HETA 94-0422-2622
Martin County Administration Building
Stuart, Florida

Kenneth F. Martinez, M.S.E.E., C.I.H.
Angela M. Weber, M.S.
Douglas B. Trout, M.D., M.H.S.

PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Kenneth F. Martinez, M.S.E.E., C.I.H. and Angela M. Weber, M.S. of the Industrial Hygiene Section (IHS); and Douglas B. Trout, M.D., M.H.S. of the Medical Section (MS), Hazard Evaluations and Technical Assistance Branch (HETAB), Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Desktop publishing by Kate L. Marlow.

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Health Hazard Evaluation Report 94-0422-2622
Martin County Administration Building
Stuart, Florida
January 1997

Kenneth F. Martinez, M.S.E.E., C.I.H.
Angela M. Weber, M.S.
Douglas B. Trout, M.D., M.H.S.

SUMMARY

On September 14, 1994, the National Institute for Occupational Safety and Health (NIOSH) received a request to conduct a health hazard evaluation (HHE) at the Martin County Administration Building (MCAB) in Stuart, Florida. The request noted "numerous problems with the building which relate to the indoor air quality." Microbiological contamination of heating, ventilating, and air conditioning (HVAC) units and building carpet was cited as possible cause of occupant symptoms. A previous epidemiologic investigation of the building identified one worker diagnosed with an immune deficiency, believed to be related to the work environment. Environmental assessments by outside consultants reported evidence of potential biological exposure to *Aspergillus* species, pigeon excreta, and other organic dusts, as well as improperly draining fan coil units (FCU), and an insufficient supply of outside air.

On October 11-14, 1994, NIOSH investigators conducted a site visit at the MCAB. The environmental evaluation included: (1) physical inspection of HVAC units (including the two outdoor central air supply package units and selected building fan coil units [FCU]); (2) collection of air samples for culturable fungi, spores, and volatile organic chemicals (VOC); (3) real-time measurements of carbon dioxide (CO_2), temperature, relative humidity, and airborne particulates; (4) collection of bulk samples from HVAC duct insulation and building carpet for microbiologic analysis; and (5) collection of carpet dust for characterization. The medical evaluation consisted of confidential, private medical interviews with 31 building employees and a review of appropriate medical records.

Bulk samples collected from various HVAC systems (FCUs and central systems) revealed potential fungal reservoirs in certain areas. However, air samples collected for culturable fungi and fungal spores did not demonstrate dissemination from these reservoirs. Thermal desorption tube analysis did not identify VOCs (qualitatively or quantitatively) that could be associated with occupant symptoms. Elevated CO_2 concentrations (above 800 ppm) were measured at various locations during the afternoon measurement period. These levels suggest that inadequate amounts of outdoor air is being introduced into some of the occupied areas of the building.

In the private medical interviews, MCAB employees reported different types of non-specific symptoms, including headache, tiredness, rhinitis, sinus congestion, and respiratory symptoms. Although no consistent pattern was found among all interviewed employees, a few employees reported worsening symptoms when at work.

Based on medical interviews, medical record review, and environmental data, the symptoms and health complaints reported at the MCAB cannot be readily associated with a specific causative agent present in the workplace at the time of the NIOSH investigation. It is possible that some of the current health symptoms are related to an inadequate supply of outdoor air. The identification of small, localized areas of microbiologic contamination should be promptly remediated as part of a comprehensive preventive maintenance program.

Keywords: Bioaerosols, Microorganisms, Fungi, Bacteria, Spores, Carbon Dioxide, Volatile Organic Compounds (VOC), Mycotoxins, Indoor Environmental Quality, Insufficient Outdoor Air

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INTRODUCTION

On September 14, 1994, the National Institute for Occupational Safety and Health (NIOSH) received a request to conduct a health hazard evaluation (HHE) at the Martin County Administration Building (MCAB) in Stuart, Florida. The request noted "numerous problems with the building which relate to the indoor air quality." Microbiological contamination of heating, ventilating, and air conditioning (HVAC) units and building carpet was cited as possible cause of occupant symptoms. On October 11-14, 1994, NIOSH investigators conducted a site visit at the MCAB. The environmental evaluation included: (1) physical inspection of HVAC units (including the two outdoor central air supply package units and selected building fan coil units [FCU]); (2) collection of air samples for culturable fungi, spores, and volatile organic chemicals (VOC); (3) real-time measurements of carbon dioxide (CO_2), temperature, relative humidity, and airborne particulates; (4) collection of bulk samples from HVAC duct insulation and building carpet for microbiologic analysis; and (5) collection of carpet dust for characterization. The medical evaluation consisted of confidential, private medical interviews with building occupants and a review of medical records. This report contains environmental sampling results, results of the medical evaluation, and recommendations regarding identified potential problem conditions in the building.

BACKGROUND

The MCAB is a brick and glass four-story structure constructed in the early 1980's and occupies approximately 65,000 square feet of floor area in a mixed suburban/commercial area in Stuart, Florida. The original design function of the building was classified for multiple tenant occupancy and, as a result, central building mechanical systems (two roof top, single packaged, 7½ ton air-conditioning units) were limited to the core areas of the building. In 1987, the building was renovated for occupancy by the County. The renovation included the addition of zoned FCU systems (approximately 50 in number ranging in capacity from 2 to 10 tons, located above the suspended ceiling), carpet, and paint to interior surfaces. The building was subsequently occupied by the County in 1988. Conditioned outdoor air, by design, is supplied to the restrooms and corridors. A separate exhaust fan to the outside connects to each of the restrooms.

In the summer of 1993, the acting County Administrator retained the services of a consultant to perform an indoor air quality investigation as a result of a County employee reportedly being diagnosed with hypersensitivity pneumonitis. The consultant evaluation (as contained in a report dated December 10, 1993) consisted of a thorough inspection of the building and the HVAC components, direct-reading environmental measurements (including CO_2, respirable particulates, temperature, and relative humidity), bulk sample collection (from duct insulation and areas around the fresh air intakes of the central HVAC systems) with subsequent analysis for culturable fungi, and select tape samples from various surfaces microscopically analyzed for fungal spore and hyphal fragments. Significant observations from the building walk-through included water incursion during heavy rains, moldy odors in the morning hours, FCU water leaks, apparent microbiologic growth in perimeter areas of the first floor, negative pressurization of the building relative to the outdoors, positive pressurization of the cafeteria relative to adjacent areas, and insufficient supply of outdoor air. All direct-reading measurement results were below applicable evaluation criteria. Analytical results from collected bulk samples indicated that most were not reservoirs or amplification sites for fungi. Microscopic analysis of tape samples revealed one problem FCU and one northwest office with a possible amplification site behind the vinyl wall covering. In the report, recommendations were made to resolve water incursion problems, remediate identified

microbiologic reservoirs, and generally improve the air quality supplied by the HVAC systems.

In September 1993, a series of medical consultation discussions began between an epidemiology investigator, contracted by the County, and other physicians caring for an employee who had been diagnosed with an immune deficiency believed to be related to the work environment at MCAB. These discussions resulted in a questionnaire survey of 149 MCAB occupants (conducted by the epidemiology investigator). In a report to the acting County Administrator dated April 20, 1994, the epidemiology investigator reported that the results of the questionnaire survey indicated that the "prevalence of medical symptoms and discomfort did not appear unusual." However, according to the investigator, several employees with work-related symptoms were identified (i.e., 14 individuals that met a definition of potential asthma and/or potential interstitial lung disease). Additionally, 11 employees were identified who had symptoms similar to those experienced by the above-mentioned employees. The epidemiology investigator recommended that screening pulmonary examinations be offered by a contracted local physician.

In February 1994, the environmental consultant retained in 1993 was contracted to conduct a follow-up investigation of MCAB and an engineering firm was contracted to evaluate the HVAC systems in the building. During the follow-up investigation, the environmental consultant focused exclusively on microbiologic analysis of dust samples collected from numerous locations (mainly carpet) throughout MCAB. Results of the analyses for culturable fungi identified four offices that could be considered mycologically "atypical from a qualitative viewpoint." Recommendations included remediation of contaminated carpet and/or other materials and the disinfection and removal of pigeon excreta identified in pipe chase columns. The engineering report of the HVAC systems evaluation concluded that the "...existing HVAC systems in this building cannot maintain the desired conditions and cannot be retrofit to be serviceable and to perform as necessary." Additional conclusions included the inability of the systems to meet outdoor air delivery as prescribed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 62-1989[1]; unserviceable FCUs based on inaccessibility; thermally incompatible zones; the use of low efficiency filters; inefficient placement of small, split systems; lack of moisture overflow trays; inadequate flow in some spaces; and the lack of positive humidity control.

