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FINAL REPORT
MICROBIOLOGICAL SCREENING OF THE INDOOR AIR QUALITY IN THE POLK COUNTY ADMINISTRATION BUILDING

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16. ABSTRACT

The report gives results of a microbiological screening of the indoor air quality in the Polk County (Bartow, Florida) Administration Building (PCAB), a large negatively pressurized building, not known to be biocontaminated. The microbiological screening included bioaerosol, bulk material, condensate, surface, and building floor dust samples taken at multiple locations. In general, the microbial results were consistent with the PCAB's being a non-problem building. However, the study was too limited in both duration and number of sample locations to completely evaluate the building. The results of a few samples indicated microbiological conditions that might warrant further investigation, but were not of themselves adequate to indicate a building-wide problem.

17. KEY WORDS AND DOCUMENT ANALYSIS

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Buildings	Stationary Sources	13M
Bioassay	Indoor Air Quality	06A, 06O
Microbiology	Microbiological Screening	06M
Condensates		07D
Dust	Bioaerosols	11G

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FOREWORD

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E. Timothy Oppelt, Director
National Risk Management Research Laboratory

ABSTRACT

Designing and operating a ventilation system for increased outdoor air rates, as required by ASHRAE Standard 62-1989, improves indoor air quality (IAQ) but is thought to extract a high penalty in energy costs and potentially increased microbial contamination in a hot, humid climate. The relationships between IAQ and comfort, building energy usage/cost, and building microbial contamination have not been studied systematically. A two-part research program into the impact of increased outdoor air rates (per ASHRAE 62-1989) on building microbial contamination and the cost of providing that outdoor air was initiated by RTI for the U. S. EPA. The Polk County Administration Building (PCAB), a negatively pressurized large building, not known to be biocontaminated and already part of a radon abatement project, was selected for the ventilation study. The building environmental parameters, ventilation system, and air exchange characterization planned for the radon project provided important data to the microbiological and energy study. As planned, microbial contamination and energy costs were to be assessed with the building in its native state and after pressurizing and otherwise modifying it to ASHRAE 62-1989. In the course of the radon study, however, the PCAB ventilation system was not modified as expected, and further study of biocontamination and energy costs was deemed unwarranted. The microbiological screening of the PCAB in its native state is the subject of this report, and the energy / cost analysis is the subject of another report.

The microbiological screening included bioaerosol, bulk material, condensate, surface, and building floor dust samples, most taken at 6 indoor locations on 3 floors. A screening study is too limited in both duration and number of sample locations to completely evaluate a building. However, in general, the microbial results were consistent with the PCAB being a non-problem building. The results of a few samples indicated microbiological conditions that might warrant further investigation, but were not of themselves adequate to indicate a building-wide problem.

TABLE OF CONTENTS

Section **Page**

FIGURES

Number **Page**

TABLES

Number **Page**

1.0 BACKGROUND

This research task was a preliminary indoor microbiological screening of the Polk County Administration Building (PCAB) in Bartow, Florida conducted as part of CR-817083, Task 11, "Ventilation for Improved Indoor Air Quality." Its goal was to generate a baseline measurement that could be used, in conjunction with additional sampling, to evaluate the impact of ventilation system design and operation on the microbiological aspects of indoor air quality (IAQ). Indoor microbiological contamination can be a significant cause of poor IAQ, and is known to be associated with building ventilation systems with some frequency (Woods, 1989.) The impact of a building's ventilation system on biocontamination is complicated. On the positive side, building pressurization reduces the infiltration of biocontaminants while maintenance of relatively dry indoor environmental conditions prevents the growth of the microorganism spores inside. [Foarde et al. (1992) have shown that biocontaminants will grow and amplify on building materials at lower moisture levels than previously reported, and the appropriate level of moisture remains under investigation.] Filtration equipment in the ventilation systems can similarly reduce the influx of environmental microorganisms (Foarde et al. 1994.) On the other hand, improperly designed, maintained, or operated ventilation systems can contribute to indoor biocontamination (Morey and Williams, 1991; Ager and Tickner, 1983.) In addition, the applicability of ASHRAE Standard 62-1989 to hot and humid climates is being challenged. The increased outdoor air rates called for in the Standard (necessarily related to building pressurization) are said to both increase building energy requirements and to lead to increased microbiological contamination in these climates.

The PCAB was chosen for this screening study primarily because an extensive study of the building's ventilation system and indoor environment was planned as part of a radon mitigation study. (This radon research was completely separate from the present task). During the radon study, the PCAB's indoor environment (temperature,

pressure, and relative humidity) and HVAC system was characterized on each of the five floors, and a detailed investigation of the building's air exchange and HVAC characteristics was conducted.

The PCAB was not thought to have a microbiological problem, and a microbial investigation was not included in the radon study design. However, a nearby building of about the same age and having the same owner / operator as the PCAB was known to have had a very significant microbial contamination problem (Fry, 1994). Thus, the opportunity existed to incorporate a microbiological screening into the PCAB study at modest cost, capitalizing on all the characterization work that was already planned for the radon study. In addition, it was originally thought that the PCAB would be pressurized to reduce radon infiltration, opening the possibility of investigating the effects of a change in building pressurization on microbial contamination indoors.

The PCAB has some unfavorable characteristics from the standpoint of a microbial investigation. The building had 2 or 3 air handling zones per floor, and not all could be investigated with the resources available. The PCAB also operated under negative pressure, which had the potential to bring in outdoor microorganisms by infiltration or through open windows and doors. Infiltration bypasses the HVAC filters, and tends to confound the meaning of indoor bioaerosol sampling. Indoor biocontaminant concentrations can vary widely over short periods of time, and the "grab-sample" nature of indoor bioaerosol samplers makes the results difficult to analyze, particularly in a screening study. Another difficulty was that changes in the building operation that were planned for the radon mitigation study might not affect microbial growth within the time frame of this study. Microbiological investigations are commonly conducted in problem buildings, and the mere presence of microorganisms is not an indication of a problem. The indoor and outdoor levels and types of organisms must be compared to those obtained in other buildings, with the investigators' judgement weighing heavily in the assessment.

During this study, microbiological data was collected from bulk, surface, and bioaerosol samples and the moisture content of some building materials was

measured. Each of the measurement types approach the question of biocontamination from different perspectives, thus addressing the problem of identifying the sources of biocontamination.

