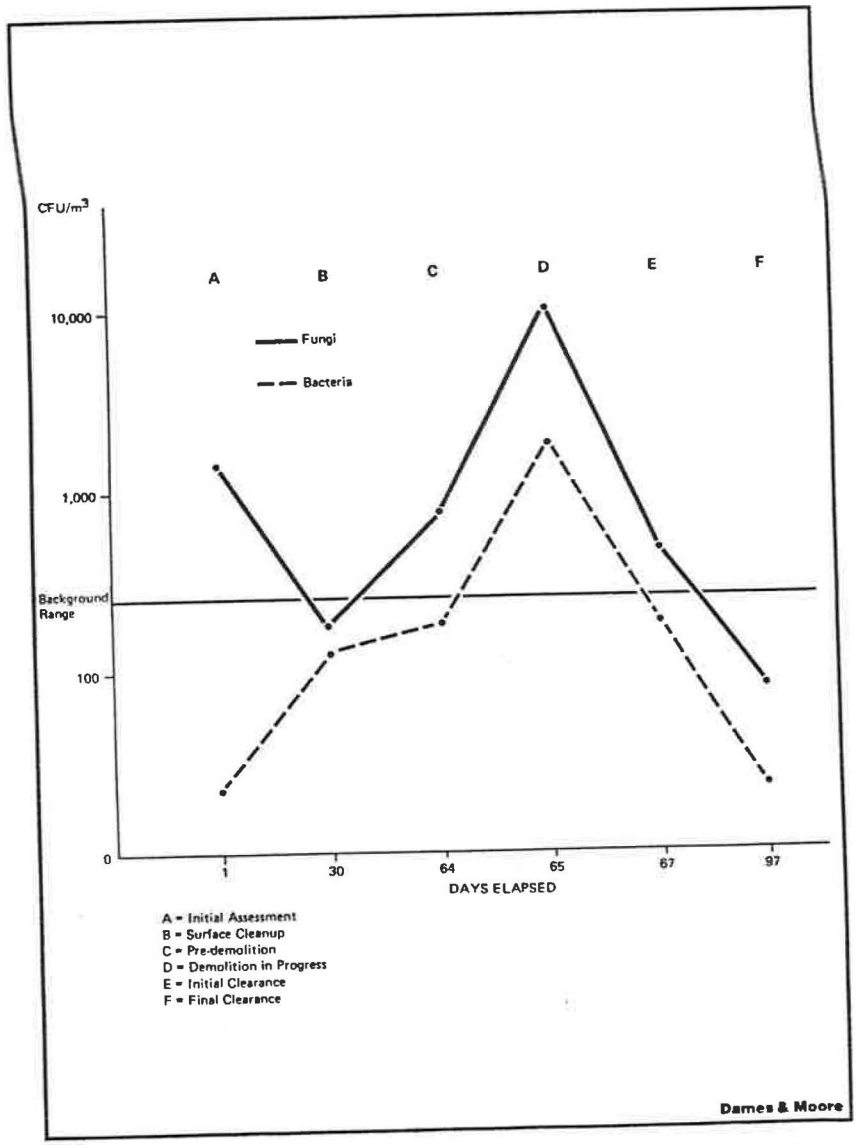

Figure 1. Bioaerosol concentrations in room A.