It is important to note that, prior to the NIOSH investigation, some remediation efforts had been conducted on the fourth floor and in the Commissioners' Chamber as a result of the previous consultant reports. These efforts included replacement of the HVAC system and carpet in the office of the employee diagnosed with an immune deficiency; replacement of the HVAC system serving the Commissioners' Chamber; replacement of the carpet in the Commissioners' Chamber; steam cleaning of the furniture in the Commissioners' Chamber; and the clean-up and patching of holes in the chase columns. (The chase columns were believed to be the source of pigeon excreta and other associated contaminants infiltrating the building.)

METHODS

Environmental

To determine the concentrations of culturable airborne fungi, the Spiral Air Systems (SAS) Portable Air Sampler (Pool Bioanalysis Italiana, Milano, Italy) was used at a calibrated flow rate of 186 liters per minute (Lpm) over a sample period of 2.7 minutes. Malt extract agar was used for the enumeration of fungi. Sample plates were incubated at 30˚C. The taxa and rank of the collected microorganisms were determined by morphological characteristics. During each sampling run with the SAS sampler, samples were collected for total particulates using the Met One Model 227 Hand-Held Particle Counter (Met One, Inc., Grants Pass, Oregon). The Met One counts particles using a solid state laser diode in two simultaneous size ranges [0.3 and 1 micrometer (μm) were selected for this

survey] at an operating flow rate of 2.8 Lpm. The data for particulates greater than 1 μm were used for analysis. All total particle count samples were collected over a sample time of 5 minutes.

Air samples for culturable fungi were collected at 17 interior building locations and one outdoor location. Sampling locations included the Commissioners' Chamber, the Commissioners' reception desk, the fourth floor corridor, and Rooms 101, 103, 105, 201, 216, 226, 231, 301, 324, 340, 352, 411, and 426. At each sample location, four replicate samples were collected for culturable fungi (with the exception of the outdoor and Commissioners' Chamber locations where eight replicate samples were collected). Three replicate samples were collected for total particulates greater than 1 μm (with the exception of the outdoor and Commissioners' Chamber locations where six replicate samples were collected). The number of replicates for the outdoor and Commissioners' Chamber sampling locations was increased for statistical confidence of these non-complaint areas for comparison to complaint areas. (The Commissioners' Chamber was designated as a non-complaint area due to the extent of remediation and remodeling work conducted.) Samples were collected over a two day period. Temperature and relative humidity (RH) were recorded at each location.

To measure the airborne concentrations of total spores (both viable and non-viable), 27 area air samples were collected at locations throughout the four floors of the building including complaint and non-complaint areas, as well as an outdoor sample location. Spores were collected with polycarbonate filters with a pore size of 0.2 μm and a diameter of 37 millimeters (mm). The filters were placed on cellulose support pads and sealed in plastic filter cassettes. The filter holders were connected via Tygon™ tubing to Gillian Hi Flow Sampler™ battery-operated personal sampling pumps operating at a flow rate of 2 Lpm over an 8-hour time period. Calibration of the flow rates was performed immediately prior to, and after, sampling. For subsequent calculation of sample volumes, the mean of the pre- and post- sampling flow rates was used. Calibration of the pumps on-site was accomplished with a Kurz Pocket Flow Calibrator™ mass flowmeter, which in turn was calibrated with a primary standard (bubble flowmeter) prior to the evaluation. Samples were analyzed for fungal spore counts by optical microscopy. Filters were cleared with acetone vapor, mounted in cotton blue/lactic acid, and scanned at 400x magnification with bright field or phase contrast illumination. Two hundred fields were counted for each sample. Only particles greater than 2 μm in diameter were considered to be possible fungal spores.

Thermal desorption tubes were used in selected areas to determine the presence of VOCs. Sample locations included Rooms 101, 103, 105, 123, 200, 216, 232, 313, 340, 346, 352, 411, 430, the Commissioners' Chamber, the third floor corridor, the fourth floor corridor, and outside (for reference). Air was drawn through each thermal tube with Gillian personal sampling pumps at a calibrated flow rate of 20 cubic centimeters per minute (cc/min). Sample times were selected to obtain a total sample volume of approximately 6 liters of air. Each stainless steel tube (configured for use with the Perkin-Elmer ATD 400 thermal desorption system) was packed with three beds of sorbent materials; a front layer of Carbotrap C (~350 mg), a middle layer of Carbotrap (~175 mg), and a back section of Carboxen 569 (~150 mg). All samples were analyzed qualitatively using the ATD 400 thermal desorption system containing an internal focusing trap packed with Carbopack B/Carboxen 1000 sorbents. The thermal unit was interfaced directly to a gas chromatograph and mass selective detector.

Direct measurements for temperature, RH, and carbon dioxide (CO_2) were collected at sixteen sample locations inside the building and one location outdoors. Sampling was conducted at approximately 10:00 a.m. and again at 3:00 p.m. Carbon dioxide was measured using a Gastech RI 411 CO_2 monitor (Gastech, Inc., Newark, California) that was calibrated before and after the day's samples were collected using 800 parts per million (ppm) CO_2 in nitrogen (Alphagaz, Division of Liquid Air Corporation, Cambridge, Maryland) as a calibrant.

Temperature and RH were measured using a TSI VelociCalc Plus, Model 8360 (St. Paul, Minnesota). This meter is capable of providing direct readings for dry-bulb temperature and RH, ranging from 14 to 140˚F ±0.5˚F and 20 to 95% ±4%, respectively.

The collection of bulk samples from floor carpet and interior duct insulation was facilitated by cutting an approximate one square inch section from the material. A representative portion of each sample was weighed and vortexed in a recorded volume of 0.2% Tween 20. Serial dilutions of the prepared samples were then plated to the appropriate nutrient media. Additionally, microscopic characterization of settled dusts on specific building materials was conducted on samples collected with a high efficiency particulate air (HEPA) vacuum collector through a filter "sock." The collection of 8 samples from carpets (in Rooms 101, 105, 200, 216, 340, 352, 430, and the Commissioners' Chamber) was conducted in a manner that produced approximately 15 cubic centimeters (cc) of dust on each filter. Dust samples were subsequently analyzed microscopically for percentages of skin flakes, cellulose fiber, synthetic fibers, fibrous glass, human hairs, cat hairs, wood chips, quartz, fungal matter, pollen, pine pollen, and miscellaneous fine particles.

Visual inspection of interior duct surfaces was accomplished with a rigid boroscope (Instrument Technologies, Inc., Westfield, Massachusetts).

Medical

The NIOSH medical officer performed private medical interviews with 31 building occupants who requested interviews. The interviews consisted of non-standardized questions regarding health symptoms and their potential relationship to the work environment. Medical records from employees who reported illnesses thought to be related to the worksite were requested and these records were reviewed.

EVALUATION CRITERIA

NIOSH investigators have completed over 1,200 investigations of the occupational indoor environment in a wide variety of non-industrial settings. Almost all of these investigations have been conducted since 1979.

The symptoms and health complaints reported to NIOSH by building occupants have been diverse and usually not suggestive of any particular medical diagnosis or readily associated with a causative agent. A typical spectrum of symptoms has included headaches, unusual fatigue, varying degrees of itching or burning eyes, irritations of the skin, nasal congestion, dry or irritated throats, and other respiratory irritations. Typically, the workplace environment has been implicated because workers report that their symptoms lessen or resolve when they leave the building.

A number of published studies have reported a high prevalence of symptoms among occupants of office buildings.[2,3,4,5,6] Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[7,8] Among these factors are imprecisely-defined characteristics of HVAC systems, cumulative effects of exposure to low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.[9,10,11,12,13,14] Indoor environmental pollutants can arise from either outdoor sources or indoor sources.

There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related to the occurrence of symptoms than any measured indoor contaminant or condition.[15,16,17] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[17,18,19,20]

Less often, an illness may be found to be specifically related to something in the building environment.

Some examples of potentially building-related illnesses are allergic rhinitis, allergic asthma, hypersensitivity pneumonitis, Legionnaires' disease, Pontiac fever, carbon monoxide poisoning, and reaction to boiler corrosion inhibitors. The first three conditions can be caused by various microorganisms or other organic material. Legionnaires' disease and Pontiac fever are caused by *Legionella* bacteria. Sources of carbon monoxide include vehicle exhaust and inadequately-ventilated kerosene heaters or other fuel-burning appliances. Exposure to boiler additives can occur if boiler steam is used for humidification or is released by accident.