This was a field screening study to evaluate the desirability, according to criteria given in Section 3.1, of conducting a more complete test at a later date. These criteria were not met, and further studies are not currently planned.

2.0 BUILDING HVAC SYSTEM

2.1 OVERVIEW OF BUILDING DESIGN

The PCAB, located in Bartow, Florida, is a 5-story, 14,000 m^2 (149,000 ft^2) brick-faced building constructed in 1988. It has a permanent occupancy of approximately 300 county employees and elected officials, and also has a large transient population who come to the building to pay bills, inquire about various aspects of zoning, utilities, building permits, and to conduct other county business. Bartow is in central Florida and has the subtropical climate typical of that area.

The footprint of the building is approximately square, and the second floor encloses about the same amount of area as the first. The third and fourth floors are set-back, with reduced square floor areas, while the fifth floor area is cross-shaped. All entrances are from ground level onto the first floor. The principal public entrances are centered on the north and south sides, and open into a central lobby that is open vertically to the fourth floor ceiling. Two smaller entrances are located on the east side of the first floor and two are located on the west side.

In addition to office space and the large lobby, the first floor houses an auditorium for public meetings. The other floors of the PCAB are devoted largely to office space and occasional larger meeting / training rooms. An employee lounge on the north side of the third floor has doors opening to a rooftop terrace. Some of the PCAB's windows were operable in response to occupant request. None were open in the rooms that were indoor test sites.

2.2 HVAC SYSTEM DESCRIPTION

The HVAC system in the PCAB utilized variable air volume delivery of conditioned air and a plenum return. The air was conditioned in chilled water coils located in variable air volume (VAV) air handling units (AHUs), filtered with 2-in. ASHRAE-30 filters, then reheated as required for delivery to the space. The air was

distributed to fan-powered VAV terminal boxes. The relative humidity in the building was controlled to approximately 40 percent. Each floor had multiple HVAC zones. The first floor of the PCAB had three AHUs and HVAC zones; the other floors had two. The mechanical rooms were located one above the other, and formed a utilities column on the east and west walls of the PCAB. All microbiological sampling was conducted on the first, fourth, and fifth floors, and only those floors are detailed below.

The three HVAC zones on the first floor were partitioned approximately as follows:

AHU1: Served the main lobby and the first floor auditorium from mechanical room 138.

AHU2: Served both interior and exterior offices on the south side of the first floor. AHU2 was located in mechanical room 123, which was located in the southwest quadrant of the PCAB. The outdoor air intake was adjacent to the mechanical room in the west wall.

AHU3: Served both interior and exterior offices on the north side of the first floor of the PCAB. AHU3 was located in mechanical room 187, which was located in the northeast quadrant of the PCAB. The outdoor air intake for AHU3 was close to the mechanical room in the east wall.

Two HVAC zones were utilized on the fourth floor. The office space was arranged in a rough square, with the central opening to the atrium lobby normally closed off with doors.

AHU 8: Served the interior office zone of the fourth floor from mechanical room 454, which was in the southwest quadrant. The outdoor air intake for AHU8 was located in the wall of the mechanical room, facing north.

AHU 9: Served the exterior office zone of the fourth floor from mechanical room 414, which was in the northeast quadrant. This large service area required that the supply and return ducts from AHU9 encircle the building. The outdoor air intake for AHU9 was located in the wall of the mechanical room, facing south.

Two HVAC zones were also utilized on the fifth floor, which was occupied in a second stage of construction and thus was not numbered consistently with the remainder of the PCAB. The central opening present on the other floors did not penetrate through to the fifth floor, whose floor area was a Greek Cross-shaped open-plan area and not subdivided into small offices. Given the open plan of the fifth floor, the HVAC systems were not zoned as thoroughly as on the other floors. The HVAC was arranged in the following manner:

AHU 10: Served the west side of the fifth floor from the (unnumbered) mechanical room in the southwest quadrant. The outdoor air intake for AHU2 was located in the wall of the mechanical room, facing south.

AHU 11: Served the east side of the fifth floor from the (unnumbered) mechanical room in the northeast quadrant. The outdoor air intake for AHU1 was located in the wall of the mechanical room, facing north.

During the microbiological screening study, the PCAB HVAC system was operating in its normal daytime operating mode, with all air handlers on and the flows controlled by the variable volume system.

3.0 EXPERIMENTAL

3.1 INTRODUCTION

This screening study had the express purpose of obtaining enough information to determine whether a continued investigation of the indoor microbiological levels and contamination was warranted as part of an investigation of the effects of building ventilation on microbial contamination. The building would have been recommended for further study if one of the following conditions existed:

1) Notable microbial contamination was detected in the PCAB, or
2) As a result of the radon mitigation study, the PCAB owner implemented a change in the HVAC operation that resulted in increased outdoor air or building pressurization that might affect the microbiological situation in the PCAB.

Since neither condition was met, the building was not recommended for further study. Therefore, the results of the screening study have significance principally as a baseline record of a negatively-pressurized public building in a hot and humid climate.

3.2 PROCEDURES

3.2.1 Overview

The screening study included a building walk-through, outdoor and indoor bioaerosol sampling, bulk and surface sampling, and occasional building material moisture measurement. Bulk samples consisted of HVAC fiberglass liner, condensate from drain pans, and composite carpet dust. Surface samples included swabs from inside selected AHUs and the back side of ceiling tiles. This study was HVAC-system driven, and the test plan allowed some adjustment of test sites and other aspects of the study based on conditions in the building. All microbial samples were shipped back to

RTI for analysis.

3.2.2 Test Locations

A walk-through of the entire building to note any visible potential microbial problems was the first step of the screening study. Observed problems (or potential problems) affected the study locations, which were generally planned to coincide with those where the environmental parameters were measured for the radon study. Each indoor bioaerosol sampling site was paired with an outdoor bioaerosol sampling site; that is, the outdoor site was near the outdoor air intake to the air handler serving the zone of the indoor site. Applying these criteria, the majority of the screening samples were collected in the following locations:

1) Room 170, which was in the northeast quadrant of the PCAB first floor, and part of the building exterior HVAC zone served by AHU3. The general location of all of the first floor sampling sites is shown in Figure 1.