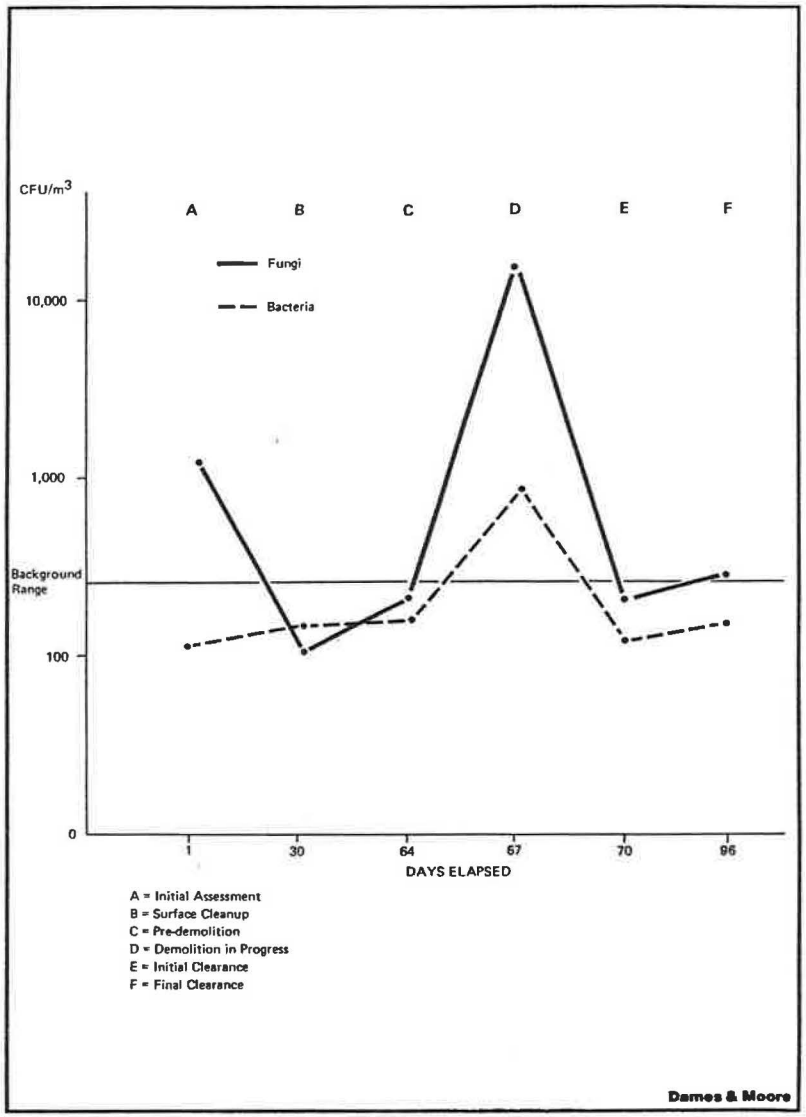

Figure 2. Bioaerosol concentrations in room B.

DISCUSSION

Air monitoring was utilized during the abatement process to provide general documentation of project conditions, identify leakage from the containment, and

