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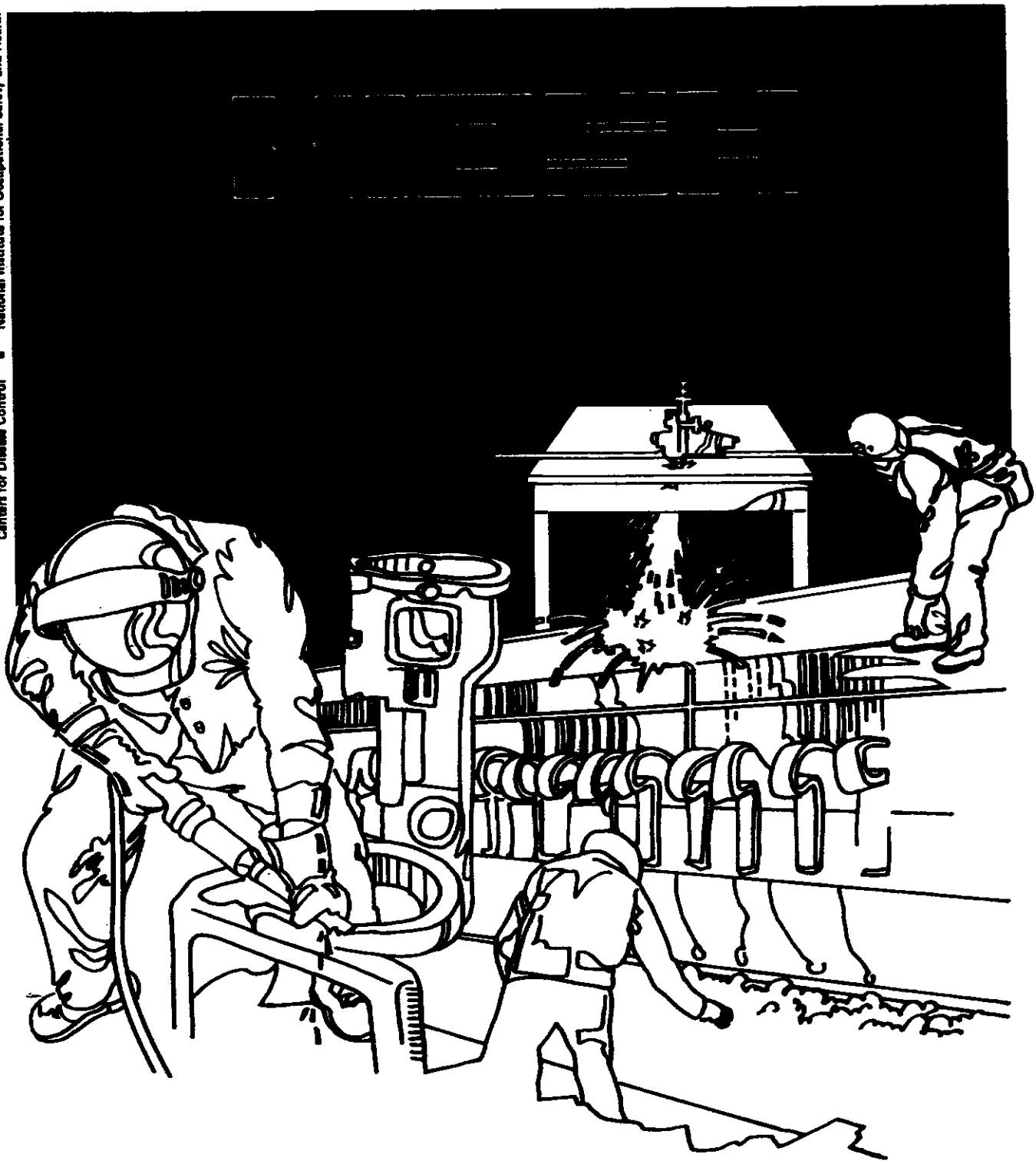

Health Hazard Evaluation Report

MHETA 88-020-1908
UNIVERSITY OF SOUTH FLORIDA
TAMPA, FLORIDA

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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I. SUMMARY