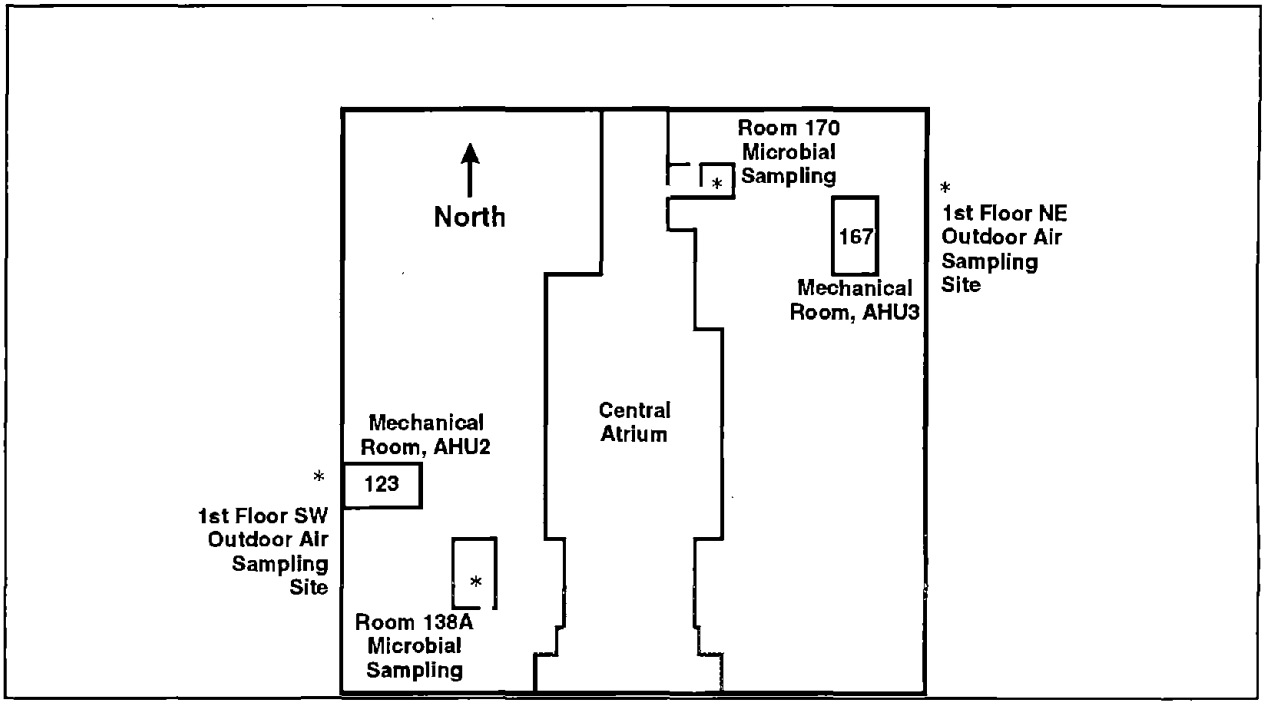

Figure 1. First Floor Outline Sketch and Sampling Positions.

2) Outdoors, approximately 1.5 m above ground level on the northeast corner of the PCAB near the outdoor air intake for AHU3.

3) Room 138A, in the southwest quadrant of the first floor, and in the interior HVAC zone of the PCAB served by AHU2.

4) Outside, approximately 1.5 m above ground level on the southwest quadrant of the PCAB near the outdoor air intake for AHU2.

5) Room 413, in the northeast quadrant of the PCAB fourth floor, and part of the fourth floor's exterior HVAC zone served by AHU9. The general location of each of the fourth floor sampling sites is shown in Figure 2.

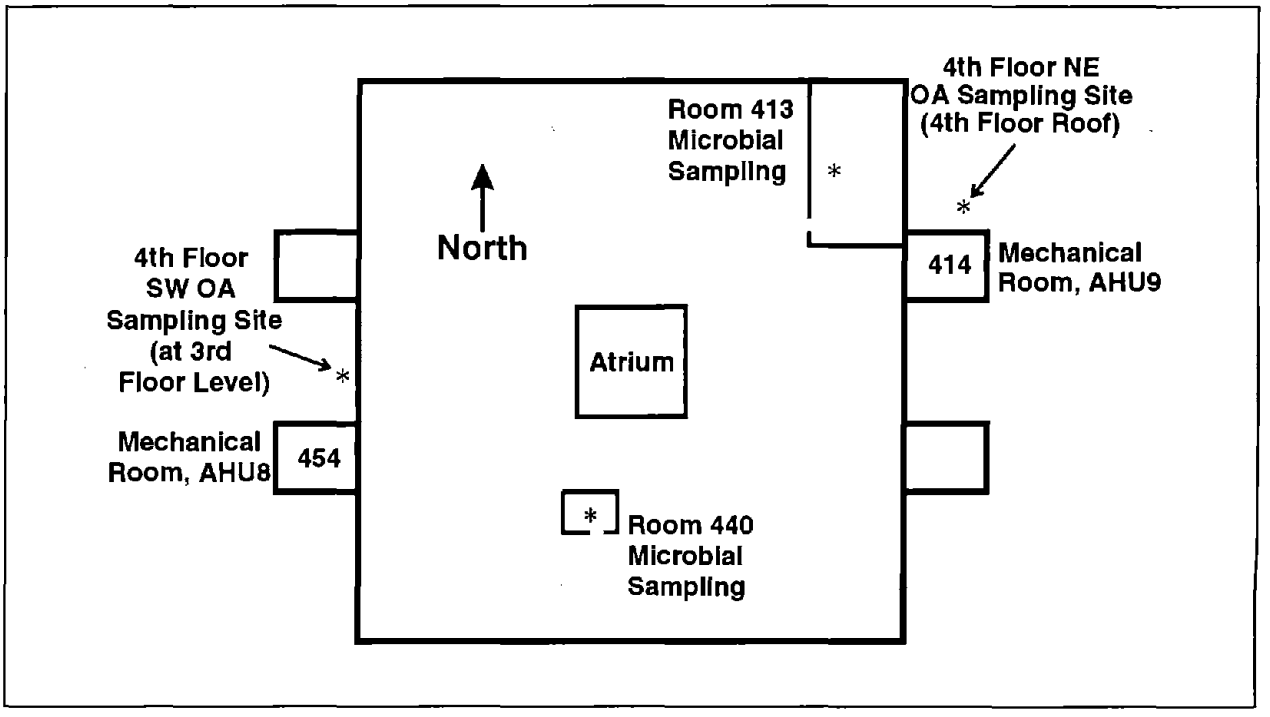

Figure 2. Fourth Floor Outline Sketch and Sampling Locations.