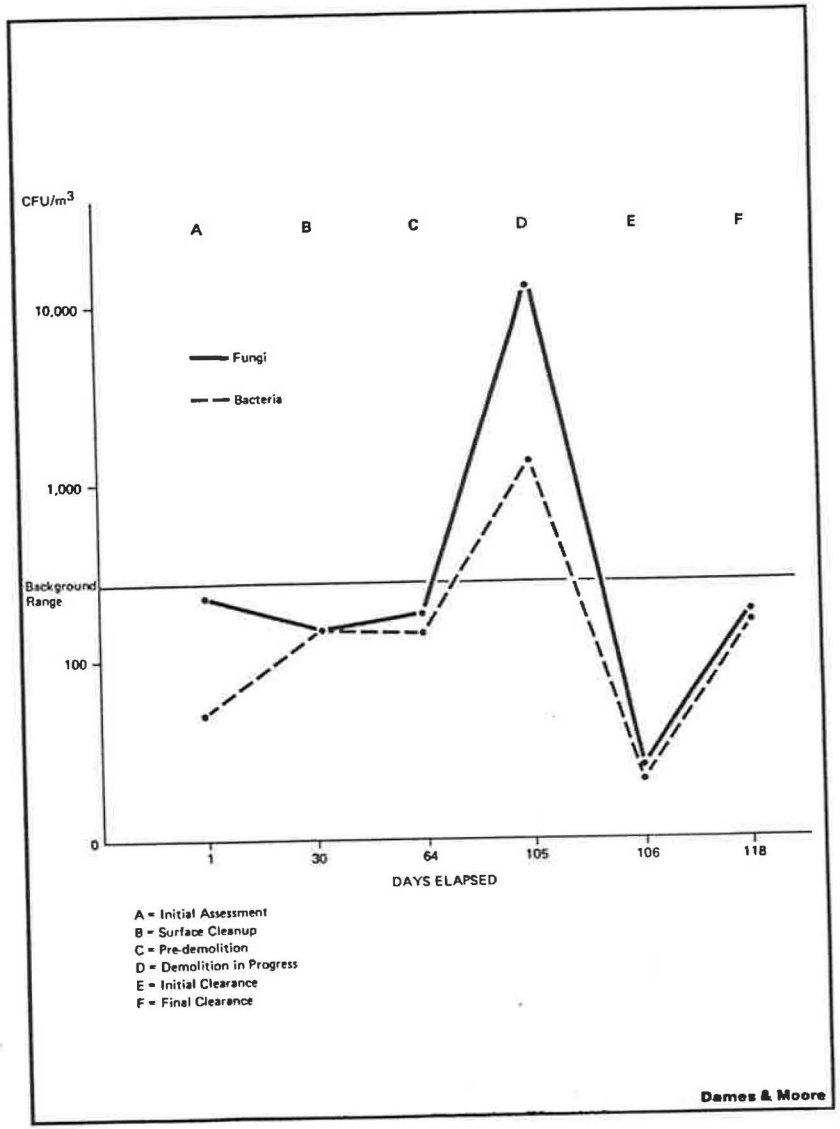

Figure 3. Bioaerosol concentrations in room C.

determine when clearance goals had been achieved. Microbial air sampling required a minimum of 3 d incubation time in order to make a preliminary count of viable organisms. This delay detracted from its utility in terms of timely correction of containment leaks on a timely basis and proved to be disruptive to project scheduling.