On October 10, 1987, the University of South Florida, College of Public Health (CPH) requested the National Institute for Occupational Safety and Health (NIOSH) to investigate work-associated complaints of chemical odors and irritation of the eyes, nose and throat among employees in MHH Building 104 (MHHB). On December 1, 1987, a screening questionnaire on indoor air quality was mailed to MHHB employees. NIOSH investigators conducted an environmental survey at the MHHB on January 6-11, 1988. Sampling was done for a number of environmental conditions/air contaminants including: carbon dioxide, carbon monoxide, formaldehyde, isocyanate compounds, other organic compounds, total airborne dusts, fibers in settled dust, airborne viable microorganisms, and temperature/relative humidity. Evaluation of the ventilation system was also done.

Forty-one (67%) of the 61 MHHB employees completed the questionnaire survey; survey results indicated that employee health/discomfort complaints were most frequent among occupants in the converted gymnasium/auditorium offices (the high bay office area). Eye irritation, sore throat, odors, headaches, sinus problems and stuffy indoor air were the predominant complaints.

Two distinct odors were noticed in the MHHB high bay area. One odor, a chemical, "Band-aid" odor, was traced to the carpet/carpet glues used in this area. The second odor, a moldy/musty odor, could not be traced to a specific source; however, the carpet and ventilation system/ventilation practices are a possible cause. Neither of these odors could be attributed to a specific, measured air-contaminant. However, many chemicals have odor threshold below analytical detection limits and below existing health/exposure standards. Airborne dust, gas, and vapor concentrations measured inside the MHHB were below existing permissible exposure limits and exposure guidelines of the Occupational Safety and Health Administration (OSHA), the American Conference of Governmental Industrial Hygienists (ACGIH), the American Society for Heating Refrigerating and Air-Conditioning Engineers (ASHRAE), and NIOSH. Some aspects of ventilation system design and ventilation practice in the high bay area were suboptimal and could contribute to the odors/complaints among employees in this building.

On the basis of data obtained during this evaluation, the symptoms reported by this group of workers can most likely be explained by low level indoor pollutants from building materials in conjunction with suboptimal ventilation system design/operation in some MHHB areas. Recommendations for resolving these problems are presented in section IX of this report.

KEYWORDS: SIC 9441 (Administration of Social, Human Resource and Income Maintenance Programs), office-buildings, indoor air pollution, ventilation, odors.

II. INTRODUCTION

On October 10, 1987, the Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health (NIOSH) received a technical assistance request to evaluate potential health/comfort problems at the University of South Florida, College of Public Health (CPH). The request cited complaints of chemical odors, and irritation of the eyes, nose, and throat among employees in the MHH Building 104 (MHHB). NIOSH investigators collected and reviewed the results from an industrial hygiene evaluation done at the MHHB by the CPH. On December 1, 1987, a standardized screening questionnaire on indoor air quality (IAQ) was mailed to MHHB employees. NIOSH investigators conducted an environmental IAQ survey at the MHHB on January 6-11, 1988.

III. BACKGROUND

Employees at the CPH occupy offices in two separate buildings of an office complex located at 13301 North 30th Street in Tampa, Florida. This office complex is approximately 12 years old and includes other university offices, a recreation center, a cafeteria, and an eye bank. The different buildings in this complex are connected by covered, outdoor walkways. The CPH moved to this office complex in December of 1985. In one building of this office complex the CPH has environmental health science laboratories, classrooms, and offices; approximately 13 employees work in this area (Building #1). The CPH occupies a second building in this complex where approximately 48 employees work; this area (Building #2) is comprised of offices, student study areas, a photocopy room, and a meeting room. A number of the offices in a portion of Building #2 are located in an area that once served as a gymnasium and auditorium; this area, now carpeted and partitioned into office space, is often referred to as the "high bay area" since it has a high ceiling from prior design/use. Four offices and 3 secretarial stations in this high bay area are located on a second story balcony; all other offices are on the ground floor level. This area is carpeted and has dry wall partitions extending to a height of about 8 feet; the ceiling height in this high bay area is about 20 feet. Approximately 24 of the employees in Building #2 work in the high bay area. The other 24 employees in Building #2 work in a single story office area separated from the high bay area by an entrance hallway. This area is carpeted and consists of individual offices and secretarial stations. The ceiling height in this area is about 9 feet.