6) Outside on the fourth floor roof, approximately 3 m above and 4 m north of the fourth floor air intake for AHU9. This sample site was at the same level and approximately 2 m north of the air intake for the fifth floor air handler, AHU11.

7) Room 440, in the southwest quadrant of the PCAB fourth floor, and part of the fourth floor interior HVAC zone served by AHU8.

8) Outside on a ledge on the west side of the PCAB, approximately 2.5 m below and 4 m north of the fourth floor air intake for AHU8 and inside the shelter formed by the building's architecture on the west side.

9) In the northeast quadrant of the fifth floor open office space generally served by AHU11 as shown in Figure 3. The outdoor air for AHU11 entered near the outdoor air sample site on the fourth floor roof described under item 6, above.

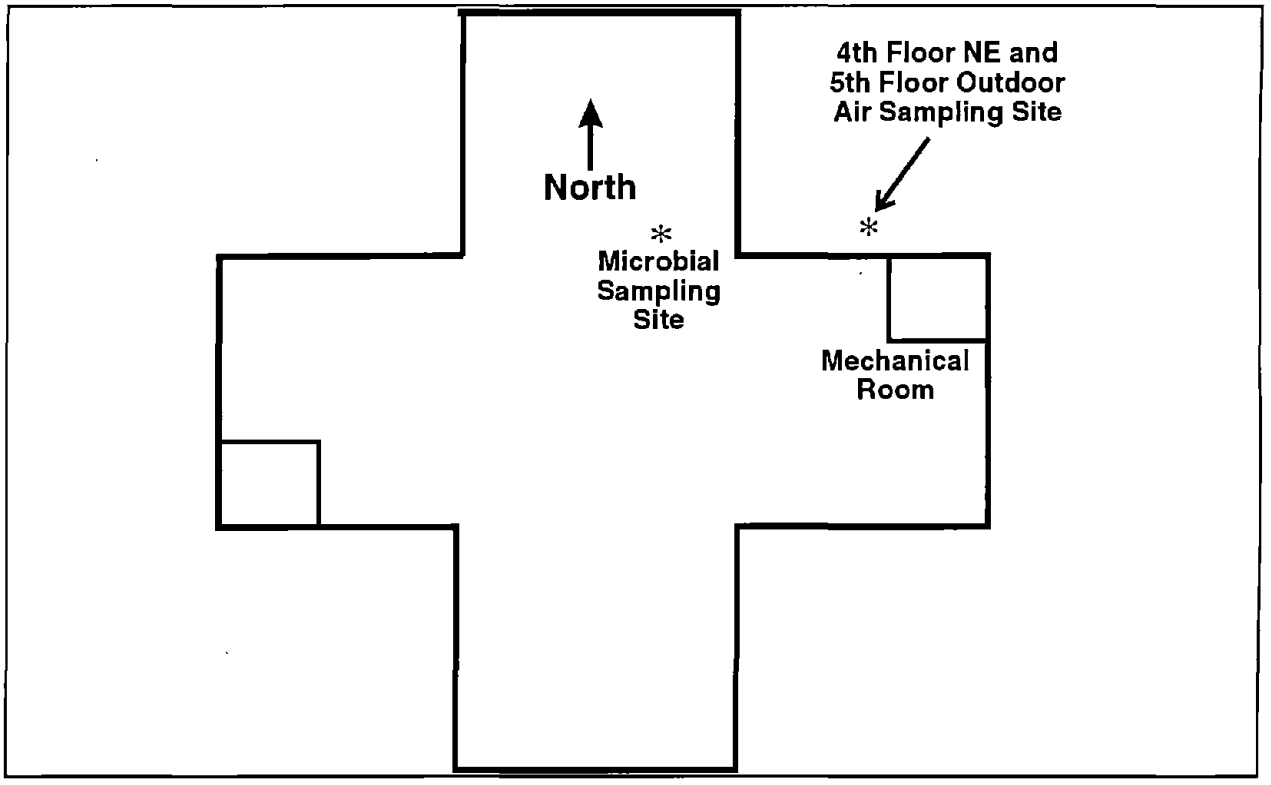

Figure 3. Fifth Floor PCAB Outline Sketch and Sampling Positions.

3.2.3 HVAC System Sampling

The HVAC systems serving the test zones were inspected for visible problems (standing water, plugged condensate drains, duct leaks, etc). Where appropriate, surface microbial samples and material moisture measurements were obtained from the outdoor air duct wall, the upstream duct wall, filter, downstream duct wall, and

condensate pan. HVAC system samples were taken and analyzed to assess their potential for microbial contamination.

3.2.4 Indoor Environment Evaluation

3.2.4.1 Cleanliness--

Cleanliness near the air sampling regions was evaluated qualitatively by inspection and noted on the data sheet by location. Notes concerning building cleanliness were also made during the walk-through. Swab samples were collected at some locations to qualitatively assess microbial flora. No quantitative evaluations were made with swab samples.

3.2.4.2 Material Moisture (Conductivity)--

Building material moisture content was evaluated using a conductivity meter internally calibrated and set on the concrete and plaster scale. The readings are relative and the instrument was intended to identify any moist locations that might be microbial reservoirs or have the potential to become microbial sources. Moisture evaluations were made at various locations deemed appropriate during the walk-through, and for the HVAC materials. The location of each measurement was noted in the project notebook. The Delmhorst Model BD-8 Moisture Meter was calibrated before initial reading by pressing the "CAL CHK" button and confirming that the meter read 20. The short-pronged electrodes of the moisture meter were carefully inserted approximately ¼ inch into the material to be tested. The "READ" button was then depressed and held down until the reading stabilized. The moisture level was read off the "plaster/concrete" scale. Duplicate readings were taken at all locations.

3.2.5 Biocontaminant Sampling

3.2.5.1 Surface and Bulk Material Sampling--

Swab surface and bulk material samples were collected at appropriate locations to assess microbial flora within the PCAB. The locations were identified during the walk-through. Some were within the HVAC systems. The location of each sample was

noted in the project notebook.