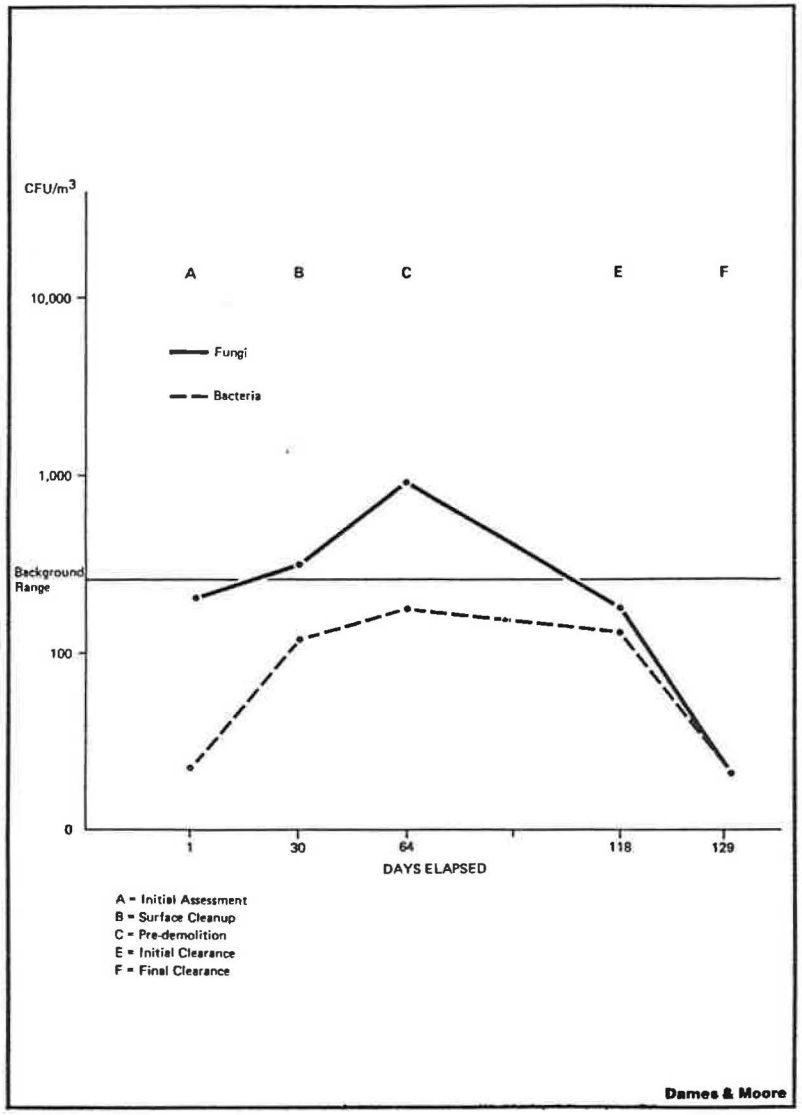

Figure 4. Bioaerosol concentrations in room D.

On-site inspector observations did provide some helpful, real-time feedback in regard to containment integrity. On one demolition day, a direct reading aerosol monitor was used to monitor the containment. Although only limited data was obtained, readings were elevated where high microbial counts were later obtained. This instrument indicates a background range for respirable dust in most buildings

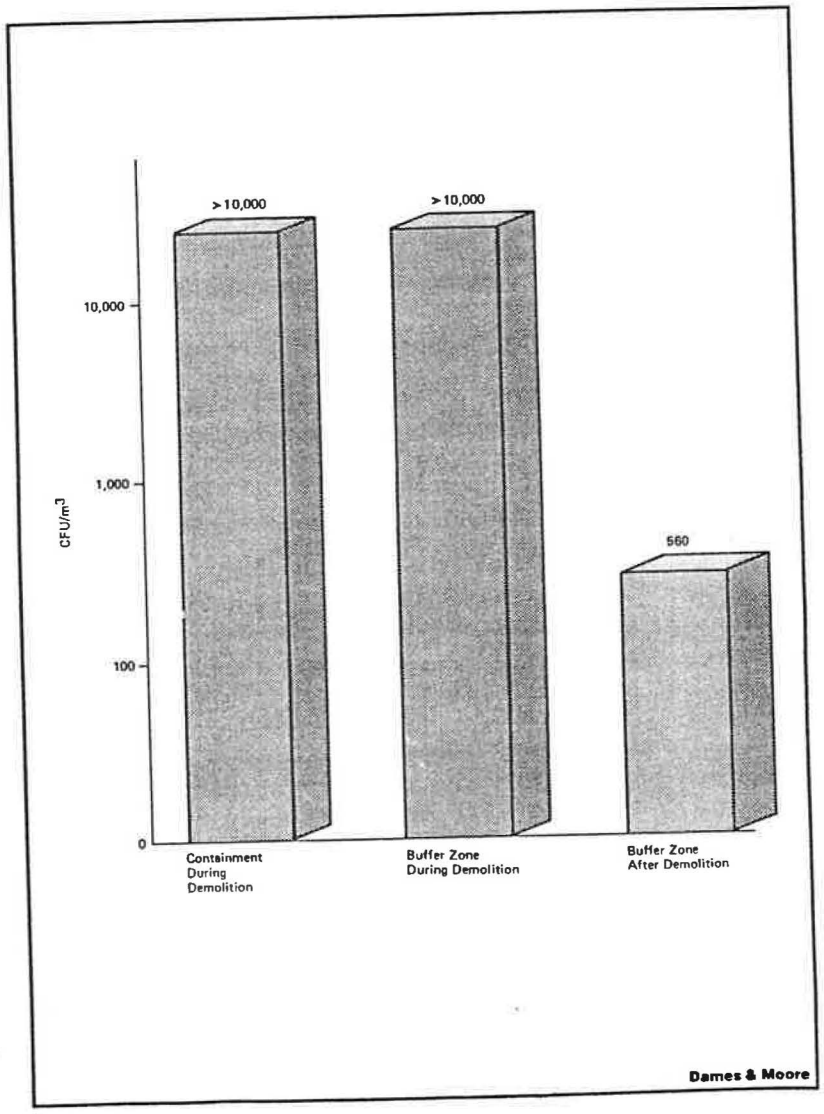

Figure 5. Leakage of airborne fungi from room A.

without significant particulate sources of 5 to 50 $\mu g/m^3$. On the day of demolition in room B, while background levels of respirable suspended particulates (RSP) in the school were around 10 $\mu g/m^3$, levels outside the containment in the room B buffer zone had risen to 300 $\mu g/m^3$. Airborne microbial data collected from the same location had a fungal count exceeding 10,000 CFU/m^3.