Problems that NIOSH investigators have found in the non-industrial indoor environment have the following: poor air quality due to ventilation system deficiencies, overcrowding, volatile organic chemicals from furnishings, emissions from office machines, structural components of the building and contents, tobacco smoke, microbiological contamination, and outside air pollutants; comfort problems due to improper temperature and RH conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job-related psychosocial stressors. In most cases, however, these problems could not be directly linked to the reported health effects.

Standards specific for the non-industrial indoor environment do not exist. NIOSH, the Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards or recommended limits for occupational exposures.[21,22,23] With few exceptions, pollutant concentrations observed in non-industrial indoor environments fall well below these published occupational standards or recommended exposure limits. ASHRAE has published recommended building ventilation design criteria and thermal comfort guidelines.[1,24] The ACGIH has also developed a manual of guidelines for approaching investigations of building-related complaints that might be caused by airborne living organisms or their effluents.[25]

Measurement of indoor environmental contaminants has rarely proved to be helpful in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proven relationship between contaminants and specific building-related illnesses. The low-level concentrations of particles and variable mixtures of organic materials usually found are difficult to interpret and usually impossible to causally link to observed and reported health symptoms. However, measuring ventilation and comfort indicators such as CO_2, temperature and RH, has proven useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems.

NIOSH and the Environmental Protection Agency (EPA) jointly published a manual on building air quality, written to help prevent environmental problems in buildings and solve problems when they occur.[26] This manual suggests that indoor environmental quality (IEQ) is a constantly changing interaction of a complex set of factors. Four of the most important elements involved in the development of IEQ problems are: (1) a source of odors or contaminants; (2) a problem with the design or operation of the HVAC system; (3) a pathway between the contaminant source and the location of the complaint; and (4) the building occupants. A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems.

The basis for measurements made during this evaluation are listed below.

Carbon Dioxide

Carbon dioxide is a normal constituent of exhaled breath and, if monitored, can be used as a screening technique to evaluate whether adequate quantities of outside air are being introduced into an occupied space. ASHRAE's most recently published ventilation standard, ASHRAE 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 cubic feet per minute per person (cfm/person) for office spaces, and

15 cfm/person for reception areas, classrooms, libraries, auditoriums, and corridors.[1] Maintaining the recommended ASHRAE outdoor air supply rates when the outdoor air is of good quality, and there are no significant indoor emission sources, should provide for acceptable indoor air quality.

Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 300-350 parts per million [ppm]). Carbon dioxide concentration is used as an indicator of the adequacy of outside air supplied to occupied areas. When indoor CO_2 concentrations exceed 800 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected.[27] Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased. It is important to note that CO_2 is not an effective indicator of ventilation adequacy if the ventilated area is not occupied at its usual level.

Temperature and Relative Humidity

Temperature and RH measurements are often collected as part of an indoor environmental quality investigation because these parameters affect the perception of comfort in an indoor environment. The perception of thermal comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures.[28] Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. The ASHRAE Standard 55-1992, specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[24] ASHRAE also recommends that RH be maintained between 30 and 60% RH. Excessive humidities can support the growth of microorganisms, some of which may be pathogenic or allergenic.

Microorganisms

Microorganisms (including fungi and bacteria) are normal inhabitants of the environment. The saprophytic varieties (those utilizing non-living organic matter as a food source) inhabit soil, vegetation, water, or any reservoir that can provide an adequate supply of a nutrient substrate. Under the appropriate conditions (optimum temperature, pH, and with sufficient moisture and available nutrients) saprophytic microorganism populations can be amplified. Through various mechanisms, these organisms can then be disseminated as individual cells or in association with soil or dust particles or water droplets. In the outdoor environment, the levels of microbial aerosols will vary according to the geographic location, climatic conditions, and surrounding activity. In a "normal" indoor environment, where there is no unusual source of microorganisms, the level of microorganisms may vary somewhat as a function of the cleanliness of the HVAC system and the numbers and activity level of the occupants. Generally, the indoor levels are expected to be below the outdoor levels (depending on HVAC system filter efficiency) with consistently similar ranking among the microbial species.[29,30]

Some individuals manifest increased immunologic responses to antigenic agents encountered in the environment. These responses and the subsequent expression of allergic disease is based, partly, on a genetic predisposition.[31] Allergic diseases which have been reported to be associated with exposures in indoor environments include allergic rhinitis (nasal allergy), allergic asthma, allergic bronchopulmonary aspergillosis (ABPA), and extrinsic allergic alveolitis (hypersensitivity pneumonitis).[29] Allergic respiratory diseases resulting from exposures to microbial agents have been documented in agricultural, biotechnology, office, and home environments.[32,33,34,35,36,37,38,39]

Symptoms vary with the type of allergic disease: (1) allergic rhinitis is characterized by episodes of sneezing, itching of the nose, eyes, palate, or pharynx, nasal stuffiness with partial or total airflow obstruction, and rhinorrhea with postnasal drainage; (2) allergic asthma is characterized by episodic or prolonged wheezing and shortness of breath due to bronchial narrowing; (3) ABPA is characterized by

the production of IgE and IgG antibodies with symptoms of cough (which is sometimes productive of mucous), fatigue, low grade fever, and wheezing.[29,40] Heavy exposures to airborne microorganisms can result in an acute form of extrinsic allergic alveolitis which is characterized by chills, fever, malaise, cough, and dyspnea (shortness of breath) appearing 4 to 8 hours after exposure. Onset of the chronic form of extrinsic allergic alveolitis is thought to be induced by a continuous low-level exposure, and onset occurs without chills, fever, or malaise but is characterized by progressive shortness of breath with weight loss.[41] However, despite these relatively well-defined diseases which have been reported to occur in office environments, as described previously, symptoms most commonly encountered by office workers are generally not associated with any particular medical diagnosis or etiologic agent.

Acceptable levels of airborne microorganisms have not been established, primarily due to the varying immunogenic susceptibilities of individuals. Relationships between health effects and environmental microorganisms must be determined through the combined contributions of medical, epidemiologic, and environmental evaluation.[25] The current strategy for on-site evaluation involves a comprehensive inspection of problem areas to identify sources of microbial contamination and routes of dissemination. In those locations where contamination is visibly evident or suspected, bulk samples may be collected to identify the predominant species (fungi, bacteria, and thermoactinomycetes). In limited situations, air samples for microorganisms may be collected to document the airborne presence of a suspected microbial contaminant. Airborne dissemination (characterized by elevated levels in the complaint area, compared to outdoor and non-complaint areas, and an anomalous ranking among the microbial species) correlated to occupant symptomology may suggest that the contaminant may be responsible for the health effects.

RESULTS

Environmental

A graphical summary of the results of bioaerosol sampling for fungi is presented in Figure 1. The geometric mean fungal concentration at various locations inside the building ranged from 3 to 25 colony forming units per cubic meter of air (CFU/m^3); outside of the building, the geometric mean fungal concentration was 87 CFU/m^3. Sampled areas on the first floor and some areas on the second floor exhibited concentrations approximately two times greater than those observed in other areas of the building. However, the taxonomic rank (i.e., the ranking of the predominant genera according to frequency of occurrence) was similar among the samples collected outdoors, in the non-complaint areas, and in the complaint areas. Speciation of fungal sample plates showed a random distribution of many genera predominated by *Alternaria*, *Aspergillus*, *Cladosporium*, *Epicoccum*, *Geotrichum*, *Penicillium*, *Microsporum*, and *Trichophyton*.

The results of the air sampling for total spores are shown in Figure 2. The spore concentrations throughout the building ranged from 170 to 7,910 spores per cubic meter of air (spores/m^3) at the time of the NIOSH investigation. The spore concentration outside the building was 23,450 spores/m^3. An approximate 25-five fold reduction in the concentration indoors (occupied areas) versus outdoors is observed. However, as reported in the culturable fungi sampling results, marginally increasing concentrations are evident from the fourth floor down to the first floor.