Swab samples were collected with sterile swabs which were wiped across the surface to be tested. The swabs were then transferred to sterile 15 ml centrifuge tubes, sealed and placed into resealable plastic bags. Ten to 50 ml samples of condensate from the drain pans were pipetted directly into sterile containers which were sealed and placed into resealable bags. Similarly, HVAC fiberglass liner was collected and placed directly into resealable bags.

Floor surface dust was sampled on the first and fourth floors using the Oreck® XL, Super Buster B, Compact Canister D vacuum with XL Double Wall filter bag reported to contain particles down to 1.0μm. A new bag was used for each sample. Before use and between samples the machine was cleaned by removing the faceplate, hose adaptor, and all attachments used for sampling. Inner surfaces were rinsed and brushed with clean hot water followed by a 70% ethanol rinse. Clean gauze wrapped around a brush was used to wipe the inside surfaces, followed by air drying when necessary. After sample collection, the entire bag was removed, the opening taped shut, and the vacuum bag placed in a resealable plastic bag.

3.2.5.2 Bioaerosol Sampling--

Both indoor and outdoor air sampling utilized the same sampling instruments. All sampling was conducted in temporarily vacated offices or after work hours to avoid disturbing the PCAB occupants. Indoor air samples were obtained with Mattson-Garvin slit-to-agar samplers operated over 30-minute periods at each test site, and outdoor air samples were also obtained with a Mattson-Garvin using a 5-minute sampling period. The Mattson-Garvin sampler draws air at 28.3 L/min through a 0.15 mm slit allowing a broad range of airborne particles to be impacted upon the surface of a 150 mm rotating agar plate. The sampler was disinfected with 70% ethanol before the initial sampling and each time the test location was changed. Table 1 presents a list of all the microbiological air samples taken. All samples were taken in duplicate sequentially.

Table 1. Summary of Microbiological Air Samples.

Location	Sample Duration (min.)	Number of Runs with each Media		
		Fungi		Bacteria
		General	Xerophilic	
Room 170, inside NE	30	2	2	2
First Floor outside, NE	5	2	2	2
Room 138A, inside SW	30	2	2	2
First Floor outside, SW	5	2	2	2
Room 413, inside NE	30	2	2	2
Fifth Floor outside, NE	5	2	2	2
Room 440, inside SW	30	2	2	2
Third Floor outside, SW	5	2	2	2
Fifth Floor inside, NE	30	2	2	2
Control runs	5	1	1	1
Media Blanks	NA	0	1	0
Total Plates Evaluated		19	2	19

A complete set of samples from each of the nine locations described in Section 3.2.2 consisted of sequential duplicate fungi samples for each of two media, and sequential duplicate bacteria samples for one media. A total of 54 Mattson-Garvin samples were obtained. Three Mattson-Garvin control runs were made, one with each media, as QA/QC for the sampler procedure. One fungal media blank was taken. After sample collection at PCAB, all samples were taped closed, wrapped with packing material, placed in sealed insulated containers containing ice, and shipped for delivery to the RTI laboratory within 24 hours.

3.2.5.3 Media Preparation and Sample Processing--

Three media were chosen for use in this microbiological screening. All samples -- air, bulk and surface -- were processed using these same media. Trypticase soy agar (TSA) was employed for the isolation and enumeration of both mesophilic and

thermophilic bacteria. TSA is a general purpose media developed for the isolation and cultivation of fastidious and non-fastidious organisms. Two different media were employed for the isolation of fungi -- Sabouraud dextrose agar (SDA) and dichloran glycerol agar (DG18). SDA is a general purpose media developed for the isolation and cultivation of fastidious and non-fastidious fungi (molds and yeasts). DG18 is a media developed for the isolation of xerophilic fungi. Xerophilic organisms are those that are able to grow under very low water conditions. Many members of the genera *Aspergillus* and *Penicillium* are xerophiles.

All media used in this study were prepared in the RTI laboratories. All commercial, dehydrated media components and reagents were inspected, dated, and stored appropriately upon receipt. Ingredients were weighed on calibrated, laboratory balances and suspended in distilled, deionized 18 megohm water. Sterilization was conducted in a steam autoclave operating at 121°C and 100 kPa. All media was incubated following preparation to insure sterility, with representative samples inoculated with known fungi and bacteria as growth controls. Organisms used included *Aspergillus versicolor*, *Penicillium glabrum*, *Staphylococcus aureus*, *Escherichia coli*, and *Bacillus stearothermophilis*. All media was inspected before use, and discarded if found to be contaminated. Field media blanks were also utilized on-site in conjunction with the Mattson/Garvin bioaerosol samplers.

3.2.5.4 Sample Processing --

Upon receipt of the samples at the RTI laboratory, they were checked in, entered into the sample tracking system, and processed. Mattson-Garvin plates were incubated at 25°C for molds and 32°C for bacteria. Surface swabs were suspended in 5 ml of phosphate-buffered saline (FTAb), vortex mixed for 1 minute, and diluted 1:10. Aliquots of 0.1 ml of the undiluted and the diluted sample were plated in duplicate on each of the 3 recovery media. An additional TSA plate incubated at 55°C (for thermophiles) was only inoculated with the undiluted sample. Condensate was diluted 1:10 and plated out like the surface swabs. Duct insulation was weighed first and the weights recorded before being suspended in 5 ml of FTAb and processed like the

previous samples. In the laboratory, each composite carpet dust sample was weighed, sieved (250 μm), and thoroughly mixed, after which 0.5 g samples of the smaller than 250 µm dust were suspended in 10 ml of FTAb, vortex mixed and diluted 1:10 and 1:100, with 0.1 ml aliquots of both dilutions plated in duplicate on the three recovery media. Duplicate additional TSA plates were plated with 0.1 ml aliquots of the undiluted sample and incubated at 55°C for thermophiles. Following inoculation, all samples were incubated like the Mattson-Garvin plates. Mold samples were grown under alternating conditions of fluorescent light and darkness for at least 10 days. Identification of isolated fungi was based on colony morphology, pigmentation, and microscopic examination, in accordance with standard reference texts and reference cultures from RTI's environmental microorganism culture collection. Bacteria samples were incubated 3-5 days. Identification of isolated bacteria was based on colony morphology, pigmentation, microscopic examination, and biochemical testing as needed, in accordance with standard reference texts and reference cultures from RTI's environmental microorganism culture collection.