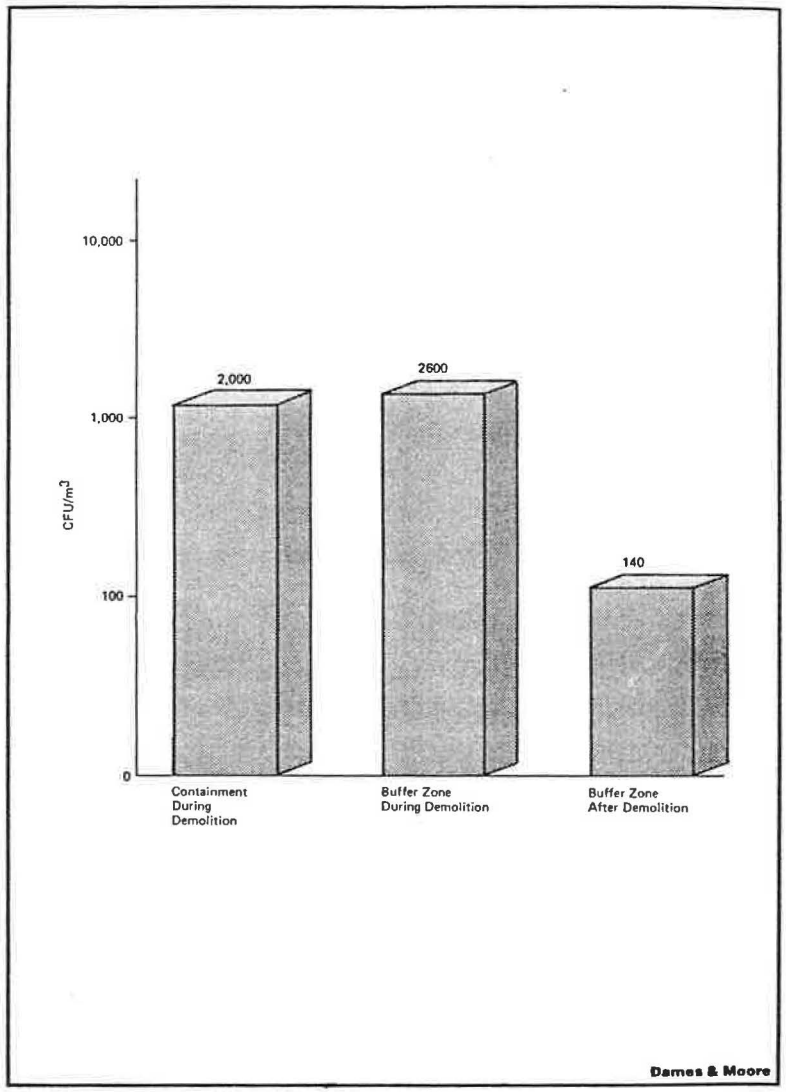

Figure 6. Leakage of airborne fungi from room B.

Further work may show the aerosol monitor based on light scattering to be a useful tool where microbial abatement involves the generation of dust (such as during demolition). Although individual bacteria and mold spores are often too small to be recorded effectively by such instrumentation, bioaerosols correlate under some conditions with general dust levels, especially when substantial dis-