The results from the analysis of bulk samples (for microbial content) are presented in Table I. Samples of interior duct lining insulation collected from select FCUs (i.e., 3, 10, 12, 20, 23, 25, 33, 46, and 48) showed a range of microbiological colonization from non-detectable to 1,800,000 colony forming units per gram of material (CFU/gm). Samples collected from FCU 12, FCU 20, FCU 25, FCU 33, FCU 46, and FCU 48 exhibited low concentrations of fungal and bacterial colonization; visual inspections made of

these same system interiors (with the use of a rigid boroscope) indicated clean interior duct lining with no visible accumulation of dirt or observable microbiologic growth. In contrast, FCU 3, FCU 10, and FCU 23 had visible accumulation on insulation material. The insulation material from FCU 3 and FCU 10 had high concentrations of predominantly yeast colonies, whereas, the samples from FCU 23 showed a high concentration of predominantly fungi (specifically, *Cladosporium*). Additionally, analysis of condensate debris from FCU 10 revealed high concentrations of *Fusarium* and yeast colonies. Bulk samples of the insulation material collected from the two central HVAC systems supplying outdoor air to the building revealed proliferation of fungi (*Penicillium*, *Cladosporium*, and *Aspergillus* species) and yeasts. Analysis of condensate water from the north system revealed high concentrations of yeasts, whereas, analysis of condensate water from the south system revealed high concentrations of *Fusarium* species in addition to yeast colonies. Both central systems had standing water in the drain pans that may be due to a clog in the drain line or insufficient trap depth.

Bulk samples of carpeted material from Rooms 101, 103, 105, 216, and 340 were obtained. These areas were selected based on reports of water incursion. Microbiologic analysis of carpet samples revealed high concentrations of bacteria (*Bacillus*, *Micrococcus*, *Staphylococcus*, *Flavobacterium*, and *Pseudomonas* species) and yeasts (excluding one of the samples collected from Room 101 which showed a low concentration) ranging from 3,300,000 to 310,000,000 CFU/gm. Additionally, bulk samples of carpet collected from Rooms 101 and 105 revealed high concentrations of predominantly *Fusarium* species, at 370,000 and 760,000 CFU/gm, respectively.

Microscopic characterization of settled dusts collected from carpet material from Rooms 101, 105, 200, 216, 340, 352, and the Commissioners' Chamber revealed nothing to support that these materials are reservoirs for microbiologic or other immunologically active agents. In all sampled materials, fungal matter was identified only at trace concentrations. Small amounts (up to 5%) of other allergens (i.e., cat hairs, insect parts, plant matter, and pollen) were present in a few samples.

The results of the air sampling for particulates greater than 1 µm are shown in Figure 3. The particle count concentrations throughout the building ranged from 80,800 to 566,500 particles per cubic meter of air (part/m^3) at the time of the NIOSH investigation. By comparison, the particulate concentration outside the building was 965,900 part/m^3. The localized trends observed in the culturable fungal and spore count results are consistent with those observed in the particulate count data. Specifically, increasing concentrations are noted from the fourth floor down to the first floor (with the exception of Room 411 which exhibited the highest count inside the building).

Carbon dioxide, temperature, and RH measurements are presented in Figures 4, 5, and 6. The CO_2 concentrations during the morning sampling period ranged from 425 to 675 ppm. During the afternoon sampling period, the CO_2 concentrations increased (ranging from 500 to 1225 ppm), with approximately 80% of the sampling locations exceeding the NIOSH criteria of 800 ppm.[27] The CO_2 concentrations measured at the outdoor sampling location for the morning and afternoon were 450 and 375 ppm, respectively. Expected background concentrations of CO_2 normally range between 300 and 350 ppm. The elevated outdoor level observed during the morning sampling period may be, in part, due to the proximity of the sampling location to a busy street. Temperatures in the building interior ranged from 73.8 to 77.7˚F during the morning sampling period and from 72.2 to 75.9˚F during the afternoon. The outdoor temperatures during the morning and afternoon were 79.3 and 83.2˚F, respectively. Relative humidity remained fairly consistent (in the mid to high 40s) for all sampling locations throughout the day.

Overall, the concentrations of VOCs, as well as the number of individual compounds identified, appeared to be much lower in the Commissioners' Chamber (non-complaint area) compared to all other

areas of the building. The most likely explanation for this phenomenon is that this area is receiving adequate amounts of outdoor air to dilute the concentration of VOCs and other contaminants. This is supported by the CO_2 measurements which were lower in this area. Renovation recently completed in this area included the addition of a new HVAC system. Some samples contained small quantities of a hydrocarbon mixture consisting mainly of branched alkanes in the range of C_9-C_{12}. These quantities were elevated compared to other compounds detected. According to NIOSH chemists, this mixture closely resembles that of a liquid toner solution used in some copier machines. Areas where samples contained the highest concentrations of hydrocarbons were located on the third floor and included rooms 346, 340, 313, and 352, as well as near the elevators.

Another hydrocarbon mixture, consisting of some alkyl benzenes, was identified throughout the first floor including the Commissioners' Chamber, and Rooms 101, 103, 105, and 123. This compound was not found in any other areas of the building, and may be associated with combustion by-products from the stove located in the cafeteria on the first floor (the stove did not have local exhaust ventilation). The cafeteria was under positive pressure relative to the adjacent areas, which would allow cafeteria generated airborne contaminants and/or odors to be disseminated to these adjacent areas. Another potential source of this compound may be from the entrainment of contaminants found outside. During the site visit, the building was found to be under negative pressure. Potential hydrocarbon sources which were identified outside include nearby traffic as well as individuals smoking near the entrances of the building.

Isopropanol was a major component of most samples, however, concentrations were low. The source of this compound is unknown. Trace amounts of several other compounds were also detected such as toluene, acetone, ethanol, 1,1,1-trichloroethane, hexane, butanol, perchloro-ethylene, butyl cellosolve, limonene, phenol, butyl acetate, and styrene.

Medical

The NIOSH medical officer conducted confidential interviews with 31 employees who requested an interview; the 31 employees made up 21% of the approximately 175 employees in the building. All four floors of the Administrative Building were represented among those interviewed, and all interviewed employees worked in office settings while in the building. Interviewed employees identified several topics of concern related to their work environment, including: 1) poor regulation of temperature and air control in the offices; 2) the presence of pigeons in parts of the building as well as the presence of bird droppings, feathers, and other debris on the ceiling tiles in some offices; and 3) increased levels of dust during some of the renovation work.

Interviewed employees reported a wide variety of health effects thought to be related to the work environment. The most common problems reported included sinus congestion, headaches, and fatigue. Two persons reported fever thought to be related to the workplace. Many employees reported having a history of allergies or upper respiratory symptoms that they felt became worse since they first started working in MCAB. There was no consistent temporal pattern reported among those who reported symptoms. Some employees noted a marked decrease in symptoms nightly when leaving work, some noted fluctuations within the day, some noted improvement only with prolonged absence from work, and some noted no change in symptoms when away from work.

Record Review

Medical records for seven employees were provided and reviewed. Two of these records described symptoms or health conditions not related to the work environment. The remaining five records described employees who each had a past history of allergies or allergic symptoms and who had experienced respiratory and systemic symptoms temporally related to presence at the worksite.

Collectively these symptoms included non-productive cough, trouble concentrating, shortness of breath, headache, fatigue, and chest tightness.

Natural killer (NK) cell function tests were performed on two of these employees. For the first employee, NK cell activity was reported as 16 lytic units (LU) (drawn after three weeks vacation) and 18 LU (after working two weeks), with the normal range given as 20 - 250 LU. (In both these samples there was a potential problem of delay in processing of the specimens which may have led to artificially low values). Previous medical testing performed six months earlier (while the employee was working in the building) revealed a NK cell function of 33 LU. In a second employee, NK cell activity was found to be decreased during periods of exposure to the Administrative Building (correlating with an increase in reported symptoms) and to be within normal ranges during periods of decreased exposure to the building.

Pulmonary function testing (PFT) for one of the individuals was performed during times of "high" and "low" exposure to the building ("high exposure" meaning working routinely in the building, "low exposure" meaning out of work for at least two weeks). The results of these PFTs were all within the normal ranges with some variability between tests. The lung diffusing capacity was measured at 83% (twice), 86%, 88%, and 97% of the predicted value. The two "low exposure" test periods resulted in diffusing capacity values of 88% and 97% (the two highest values), and the employee reported decreased symptoms during this "low exposure" period.

DISCUSSION

To elicit an immunologic response in a susceptible individual, a microorganism must be present in the environment (reservoir), capable of propagation to concentrations necessary to induce a response (amplification), and be dispersed as an aerosol to the susceptible individual (dissemination).[29] The analysis of bulk insulation material collected from three building FCUs with visible accumulation of dirt and debris showed high numbers of viable yeast and fungal colonies. Additionally, condensate material from one of the FCUs and condensate water from the south central HVAC system revealed viable colonies of *Fusarium*. Certain *Fusarium* species (*Fusarium roseum*, *Fusarium tricinctum*, *Fusarium oxysporum*, etc.) are known to produce a variety of toxigenic agents (i.e., trichothecenes and zearalenone).[42,43] However, the mean concentration of airborne culturable fungi inside the building was well below the concentrations observed outdoors. The taxonomic ranking seen in the culturable sample results does **not** indicate dissemination of reservoirs of fungal species that have typically been associated with building-related health effects (i.e., *Aspergillus*, *Penicillium*, *Sporobolomyces*, *Alternaria*, etc.).[25] Speciation of fungal sample plates showed a random distribution of many genera predominated by *Alternaria*, *Aspergillus*, *Cladosporium*, *Epicoccum*, *Geotrichum*, *Penicillium*, *Microsporum*, and *Trichophyton*.