3.3 DATA QUALITY INDICATORS

This program was a screening study, and as such the purpose of the measurements were generally qualitative rather than quantitative. Surface samples (for moisture or microbial contamination) were made at selected sites within the building, and these sites were generally selected to have a relatively high potential for microbial contamination (i.e., wet spots, collected dirt on the floor or carpet, likely locations for condensation). In all these cases, microbial contamination is highly site-specific, and the variance from site-to-site is much larger than the measurement error. Swabbed surface areas vary for each sample, and are not comparable for the broad range of surfaces encountered during this screening study. The swab surface samples are qualitative. Microbial growth was identified to the genus-level, with occasional semi-quantitative evaluations of organism levels in specific, comparable locations.

The same general concerns about the routine variability of indoor bioaerosol levels apply to the air samples, though the air samples were quantitative. The presence of microorganisms in the air does not necessarily indicate that a building is contaminated, and their absence does not necessarily indicate that it is not contaminated. A combination of factors must be considered. The primary indications of a problem will be observation of a significant amplification site (for instance, visible growth on a surface coupled with elevated indoor levels of the same organism) or a difference in the distribution of microbial flora from outdoor to indoor. Within this context, data quality indicators for the measurements are given in Table 2. The microbial samplers used during this screening study readily met these DQIs.

Table 2. Quality Goals for Critical Measurements

Measurement	Reference Method	Precision	Accuracy
Moisture by Conductivity	Gravimetric	± 5%	± 10%
Mold presence on surface*	Not Available	Not Applicable	Not Applicable
Mold presence in air*	Not Available	± 10 fold	Not Applicable

* Visual determination of predominant genus, only.

3.4 QUALITY ASSURANCE

3.4.1 Cleanliness

Cleanliness was a qualitative evaluation, and no measurements were associated

with that assessment.

3.4.2 Material Moisture

QA/QC for the measurement is described in Section 3.2.4.2. This measurement was seldom used at the PCAB because only in a single case was visible evidence of interior moisture observed, and the water-marked material in question gave a material moisture reading below the detection limit of the instrument. Therefore, no material moisture results are reported.

3.4.3 Surface and Bulk Material Microbiological Samples

QA/QC for the surface and bulk material microbial samples consisted primarily of control plates and samples that were subjected to the entire analysis procedure but never exposed to the environment being sampled. These controls were all negative indicating the collection procedures were satisfactorily performed.

3.4.4 Microbiological Air Samples

QA/QC for the microbiological air samples consisted primarily of control samples. One control sample of each media was exposed during the test period. This control run consisted of preparing the sampler following standard procedures, placing the media in the sampler, attaching a HEPA filter capsule to the Mattson-Garvin inlet, and conducting a 5-minute test run. The control runs provided a final check to establish the effectiveness of the disinfection procedures used between runs. The control Mattson-Garvin runs obtained during this preliminary screening study did not indicate any systematic error in the sampling procedure.

4.0 RESULTS AND DISCUSSION

4.1 AIR SAMPLES

As described above, sequential duplicate air samples were collected for both bacteria and fungi; and the fungi were collected on two different media, one general purpose media and one primarily for the isolation of xerophilic molds. The results are summarized below, and tables containing the data from the individual duplicate runs (including the means and standard deviations) for the xerophilic and overall fungi as well as the bacteria are included in Appendix A. A comparison of the results from the two fungal media (SDA, or general purpose, and DG18, for xerophilic organisms) demonstrated very little difference in the numbers of CFU/m^3 or distribution of organisms; therefore, this discussion will be confined to only the results from the xerophilic media.

4.1.1 Total Colony Forming Units

Table 3 presents a summary of the mean levels of CFUs/m^3 for the xerophilic fungi and the bacteria at each of the nine sites sampled. Multiple outdoor locations were sampled and the data in the table are arranged so that the results of the outdoor air sampling is directly above the corresponding indoor sample. For example, on the first floor both the northeast and southwest zones were sampled. Room No. 170 was located in the northeast zone so the results in the table are paired with the outdoor results for the northeast. For the fourth floor northeast zone inside sample, the fifth floor outside sample is the corresponding sample.

Table 3. Mean Total Airborne Fungi and Bacteria in CFU/m^3.

Location	Room	Xerophilic Fungi	Bacteria
1st floor NE	Outdoor Air	1100	520
1st floor NE	Room 170	610	330
1st floor SW	Outdoor Air	580	1900
1st floor SW	Room 138A	110	270
4th floor NE*	Outdoor Air	530	250
4th floor NE*	Room 413	210	80
4th floor SW	Outdoor Air	830	440
4th floor SW	Room 440	80	190
5th floor NE*	Outdoor Air	530	250
5th floor NE*	Inside	30	30

* The Outdoor Air sample collected on the 5th floor NE was paired with both the 5th floor inside sample and the sample collected in Room 413 because it was near both the 4th and 5th floor outdoor air intakes.

A comparison of the outdoor and indoor mean levels shows that for all the pairs there were less organisms isolated indoors than out. This result is consistent with that found in a non-problem building. An examination of the data for the individual samples, shown in Tables A-1, A-2 and A-3 of Appendix A, confirms that result for most of the sampling locations. However, for Rooms 170 and 413 there are considerable differences between the results on both of the fungal media for the two sequential duplicates. The first run in Room 170 for xerophilic organisms yielded 155 CFUs/m^3, while the second isolated 971 CFUs/m^3 (Table A-1). Similar results were obtained on the general purpose media (Table A-2). A less dramatic but equally noteworthy difference was seen in the samples collected in Room 413. This difference between sequential duplicate sampling runs in the same room requires further examination of the data, specifically the identification of the organisms that may be responsible for the variation measured.

4.1.2 Identification of Predominant Fungi

Table 4 shows the percentage breakdown for the three most commonly isolated molds (xerophilic media) for each of the duplicate samples from each site. The sampling results employing the general purpose media are found in Table A-4 in Appendix A, and again confirm the results seen with the xerophilic media.

Table 4. Distribution of Predominant Airborne Xerophilic Fungi.