After relocating to the MHHB, several CPH employees complained of irritation and odors in their work environment. In October of 1987, the CPH initiated an in-house evaluation of indoor air quality problems; the high bay area was the center of this evaluation since most complaints were from this area. In November of 1986, the carpets in the high bay area were steam rinsed based on concerns of possible employee irritation from residual surfactants in the carpet. Additional recommendations from the CPH evaluation included increasing the outside air intake to 20 cubic feet per minute (CFM) for each occupant and installing fans for better air mixing. On January 22, 1987, MHHB engineers reported that the outside air intake damper for the ventilation system serving the high bay area was opened to the maximum setting per CPH request. Three large, free-standing floor fans were also placed in the high bay area to bring in outside air through two entrances and provide

distribution/mixing of this air. Complaints continued after these changes; however the university investigators discontinued their in-house evaluations over concern of impending legal action by some MHHB employees.

IV. METHODS

A. Indoor Air Quality Questionnaire

On December 1, 1987, a one-page, self-administered questionnaire (See Appendix A) was mailed to all MHHB employees to assess the nature, frequency, and demographics of the reported health/comfort complaints. Employees were asked to complete the questionnaire and return it by mail in the stamped envelope provided with each questionnaire. The results from this questionnaire survey were used primarily to help direct this evaluation.

B. Environmental Survey

An industrial hygiene evaluation of the MHHB was done to identify potential indoor air pollution problems related to the health/comfort complaints. This evaluation included physical, chemical, and biological assessments of building conditions and indoor air quality. Our evaluation efforts were directed at the high bay area since the majority of IAQ complaints were from employees working in this area.

Physical evaluation aspects involved an inspection of office areas for problem conditions including mold growth, and flooding/water incursions. Temperature and relative humidity measurements were taken and an evaluation of the ventilation system was done. Ventilation system flow rates were measured with a pitot tube/inclined manometer.[1] A heated wire anemometer and a flowhood with a deflecting vane anemometer were used to take air flow measurements from ceiling air supply terminals and office areas.

Airborne sampling was also done to assess levels of carbon dioxide, carbon monoxide, and organic gases and vapors including formaldehyde, isocyanates, or any other organic compounds identified in bulk air samples. Samples were also taken to measure airborne total dust concentrations.

Carbon dioxide and carbon monoxide concentrations were sampled using direct reading indicator tubes. These short term samples were collected over a time period of about 5 minutes.[2] Additional direct air readings for nonspecific organic gases/vapors were taken with a photoionization meter.[1]

Formaldehyde samples were taken with a midget impinger operated at 1 liter per minute (lpm). A sodium bisulfite collection media was used. Full shift samples were collected. The samples were analyzed by spectrophotometry. This method has a LOD of about 0.001 ppm for an 8 hour sample.[3]

Airborne isocyanate compounds were sampled using glass wool tubes impregnated with nitro reagent. Samples were collected over a 2 1/2 hour sampling period using portable sampling pumps calibrated to 1 lpm. The samples were analyzed by high performance liquid chromatography.[3]

Bulk organic gas/vapor samples were collected on activated charcoal media and silica gel media using portable sampling pumps calibrated to 200 milliliters per minute (ml/min). Samples were taken over a 6-8 hour period and analyzed qualitatively for organic compounds by gas chromatography in conjunction with mass spectroscopy.[3] Additional charcoal and silica gel samples were taken for the quantification of those organic compounds detected in the bulk samples. These samples were collected over a 6-8 hour sampling period at a flow rate of 50 ml/min.[3]

Airborne total dust samples were collected on 37 millimeter diameter polyvinyl chloride (PVC) filter media at a sampling rate of 2.5 lpm. These samples were time-weighted over a 2 shift sampling period of approximately 15 hours. The samples were analyzed gravimetrically using an electrobalance with a precision of about 0.01 milligrams (mg).[3]

Biological measures of indoor air quality involved sampling for viable airborne microorganisms (fungi and bacteria). Airborne microorganisms were collected using the Andersen (N6) biological sampler with malt extract agar.[4] Partial period samples (3-20 minutes) were collected at a sampling rate of approximately 28 lpm. The samples were incubated at room temperature (about 72-74°F) and counted for growth of microorganisms over a 4-day period.