Measured airborne spore concentrations do not indicate the dissemination of fungal reservoirs in the building, which is consistent with the culturable sampling results. Outdoor concentrations of fungal spores were at least 5-times higher than the concentration of spores indoors. (The determination of total spore numbers is desirable because allergic and hypersensitivity reactions may be caused by the presence of fungal antigens and may not be linked to the viability of fungi.[44]) Examination of the total particulate counts (for particles greater than 1 μm) shows a consistent reduction in the concentration indoors versus outdoors. The reduction of particle concentrations from outdoor levels by 50-90% (and the reduction in spore concentrations) indicates that the filtration on the outdoor air intakes of the central HVAC units is effectively removing a portion of the outdoor particulate load. The observed trend of increasing concentrations of culturable fungi, spores, and total particulates sampling from the fourth floor down to the first floor is most likely due to the increased level of occupant traffic in the lower floors. For example, the entry and egress of people through the main entry door (on the ground floor)

can significantly increase measured concentrations due to the disruptive action of walking on carpeted and non-carpeted areas and the entrainment of outdoor air (and contaminants) with individual or door movement.

Elevated CO_2 concentrations were observed for all sampling locations during the afternoon measurement period. Many of these concentrations exceeded 800 ppm, used by NIOSH investigators as a criterion level.[27] Management reports have indicated that efforts were being made to address this issue through modification of the two existing central supply systems. The temperature and RH levels were within the temperature and RH comfort guidelines recommended by the ASHRAE.[24]

In our record review, measures of obstructive and restrictive airway disease, as well as a measure of lung diffusing capacity, were all within the normal ranges. There was, however, evidence in the records reviewed for one employee of mildly improved diffusing capacity during periods of "low" exposure in the building. This same employee had been found by personal physicians to have an IgG subclass deficiency and to have intermittently-reduced NK cell function, potentially a sign of reduced immune system function. The clinical significance, as well as the etiology, of these tests of immune function and the changes in lung diffusing capacity are unclear at this time.

CONCLUSIONS

Reports of building-related health complaints have become increasingly common in recent years; unfortunately, the causes of these symptoms have not been clearly identified. Many factors are suspected (e.g., VOCs, formaldehyde, microbial proliferation within buildings, inadequate amounts of outside air, etc.). While it has been difficult to identify concentrations of specific contaminants that are associated with the occurrence of symptoms, it is felt by many researchers in the field that the occurrence of symptoms among building occupants can be lessened by providing a properly maintained interior environment. Adequate control of the temperature is a particularly important aspect of employee comfort.

Bulk samples collected from various HVAC systems (FCUs and central systems) in MCAB revealed potential fungal reservoirs in certain areas of the building. However, air samples collected for culturable fungi and fungal spores did not demonstrate dissemination from these reservoirs. Additionally, the analysis of thermal desorption tube samples collected throughout the building did not reveal information about VOCs (qualitatively or quantitatively) that could be associated with occupant symptoms. Administrative Building employees have reported different types of non-specific symptoms, including headache, tiredness, rhinitis, sinus congestion, and respiratory symptoms. Although no consistent relationship was found among all interviewed employees, a few employees reported a temporal relationship of worsening of these symptoms with presence at the worksite. Elevated CO_2 concentrations were observed at various locations during the afternoon measurement period. These levels are suggestive of inadequate amounts of outdoor air being introduced into some of the occupied areas of the building and could potentially be related to some of the current health symptoms and discomfort reported by employees.

The industrial hygiene survey did not suggest any specific causative agent in the MCAB, present at the time of the investigation, which would account for the illnesses or symptoms experienced by those employees whose medical records were reviewed. However, it is important to note that prior to the conduct of the NIOSH investigation, remediation efforts were made to correct some of the deficiencies noted by the medical and environmental consultants contracted by the County. These efforts were focused in the Commissioners' Chamber and on the fourth floor.

RECOMMENDATIONS

The following recommendations are offered to correct deficiencies and optimize employee comfort:

! Three FCUs (out of 9 inspected systems) and both central outdoor air supply systems exhibited evidence of microbiological contamination of insulation material and/or condensate pans. Visible or suspected microbial contamination requires remediation efforts. Remediation should include removal of the contaminated material and/or clean-up with a high efficiency particulate air filter (HEPA) vacuum and decontamination with an effective chemical agent (i.e., 5 to 10% solution of chlorine bleach). Removal should be limited to those materials not conducive to clean-up (i.e., porous building components). Remediation personnel should be appropriately equipped with personal protective equipment (i.e., HEPA-filtered respirators, clothing, gloves, etc.). The interior of all remaining building FCUs (i.e., those units that were not inspected during the NIOSH investigation) should be inspected for microbiologic contamination. Systems identified as contaminated should be remediated as above.

  For respirator use, the OSHA requires a respiratory protection program that includes the following components: written standard operating procedures, user instruction and training, cleaning and disinfection, storage, inspection, surveillance of work area conditions, evaluation of respirator protection program, medical review, and use of certified respirators.[45]

! Microbiologic analysis of carpet samples showed contamination by fungi, yeast, and bacteria. Gram positive bacterial species are normally found in association with human occupancy (i.e., from desquamated skin) and as normal constituents of the soil. However, the identification of Gram negative bacteria and yeast colonies are characteristic of microbial proliferation due to high moisture availability (i.e., water incursion into carpeted areas). Additionally, the identification of *Fusarium* may warrant special consideration because of the potential health effects of toxins produced by these organisms. Contaminated carpeting should be replaced following the guidelines presented above for HVAC remediation.

! Investigation of building air flow patterns revealed infiltration of untreated outdoor air into the building. This condition was primarily a result of the building's negative pressure and cracks in its envelope (including poor seals in the entry/exit doors and between windows and masonry). The amount of outdoor air delivered by the central supply systems should be increased to put the building under positive pressure and insure an adequate amount of outdoor air to the occupied spaces according to ASHRAE 62-1989.

! Poor envelope seals allow for the incursion of water into interior spaces (observed on the first floor) which can result in conditions conducive for the growth of microorganisms. Cracks and poor seals in the building envelope should be rectified.

! During the NIOSH investigation, occupant reports indicated continued leaks in the four building chases ("columns") that appeared responsible for the original infiltration of pigeon elements (e.g., feces, feathers, dander, etc.). The condition of these chases should be re-evaluated and all leaks repaired. The potential for infiltration from unidentified chase perforations is minimized if the building is maintained under positive pressure.

! During the NIOSH investigation, building occupants reported insect infestation. While insect intrusion management efforts appeared effective during the site visit, continued surveillance is warranted. Additionally, focused clean-up efforts should be instituted; it was observed during interior inspection of the FCUs that specific systems displayed dead insects and/or insect parts.

REFERENCES

1. ASHRAE [1990]. Ventilation for acceptable indoor air quality. Atlanta, GA: American Society of Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 62-1989.

2. Kreiss KK, Hodgson MJ [1984]. Building associated epidemics. In: Walsh PJ, Dudney CS, Copenhaver ED, eds. Indoor air quality. Boca Raton, FL: CRC Press, pp 87-108.

3. Gammage RR, Kaye SV, eds. [1985]. Indoor air and human health: Proceedings of the Seventh Life Sciences Symposium. Chelsea, MI: Lewis Publishers, Inc.

4. Woods JE, Drewry GM, Morey PR [1987]. Office worker perceptions of indoor air quality effects on discomfort and performance. In: Seifert B, Esdorn H, Fischer M, et al., eds. Indoor air '87, Proceedings of the 4th International Conference on Indoor Air Quality and Climate. Berlin Institute for Water, Soil and Air Hygiene.

5. Skov P, Valbjorn O [1987]. Danish indoor climate study group. The "sick" building syndrome in the office environment: The Danish town hall study. Environ Int. *13*:399-349.

6. Burge S, Hedge A, Wilson S, Bass JH, Robertson A [1987]. Sick building syndrome: a study of 4373 office workers. Ann Occup Hyg. *31*:493-504.