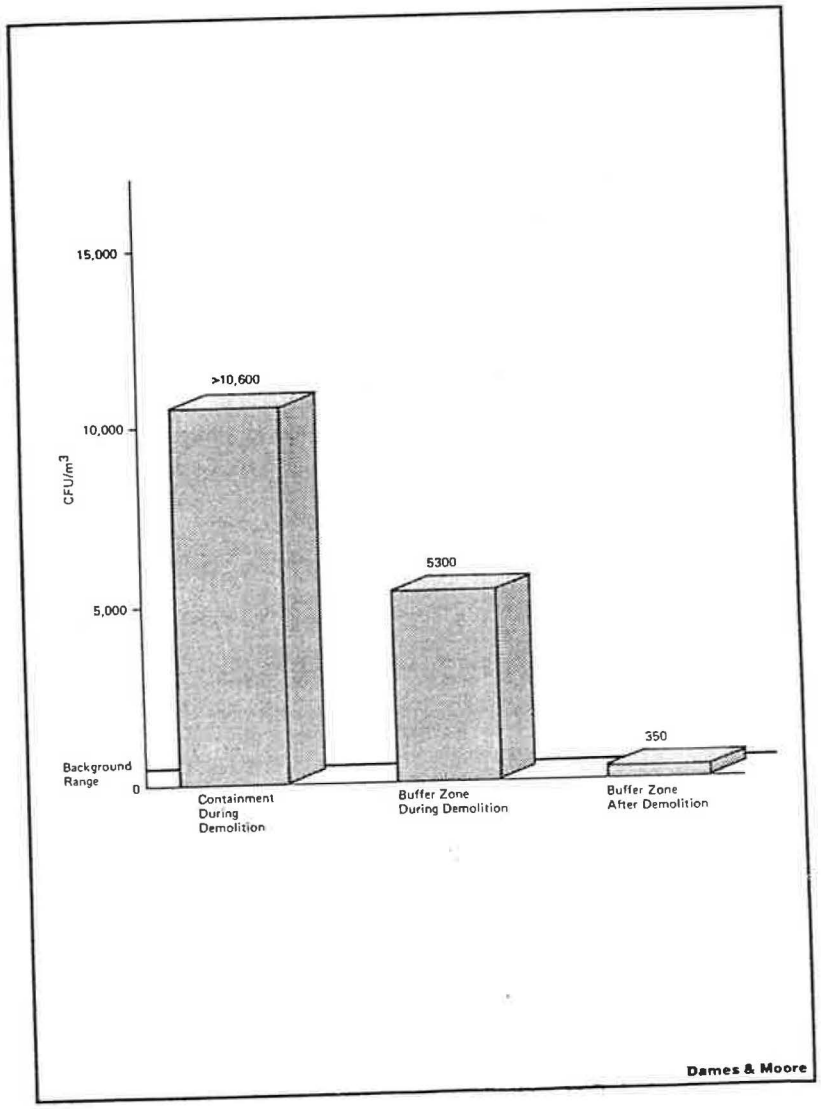

Figure 7. Leakage of airborne fungi from room C.

turbance of contaminated materials is ongoing. This general indicator can be available immediately to those regulating the abatement process while more specific microbial sampling results are being developed.

Another possible approach to the problem of sample turnaround time during microbial abatement involves spore trapping. One method being investigated by

Table 2. Bioaerosol Concentrations in Adjacent Corridor

Project Day	Bacteria CFU/m³	Fungi CFU/m³	Project Status	Other Activity
37	110	<35	Day after demolition	—
94	280	<35	During demolition	—
95	1500	780	Day after demolition	Sweeping
104	71	3600	During demolition	Sweeping
117	460	490	Day after demolition	—
129	250	<35	All work completed	—

the authors involves passing a known volume of air through a cellulose ester filter, which is then cleared and mounted for examination under a phase contrast microscope (similar to procedures for sampling fibers-in-air). Although bacteria are too small for analysis by this technique, fungal spores can be distinguished and counted under the supervision of the mycologist. This may allow a quantitative estimate of total (viable and nonviable) spores within a few hours, bypassing the incubation step. With further development and validation, such a procedure could expedite decision making at microbial abatement projects where airborne fungi are the most critical measurement.