Location	Room	Fungi		
		Cladosporium	*Penicillium*	*Aspergillus*
1st floor NE	Outdoor Air	64	11	0
		72	6	0
1st floor NE	Room 170	55	7	3
		43	28	28
1st floor SW	Outdoor Air	68	6	0
		79	4	0
1st floor SW	Room 138A	16	48	0
		39	20	0
4th floor NE*	Outdoor Air	71	11	1
		61	8	0
4th floor NE*	Room 413	73	14	1
		26	67	1
4th floor SW	Outdoor Air	59	24	1
		NA	NA	NA
4th floor SW	Room 440	42	12	2
		39	25	7
5th floor NE*	Outdoor Air	71	11	1
		61	8	0
5th floor NE*	Inside	33	43	5
		29	38	10

* The 5th floor NE outdoor air sample was also paired with the 4th floor NE indoor sample because it was the accessible location closest to the 4th floor NE AHU outdoor air intake.

In many regions of the world, the molds most commonly isolated outdoors belong to the genus *Cladosporium* (Seller, 1984). As can be seen in Table 4, *Cladosporium spp.* predominated in all the outdoor samples, with over 50% of the total CFUs identified as belonging to that genus. The second most commonly isolated mold in the outdoor air was *Penicillium*. In all cases outdoors, less than 25% of the total colonies were identified as *Penicillium spp.*

It is generally expected that the numbers and distribution of indoor airborne fungi in mechanically ventilated non-problem buildings will reflect those found in the outdoors, but at lower levels. As with the outdoor samples, in most of the indoor sampling locations in the Polk Administration Building, *Cladosporium* was the predominant genus followed by *Penicillium*. In four out of five indoor locations and two out of four outdoor locations, there were a few Aspergilli isolated.

As discussed in Section 4.1.1, the levels of total fungi isolated in the duplicate samples for each of rooms 170 and 413 were noticeably different. In addition, there was a change in the distribution of the predominant fungi. As can be seen in Table 4, in Room 170 there was an increase in the percentage of *Penicillium* isolated. In the first sample only 7 percent of the total fungi were *Penicillium*; however, in the replicate 28 percent were *Penicillium*. For the first sample taken in room 413, 14 percent of the total fungi were *Penicillium*, while in the second 67 percent were *Penicillium*. The results from both rooms give some cause for concern, but for different reasons. The 28 percent *Penicillium spp.* isolated from Room 170 in itself might not be excessive. However, there was also a 10-fold increase in total *Penicillium* counts between the first and second samples, from 11 CFU/m^3 to 272 CFU/m^3. In the same samples, the airborne concentrations of *Aspergillus spp.* also increased. Combined, these data suggest that additional investigation might be warranted. The sample plates gave no evidence of being anomalous, and the results may be significant. In the case of Room 413, while the counts on the second replicate increased, the total CFU/m^3 were only 332 and therefore are not necessarily excessively high. However, the fact that 67% of those were *Penicillium* suggests further investigation may also be advisable. Again, the

sample plates gave no evidence of being anomalous. Although airborne fungal measurements are grab samples and subject to considerable variability, in both of these rooms the increase in total counts was detected by two different samplers on two different media at the same time. An increase in the fraction of *Penicillium* was confirmed in Room 413 by both media. For the samples collected in Room 170, an increase in the fraction *Penicillium* was detected on the xerophilic media (DG18). However, the second run on the general purpose media was overgrown and the actual number of *Penicillium* colonies could not be counted, though the results were not contradictory. These results indicate that there may be potential source reservoirs of *Penicillium* contaminating the rooms.

4.2 SURFACE AND BULK SAMPLES

A number of different surface and bulk samples were collected - condensate from drain pans, swabs of ceiling tiles and AHUs, bulk samples of fiberglass liner, and composite carpet dust. The complete xerophilic fungi results for the bulk condensate and composite dust samples are presented in Tables A-5 and A-7 in Appendix A. The ceiling tile swab data is in Table A-6 in Appendix A. None of these samples showed any remarkable levels or distribution of organisms, either bacterial or fungi.

The other bulk samples, fiberglass liner from the 4th floor AHU and swab samples from the 1st floor southwest AHU and the 4th floor northeast AHU, yielded potentially significant numbers of *Penicillium* in practically pure culture. Table 5 presents the results of the analysis of the wet and dry fiberglass insulation samples.

Table 5. Predominant Xerophilic Fungi Genera Isolated from 4th Floor AHU Fiberglass Liner.

Location	CFU/gram	Fungi, %		
		Cladosporium	*Penicillium*	*Aspergillus*
WET	1.2×10^3	0	100	0
DRY	7.7×10^4	8	92	0

Swab samples of a small patch of white mycelial-like material were taken in AHU2 located on the 1st floor (southwest) and AHU9 located on the fourth floor (northeast). Analysis showed a pure growth of *Penicillium*. Isolation of *Penicillium* species from both the AHU swabs and the fiberglass liner suggest that possible source reservoirs may have been identified. Although speciation of the *Penicillium* was not performed, isolation of the colonies in some of the AHUs is consistent with the evidence of potential contamination suggested by the elevated air sampling replicates, though it does not confirm that the AHUs are the source reservoir.

4.3 MOISTURE AND CLEANLINESS

Moisture meter readings were taken at a variety of locations within the building. Only one potential water stain was identified during inspection of the building. No readings above 0 were measured. Cleanliness was also determined visually. Overall, the impression of the building was that of a clean, well-maintained facility. Swab samples were taken when potential biocontaminant sources were identified. These results have already been discussed.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The overall impression of the Polk County Administration Building was of a clean, well-maintained, low occupancy structure. The majority of the microbiological screening results were consistent with those of non-problem buildings (Cole et al, 1994). The combined results of the air, bulk, and surface sampling did not indicate a clear biocontaminant problem in the building. On the other hand, the sampling period was short and samples were taken in only a few locations. The elevated airborne levels for one of two sequential airborne fungi samples in each of two different rooms (confirmed by the second fungal media), coupled with the isolation of essentially pure *Penicillium* in some of the AHUs, gives some cause for concern. Considering that the building is located in a hot, humid climate, that biological contamination problems have occurred in adjacent buildings, and that some occupants may have been sensitized to fungal contamination, further investigation for potential source reservoirs might be prudent.