7. Kreiss K [1989]. The epidemiology of building-related complaints and illness. Occupational Medicine: State of the Art Reviews. *4*(4):575-592.

8. Norbäck D, Michel I, Widstrom J [1990]. Indoor air quality and personal factors related to the sick building syndrome. Scan J Work Environ Health. *16*:121-128.

9. Morey PR, Shattuck DE [1989]. Role of ventilation in the causation of building-associated illnesses. Occupational Medicine: State of the Art Reviews. *4*(4):625-642.

10. Mendell MJ, Smith AH [1990]. Consistent pattern of elevated symptoms in air-conditioned office buildings: A reanalysis of epidemiologic studies. Am J Public Health. *80*(10):1193-1199.

11. Molhave L, Bach B, Pedersen OF [1986]. Human reactions during controlled exposures to low concentrations of organic gases and vapours known as normal indoor air pollutants. Environ Int. *12*:167-175.

12. Fanger PO [1989]. The new comfort equation for indoor air quality. ASHRAE J. *31*(10):33-38.

13. Burge HA [1989]. Indoor air and infectious disease. Occupational Medicine: State of the Art Reviews. *4*(4):713-722.

14. Robertson AS, McInnes M, Glass D, Dalton G, Burge PS [1989]. Building sickness, are symptoms related to the office lighting? Ann Occup Hyg. *33*(1):47-59.

15. Wallace LA, Nelson CJ, Dunteman G [1991]. Workplace characteristics associated with health and comfort concerns in three office buildings in Washington, D.C. In: Geshwiler M, Montgomery L, and Moran M, eds. Healthy buildings. Proceedings of the ASHRAE/ICBRSD conference IAQ'91.

Atlanta, GA. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

16. Haghighat F, Donnini G, D'Addario R [1992]. Relationship between occupant discomfort as perceived and as measured objectively. Indoor Environ. *1*:112-118.

17. NIOSH [1991]. Hazard evaluation and technical assistance report: Library of Congress Madison Building, Washington, D.C. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 88-364-2104 - Vol. III.

18. Skov P, Valbjørn O, Pedersen BV [1989]. Influence of personal characteristics, job related factors, and psychosocial factors on the sick building syndrome. Scand J Work Environ Health. *15*:286-295.

19. Boxer PA [1990]. Indoor air quality: A psychosocial perspective. J Occup Med. *32*(5):425-428.

20. Baker DB [1989]. Social and organizational factors in office building-associated illness. Occupational Medicine: State of the Art Reviews. *4*(4):607-624.

21. CDC [1992]. NIOSH recommendations for occupational safety and health: Compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 92-100.

22. Code of Federal Regulations [1989]. OSHA Table Z-1-A. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

23. ACGIH [1996]. 1996 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

24. ASHRAE [1992]. Thermal environmental conditions for human occupancy. Atlanta, GA: American Society for Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 55-1992.

25. ACGIH [1989]. Guidelines for the assessment of bioaerosols in the indoor environment. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

26. NIOSH/EPA [1991]. Building air quality: a guide for building owners and facility managers. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 91-114.

27. NIOSH [1994]. NIOSH testimony to the U.S. Department of Labor: statement of the National Institute for Occupational Safety and Health. Presented at the public hearing on the proposed rulemaking on Indoor Air Quality, September 28, 1994. NIOSH policy statements. Cincinnati, OH: Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

28. NIOSH [1986]. Criteria for a recommended standard: occupational exposure to hot environments, revised criteria. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-13.

29. Burge, HA [1988]. Environmental allergy: definition, causes, control. Engineering Solutions to Indoor Air Problems. Atlanta, GA: American Society of Heating, Refrigeration and Air-Conditioning Engineers pp. 3-9.

30. Morey, MR, Feeley, JC [1990]. The landlord, tenant, and investigator: their needs, concerns and viewpoints. Biological Contaminants in Indoor Environments. Baltimore, MD: American Society for Testing and Materials pp. 1-20.

31. Pickering, CA [1992]. Immune respiratory disease associated with the inadequate control of indoor air quality. *Indoor Environ* 1:157-161.

32. Vinken W, Roels P [1984]. Hypersensitivity pneumonitis to *Aspergillus fumigatus* in compost. *Thorax* 39:74-74.

33. Malmberg P, Rask-Andersen A, Palmgren U, Höglund S, Kolmodin-Hedman B, Stålenheim G [1985]. Exposure to microorganisms, febrile and airway-obstructive symptoms, immune status and lung function of swedish farmers. *Scand J Work Environ Health* 11:287-293.

34. Topping MD, Scarsbrick DA, Luczynska CM, Clarke EC, Seaton A [1985]. Clinical and immunological reactions to *Aspergillus niger* among workers at a biotechnology plant. *British J Ind Med* 42:312-318.

35. Edwards JH [1980]. Microbial and immunological investigations and remedial action after an outbreak of humidifier fever. *British J Ind Med* 37:55-62.

36. Weiss NS, Soleymani Y [1971]. Hypersensitivity lung disease caused by contamination of an air-conditioning system. *Annals of Allergy* 29:154-156.

37. Hodgson MJ, Morey PR, Attfield M, Sorenson W, Fink JN, Rhodes WW, Visvesvara GS [1985]. Pulmonary disease associated with cafeteria flooding. *Archives Environ Health* 40(*2*):96-101.

38. Fink JN, Banaszak EF, Thiede WH, Barboriak JJ [1971]. Interstitial pneumonitis due to hypersensitivity to an organism contaminating a heating system. *Annals Internal Med* 74:80-83.

39. Banazak EF, Barboriak J, Fink J, Scanlon G, Schlueter EP, Sosman A, Thiede W, Unger G [1974]. Epidemiologic studies relating thermophilic fungi and hypersensitivity lung syndrome. *Am Review Resp Disease* 110:585-591.

40. Kaliner M, Eggleston PA, Mathews KP [1987]. Rhinitis and asthma. *JAMA* 258(*20*):2851-2873.

41. Jordan FN, deShazo R [1987]. Immunologic aspects of granulomatous and interstitial lung diseases. *JAMA* 258(*20*):2938-2944.

42. Mirocha CJ, Sadanand PV, Christensen CM [1977]. Chemistry of *Fusarium* and *Stachybotrys* mycotoxins. In: Wyllie TD, Morehouse LG, eds. Mycotoxic fungi, mycotoxins, mycotoxicoses: An encyclopedic handbook. Vol. 1. New York, NY: Marcel Dekker, Inc., p. 365.

43. Kim JC, Kang HJ, Lee DH, Lee YW, Yoshizawa T [1993]. Natural occurrence of *Fusarium* mycotoxins (tricothecenes and zearalenone) in barley and corn in Korea. Applied and Environmental Microbiology. *59*(11):3798-3802.

44. ACGIH [1989]. Guidelines for the assessment of bioaerosols in the indoor environment. American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio.

45. Code of Federal Regulations [1992]. OSHA Respiratory Protection. 29 CFR 1910.134. Washington, DC: U.S. Government Printing Office, Federal Register.

Table I. Microbiological Results of Bulk Samples

Sample Location	Fungi		Bacteria	
	(CFU/gm)	Taxa Rank	(CFU/gm)	Taxa Rank
B1 (Room 105 carpet sample)	760,000	Fus>Pen	67,000,000	Bac>Staph>Micro>Yea
B2 (Room 101 carpet sample)	370,000	Fus>Asp>Pen	15,000,000	Ps>Bac>Staph>Flavo
B3 (Room 103 carpet sample)	4000	Asp>Micro>NS	9,400,000	Micro>Bac>Staph>Flavo
B4 (Room 340 carpet sample)	6000	Asp	3,300,000	Micro>Yea>Staph>Bac
B5 (North HVAC insulation sample)	52,000	Pen>>Clad>Asp	8000	Micro>Bac
B6 (Room 101 carpet sample)	136,000	Yea	10,000	Bac>>Micro>Staph
B7 (FCU 20 insulation sample)	ND		1000	Bac
B8 (FCU 12 insulation sample #1)	2000	Clad	2000	Bac
B9 (FCU 12 insulation sample #2)	1000	Pen	2000	Bac
B10 (FCU 10 insulation sample)	26,000	Clad>>Pen>Asp	17,000,000	Yea
B11 (FCU 23 insulation sample #1)	1,800,000	Clad>Pen>Asp	30,000	Bac
B12 (FCU 25 insulation sample #1)	2000	Asp	2000	Bac
B13 (FCU 33 insulation sample #1)	6000	Clad	5000	Bac>Micro>Staph
B14 (FCU 23 insulation sample #2)	310,000	Clad>>Pen	2000	Bac
B15 (FCU 33 insulation sample #2)	2000	Muc=Pen	6000	Bac
B16 (FCU 48 insulation sample)	3000	Clad	6000	Micro>Bac>Staph
B17 (FCU 25 insulation sample #2)	1000	Clad	2000	Bac
B18 (FCU 46 insulation sample)	3000	Clad	6000	Bac
B19 (wet ceiling tile sample)	ND		265,000,000	Yea>Bac
B20 (FCU 3 insulation sample #1)	ND		410,000,000	Yea
B21 (North HVAC insulation sample #2)	1,200,000	Pen	250,000,000	Yea
B22 (FCU 3 insulation sample #2)	12,000	Clad	330,000,000	Yea
B23 (South HVAC insulation sample #1)	190,000	Pen>Asp>Clad	230,000,000	Yea
B24 (South HVAC insulation sample #2)	5000	Clad	260,000,000	Yea
B25 (Room 216 carpet sample)	ND		310,000,000	Yea
B26 (North HVAC condensate water sample)	47,000	Pen>>Asp	1,000,000	Yea
B27 (FCU 20 condensate water sample)	5700	Fus>>Micro	260,000	Yea
B28 (FCU 10 condensate pan debris sample)	16,000,000	Fus	370,000,000	Yea
B29 (South HVAC condensate water sample)	5,000,000	Fus	370,000,000	Yea