One final issue highlighted by this project verified was importance of tracking outdoor microbial levels. On some days, outdoor fungal counts were very high (e.g., 10,000 CFU/m³) while on other days they were very low. Unfiltered outside air was drawn into containments at various times with an obvious potential to influence both demolition monitoring and clearance results. Under the procedure adopted, when outdoor counts were elevated, containment levels simply had to be lower than outside to achieve clearance. However, on days when outside counts were very low, readings up to 500 CFU/m³ would still be allowed inside in order to be consistent with the "normal" background range. Follow-up testing of each room after the containment passed initial clearance testing indicates that airborne microbial concentrations remained in the background range (see Figures 1 through 4). Monitoring of future microbial abatement projects might be facilitated by locating access points that prevent unfiltered outside makeup air from being drawn into the containment.

CONCLUSIONS

1. Moisture accumulation in wall cavities was the primary source of microbial contamination and IAQ complaints at the school investigated.
2. Stringent control over the microbial abatement process was justified by the sensitivity of the building population (school children and atopic faculty members) and potential spore release during wall demolition. As a result, work was conducted after hours, inside a containment surrounded by unoccupied buffer zones.

3. Levels of airborne fungi and bacteria increased inside the containments during demolition. Leakage into adjacent buffer zones during demolition was apparently caused by loss of negative pressurization within the containment. Contamination of the buffer zone was short-term and was readily eliminated by standard disinfection techniques.
4. Use of a general contractor with no experience in disinfection or the handling of hazardous materials led to enforcement problems resulting in technical errors and major project delays.
5. Air monitoring based on counts of viable organisms resulted in 3- to 5-d delays in the identification of containment leaks and determination of area clearance. Use of a direct-reading aerosol monitor might provide an effective monitoring supplement when remediation generates dust (e.g., demolition). Direct counting of spores collected on cellulose ester membrane filters may also prove to be a useful sampling tool during microbial abatement.
6. A formal clearance procedure was followed to determine when each work area was safe for reoccupancy. This included visual confirmation by an industrial hygienist that the work specifications had been followed. Clearance sampling results in terms of fungal and bacterial counts had to be below 500 CFU/m³ or, where outdoor counts were higher, less than outside concentrations measured at the same time. This criteria appeared to provide a reasonable basis for concluding that the work area had returned to a stable, background level.
7. Despite several problems encountered, the remedial measures employed in this case study successfully eliminated microbial contamination. These included replacement of gypsum board and insulation in wall cavities, HEPA vacuuming, application of bleach solution, and treatment with a sealant containing an antimildew agent.

RECOMMENDATIONS

1. The extent to which special precautions are needed during the remediation of microbial air quality problems should be based on the degree that contaminated materials must be disturbed and the potential health risk to exposed individuals.
2. Microbial abatement projects perceived as presenting major risks to occupants should be conducted inside contained work areas. Abatement workers should ideally be experienced in both the handling of hazardous materials and disinfection techniques. Such projects should be supervised by an industrial hygienist.
3. Clearance of microbial abatement areas for reoccupancy should be based on verification that specified work practices have been completed and confirmation that air contaminants have returned to background levels.

APPENDIX A

Specification for Microbial Decontamination

SUMMARY

Gypsum board and insulation will be removed from rear (exterior) wall and the wall cavity disinfected. All work shall be performed within an asbestos-type containment to control the release of mold and bacteria. Work shall be conducted after-hours in one-room segments. Work will be stopped and corrective actions taken if monitoring conditions do not meet standards established by this specification. The wall can be reconstructed and barriers removed when clearance criteria are met.

Special equipment/materials needed:

- HEPA filter. A high efficiency particulate air filter capable of removing particles greater than 0.3 mm in diameter with 99.97% efficiency.
- HEPA Vacuum. A vacuum system equipped with HEPA filtration.
- Negative pressure ventilation system. A portable exhaust system capable of maintaining a constant low-velocity air flow into contaminated areas from adjacent uncontaminated areas. For this project, a Microtrap or equivalent shall be used in each work room.
- Disinfectant. Bleach or a bleach alternative shall be used.

SITE PREPARATION

Monitoring

Prior to site preparation, collect background samples for airborne bacteria and fungi (counts only) in each occupied classroom and the outside air.