The overall question to which the study was addressed -- the impact of a building's ventilation system on microbial contamination -- could not be investigated in the PCAB beyond the baseline level. No ventilation modifications that were expected to be microbiologically significant were planned for the building at the time the project was completed. The PCAB is negatively pressurized and appears to have restricted outdoor air intakes. Infiltration air is therefore unfiltered and unconditioned, and the potential exists for transport of biocontaminants in the infiltrating air, for condensation of water vapor in infiltration paths, and consequent building contamination. On the other hand, the PCAB is operated at a low relative humidity that tends to prevent microbial growth, though it is presumably expensive to operate. This combination of characteristics presents a number of research opportunities:

1) The results of this screening study are not conclusive to either identify the PCAB as a biocontaminated problem building or to clearly show that biocontamination

is not an issue in the PCAB. The study was not designed to accomplish that task. The results do show that fungi (*Penicillium spp.*) have become established in some AHUs and are either established in some parts of the ventilation system downstream of the filters or are at least occasionally transported through the filters to some rooms at levels above those found in most PCAB indoor locations and roughly equivalent to outdoor levels. The building may be in transition from non-problem to problem, and as such presents an unusual opportunity to study some important questions, such as: a) How extensive is the HVAC system contamination?, b) What conditions led to that contamination?, c) Is PCAB becoming a problem building and is the contamination getting worse?, and d) Can conditions be modified to prevent a serious contamination problem from developing?

2) The PCAB could be modified physically to operate at a controlled positive pressure to ensure that air entering the building was conditioned. This would require both duct and control modifications. Both short- and long-term studies of the microbial ecology in the building would provide valuable information concerning the impact of building pressurization in a hot and humid climate.

3) In combination with pressurization, a reduced-energy operating mode could be designed for the PCAB to, potentially, provide both reduced costs and reduced microbial contamination potential.

4) In addition to building pressurization, the impact of building ventilation rates on microbial contamination and general indoor air quality could be studied by modifying the outdoor air intakes to allow increased outdoor air delivery. Such operation should be optimized for energy efficiency consistent with prevention of conditions conducive to microbial growth in the building.

6.0 REFERENCES

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APPENDIX A. MICROBIOLOGICAL SAMPLING RAW DATA

TABLE A-1. RAW DATA FOR XEROPHILIC FUNGI

Location	Room	CFU/m^3	Mean	Standard Deviation
1st floor NE	Outdoor Air	1187	1095	130
		1004		
1st floor NE	Room 170	155	563	576
		971		
1st floor SW	Outdoor Air	551	580	40
		608		
1st floor SW	Room 138A	120	113	10
		106		
4th floor NE*	Outdoor Air	495	530	50
		565		
4th floor NE	Room 413	92	212	170
		332		
4th floor SW	Outdoor Air	827	827	NA
		NA		
4th floor SW	Room 440	98	75	32
		52		
5th floor NE	Outdoor Air	495	530	50
		565		
5th floor NE	Inside	25	25	0
		25		

* The 4th floor NE outdoor air sample was the same as the 5th floor NE outdoor air sample.

TABLE A-2. RAW DATA FOR GENERAL FUNGI

Location	Room	CFU/m^3	Mean	Standard Deviation
1st floor NE	Outdoor Air	1110	901	295
		693		
1st floor NE	Room 170	111	1191	1527
		2271		
1st floor SW	Outdoor Air	664	643	30
		622		
1st floor SW	Room 138A	86	74	17
		61		
4th floor NE*	Outdoor Air	410	456	65
		502		
4th floor NE	Room 413	61	147	121
		232		
4th floor SW	Outdoor Air	749	710	55
		671		
4th floor SW	Room 440	77	65	16
		54		
5th floor NE	Outdoor Air	410	456	65
		502		
5th floor NE	Inside	32	32	1
		33		

* The 4th floor NE outdoor air sample was the same as the 5th floor NE outdoor air sample.

TABLE A-3. RAW DATA FOR BACTERIA

Location	Room	CFU/m^3	Mean	Standard Deviation
1st floor NE	Outdoor Air	318	523	290
		728		
1st floor NE	Room 170	Overgrown	325	Not Avail.
		325		
1st floor SW	Outdoor Air	2686	1898	1114
		1110		
1st floor SW	Room 138A	265	266	2
		267		
4th floor NE*	Outdoor Air	240	254	20
		37		
4th floor NE	Room 413	79	84	7
		90		
4th floor SW	Outdoor Air	657	435	315
		212		
4th floor SW	Room 440	241	192	70
		143		
5th floor NE	Outdoor Air	240	254	20
		37		
5th floor NE	Inside	29	33	5
		25		

* The 4th floor NE outdoor air sample was the same as the 5th floor NE outdoor air sample.

TABLE A-4. PREDOMINANT AIRBORNE GENERAL FUNGI

Location	Room	Fungi, Percent of Total Colonies		
		Cladosporium	*Penicillium*	*Aspergillus*
1st floor NE	Outdoor Air	68	6	1
		64	8	0
1st floor NE	Room 170	54	7	0
		NA	NA	NA
1st floor SW	Outdoor Air	68	6	0
		59	0	1
1st floor SW	Room 138A	27	38	0
		23	27	2
4th floor NE*	Outdoor Air	57	5	0
		51	8	3
4th floor NE	Room 413	37	25	0
		17	60	2
4th floor SW	Outdoor Air	50	25	25
		53	14	14
4th floor SW	Room 440	32	15	2
		28	26	0
5th floor NE	Outdoor Air	57	5	0
		51	8	3
5th floor NE	Inside	33	33	4
		25	29	0

NA results not available due to overgrowth of plate with *Rhizopus*.

* The 4th floor NE outdoor air sample was the same as the 5th floor NE outdoor air sample.

TABLE A-5. PREDOMINANT XEROPHILIC FUNGI ISOLATED FROM AHU CONDENSATE SAMPLES

Location	CFU/ml	Fungi, Percent of Total Colonies		
		Cladosporium	*Penicillium*	*Aspergillus*
1st floor SW	40	0	0	0
4th floor NE	20	0	0	1
5th floor NE	230	0	0	0

TABLE A-6. PREDOMINANT GENERA OF XEROPHILIC FUNGI ISOLATED FROM SWAB SAMPLES OF CEILING SPACES

Location	CFU/sample	Fungi, Percent of Total Colonies		
		Cladosporium	*Penicillium*	*Aspergillus*
4th floor	3	34	0	50
4th floor NE	25	52	8	8
5th floor	47	24	2	7
1st floor	18	29	13	23

TABLE A-7. PREDOMINANT DUST XEROPHILIC FUNGI PERCENT

Location	CFU/g	Fungi, Percent of Total Colonies		
		Cladosporium	*Penicillium*	*Aspergillus*
1st floor	2.3×10^5	9	17	4
4th floor	1.5×10^5	29	9	8