NOTE:
Asp = *Aspergillus*
Clad = *Cladosporium*
Fus = *Fusarium*
Micro = *Microsporum*
Pen = *Penicillium*
Muc = *Mucor*
NS = non-sporulating mold
Bac = *Bacillus*
Flavo = *Flavobacterium*
Micro = *Micrococcus*
Ps = *Pseudomonas*
Staph = *Staphylococcus*
Yea = unidentified yeast
ND = non-detected

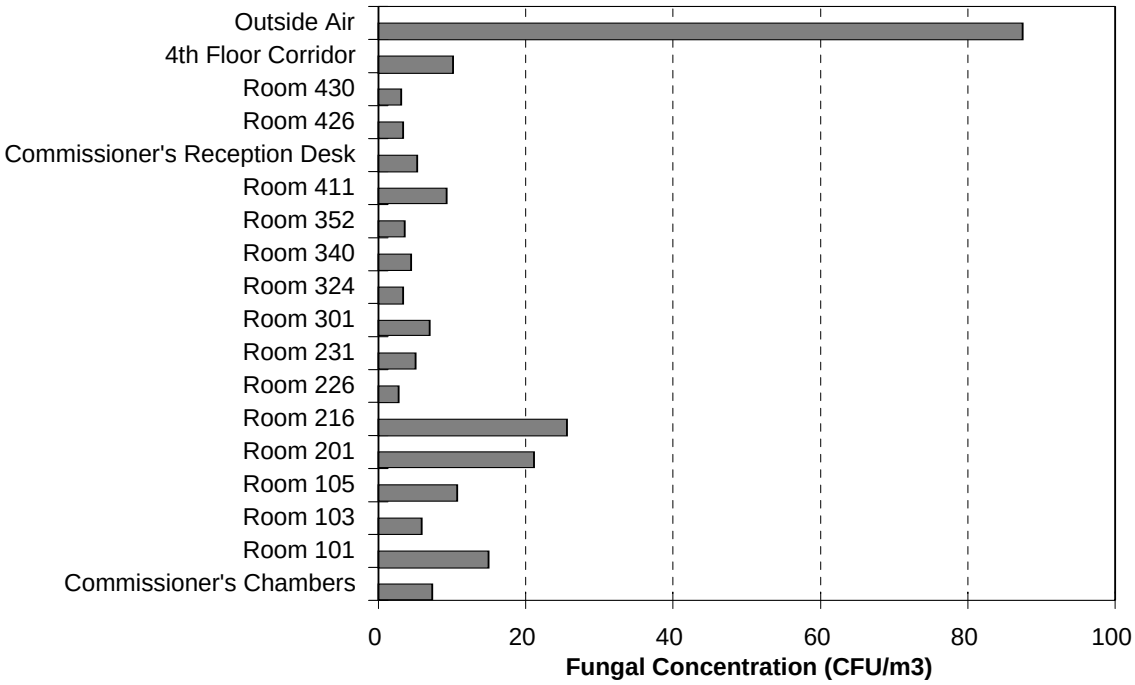

Figure 1. SAS Sample Measurement Results

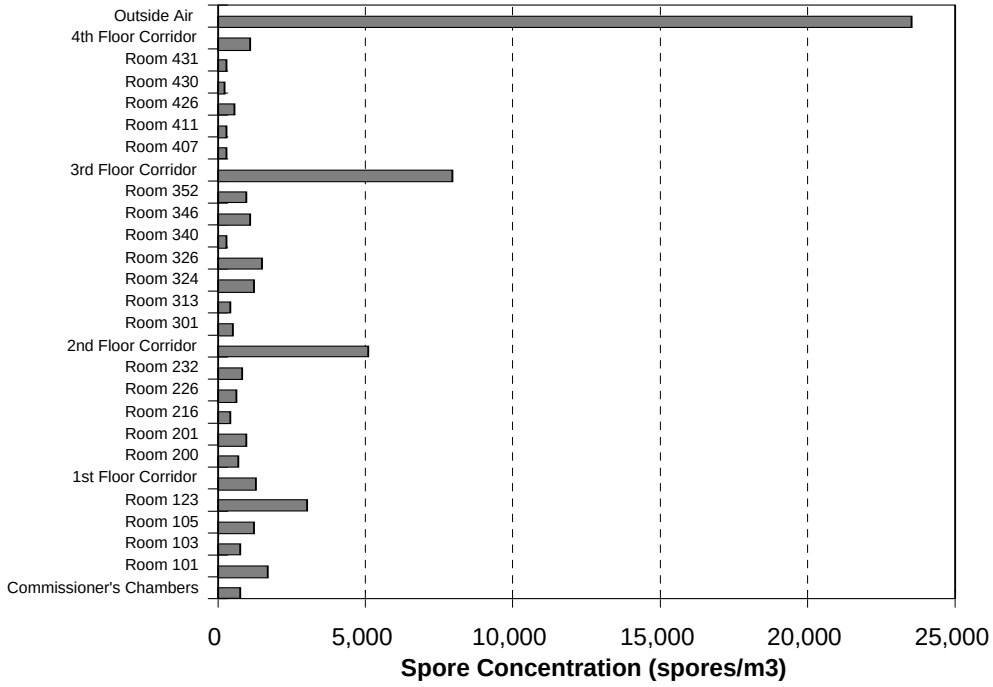

Figure 2. Spore Sample Measurement Results

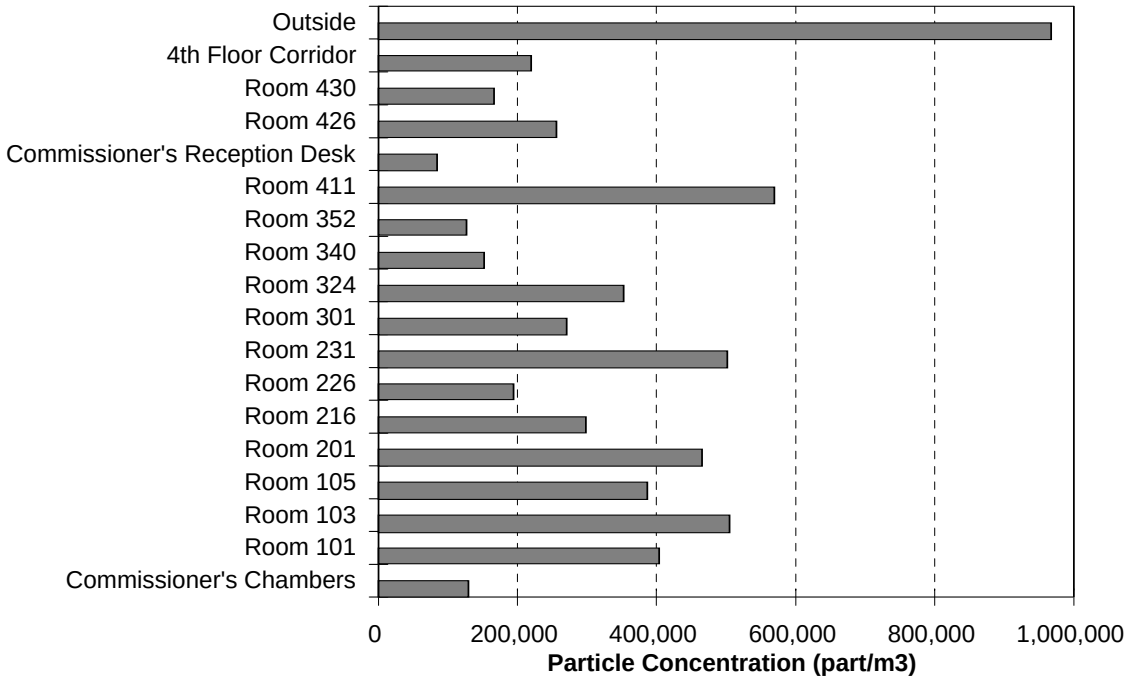

Figure 3. Met One Measurement Results (particles greater than 1 μm)