Adjacent Areas

Room in which containment is to be located shall be vacant for duration of activity. Staff may enter room to collect materials. Fan/coil unit in the work area shall remain off. All interior surfaces shall be cleaned and disinfected and be sealed with plastic so as to prevent any dust from entering during demolition. A plastic drop cloth shall be placed over the floor in the room outside the containment.

Containment

Unless otherwise noted, seal all walls and floors with two layers of six mil plastic sheets. Seal off all openings, doors, windows, fan coil units, light fixtures, etc., with two layers of six mil plastic. Remove ceiling tiles; if there is any water-damaged insulation, remove carefully and disinfect underlying surface. Extend the plastic sheeting from the floor to the roof and wall-to-wall, making a containment of about 3000 ft^2. Ensure that barriers are effectively sealed and taped. Repair damaged barriers and remedy defects immediately and visually inspect enclosures prior to each workday. Use smoke methods to test effectiveness of barriers. Barrier must remain in place until the clearance criteria are met.

Access

Curtained Doorway. A device to allow worker ingress or egress from the outside only through a window while permitting minimal air movement, constructed by placing two overlapping sheets of plastic over a window, securing each along the top of the doorway, securing the vertical edge of one sheet along one vertical side of the doorway and securing the vertical edge of the other sheet along the opposite vertical side of the doorway. Other effective designs are permissible. All waste shall leave the containment through this window.

Negative Air

Negative pressure ventilation units or exhaust fans will work continuously from the start of demolition until clearance is granted. Makeup air and exhaust shall be located so as to provide for the flow of air throughout the containment. The primary source of makeup air shall be from inside the building through a flap-type air lock in the containment barrier.

DEMOLITION

Worker Protection

There are no mandatory respirator standards for work around environmental molds and bacteria. Air purifying respirators equipped with HEPA filters are recommended. Individuals with preexisting allergies should avoid this type of work area, if possible. Dust masks offer some, but not complete protection. Full body disposable protective clothing is optional except in circumstances where a worker must enter the school from the containment. This should be avoided if at all possible and the suite (including foot coverings) removed before leaving the containment.

Removal

Minimize dust generation. Mist with water as needed to suppress dust. Inspect exposed wall cavity to determine moisture sources, document damage, and confirm scope of work with owner. The industrial hygienist must verify that removal of potentially contaminated porous materials is complete.

Cleaning

All surfaces in the containment shall be cleaned in the following sequence:

1. Remove any gross debris.
2. Vacuum clean (HEPA).
3. After a minimum settling time of 1 h, damp wipe with disinfectant (e.g., 10% bleach solution). All surfaces must stay wet for a minimum contact time of 20 min. Cracks and crevices in wall cavity shall be sprayed with 10% bleach.
4. After all surfaces pass a visual inspection by the industrial hygienist, the contractor shall encapsulate the wall cavity and sill plate with sealant containing appropriate biocide approved by the industrial hygienist (e.g., antimildew agent).

Monitoring

Work is in progress

Project will be inspected to ensure it is in conformance with this specification and to conduct periodic air quality tests to document the containment effectiveness. Work must stop and corrections made if there is musty odor, haze, or excessive dust outside the containment, or work is not being performed in conformance with this specification.

Clearance

Final air samples will be collected after all surfaces in the containment are inspected and are found to be dry and free of any debris or settled dust. Aggressive microbial air samples (exhaust fan running) collected in the containment must be less than 500 cfu/m^3 or less than outside air levels collected at the same time.

Reconstruction

Reinsulation and installation of wallboard shall be conducted within the containment after air samples are cleared by the industrial hygienist.

Reestablishment of Classroom

Removal of barriers and reinstallation of systems shall be conducted with a small exhaust fan in an open window. Any necessary repair work shall be completed along with one final cleaning of the room. Filters shall be changed in fan coil unit and ceiling tiles reinstalled.

Final Testing

Air quality shall be retested after the above procedures have been completed in all areas to ensure that major sources of microbial contamination have been controlled.

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