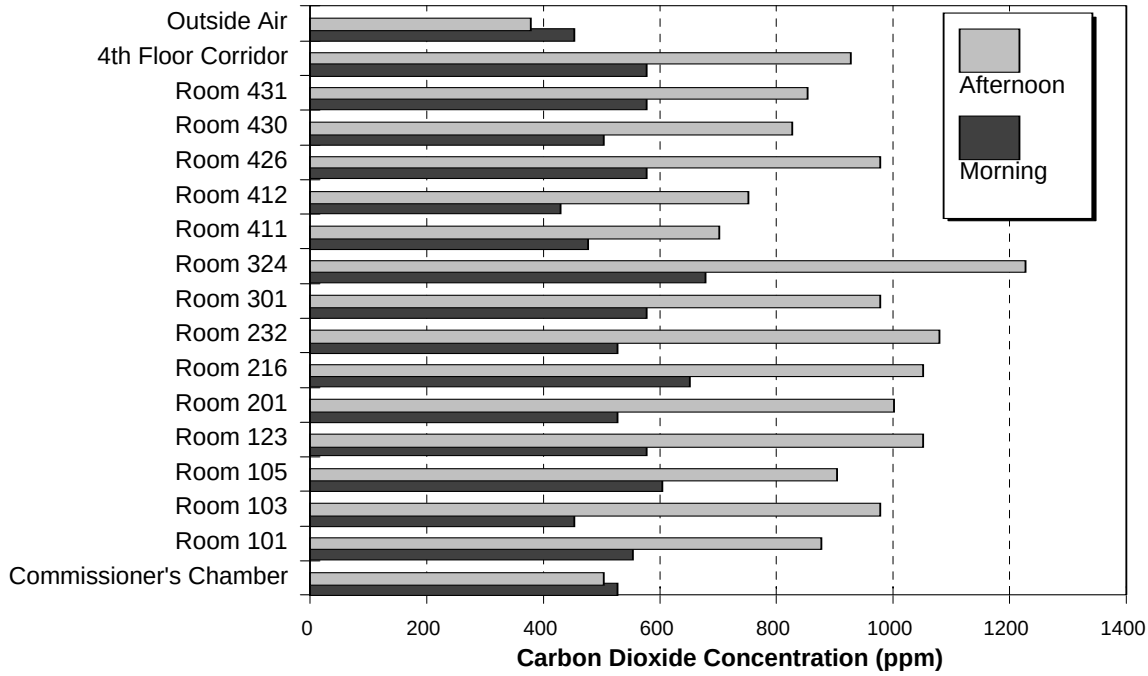

Figure 4. Carbon Dioxide Measurement Results

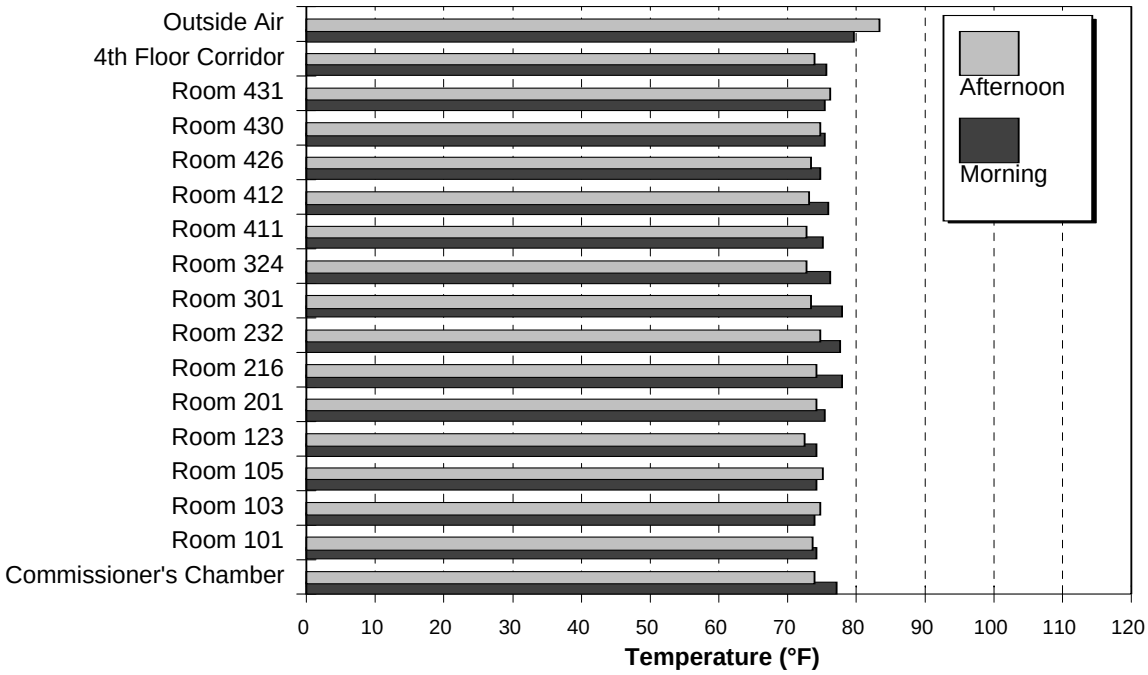

Figure 5. Temperature Measurement Results

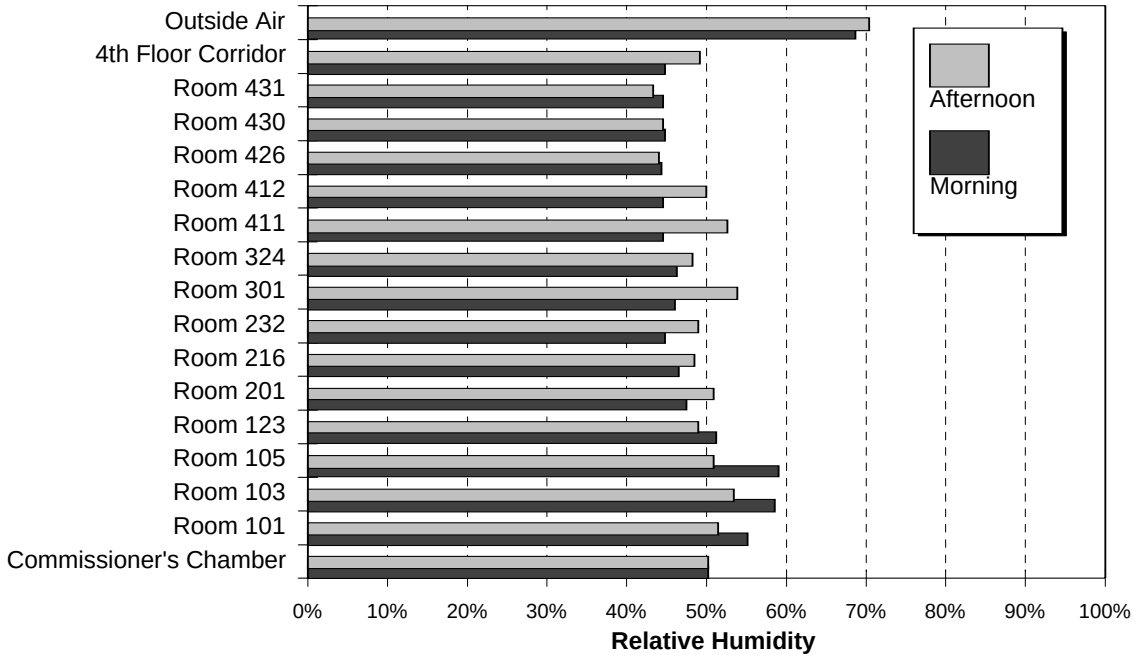

Figure 6. Relative Humidity Measurement Results

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