Bulk samples of settled dust were collected from desktops, door ledges, and HVAC ceiling supply diffusers in the high bay area using a miniature vacuum consisting of a PVC filter, a small battery operated sampling pump (2.5 lpm), tygon tubing and a plastic eye dropper. Dust collected on the filter media was removed and analyzed for glass fibers by polarizing light microscopy. Bulk samples of HVAC dust lining were also collected and analyzed by polarizing light microscopy.[8]

The selection of environmental analyses for this evaluation was based on: (1) The screening questionnaire results from MHHB; (2) Past IAQ evaluations done in the MHHB by the CPH; and (3) NIOSH experience from IAQ evaluations in other office buildings. Area sampling was done at four designated sampling stations. Two of the sampling stations were located in the high bay area. One of these high bay locations (sample station A) was on the balcony area; the second location (sample station B) was a ground level office located along the west perimeter wall. Two sample stations were located away from the MHHB for comparison purposes. This included sample station C located outside the building by the flag pole, and sample station D, located in the adjacent eye bank area. Samples were collected during normal operating hours/conditions on Thursday and Friday (January 7-8, 1988); samples were also collected on Sunday (January 10, 1988) when the building was closed and the ventilation systems were off.

V. EVALUATION CRITERIA

Evaluation criteria are used as guidelines to assess the potential health effects of occupational exposures to substances and conditions found in the work environment. These criteria consist of exposure levels for substances and conditions to which most workers can be exposed day after day for a working lifetime without adverse health effects. Because of variation in individual susceptibility, a small percentage of workers may experience health problems or discomfort at exposure levels below these existing criteria. Consequently, it is important to understand that these evaluation criteria are guidelines, not absolute limits between safe and dangerous levels of exposure.

Several sources of evaluation criteria exist and are commonly used by NIOSH investigators to assess occupational exposures. These include:

1. The U.S. Department of Labor (OSHA) Federal Occupational Health Standards; permissible exposure limits (PEL's);[5]

2. The American Conference of Governmental Industrial Hygienist (ACGIH) Threshold Limit (Exposure) Values (TLV's);[6]

3. NIOSH criteria documents and recommendations. (Recommended exposure limits or REL's.)[7]

These criteria have been derived from industrial experience, from human and animal studies, and when possible, from a combination of the three. Consequently, due to differences in scientific interpretations of these data, there is some variability in exposure recommendations for certain substances. Additionally, OSHA considers economic feasibility in establishing occupational exposure standards; NIOSH and ACGIH place less emphasis on economic feasibility in development of their criteria.

The exposure criteria described below are reported as time-weighted average (TWA) exposure recommendations averaged over the full work shift; short term exposure limit (STEL) recommendations for a 10-15 minute exposure period; and ceiling levels (C) not to be exceeded for any amount of time. These exposure criteria and standards are commonly reported as parts contaminant per million parts air (ppm), or milligrams of contaminant per cubic meter of air (mg/m^3). Occupational criteria for the contaminants evaluated in this study are as follows:

Substance	NIOSH (REC.)	ACGIH (TLV)	OSHA (PEL)
Carbon Dioxide	10,000 ppm	5,000 ppm	5,000 ppm
Carbon Monoxide	35 ppm	50 ppm	50 ppm
Formaldehyde[1]	LFL	1 ppm	3 ppm
Toluene2,4 Diisocyanate	0.005 ppm 0.02 ppm (20 min. C)	0.005 ppm 0.02 ppm STEL	0.02 ppm
Methyl Isocyanate	-	0.02 ppm	0.02 ppm
Total Airborne Dust	-	10 mg/m^3	15 mg/m^3
Airborne Microorganisms (Bacteria or Fungi)	-	-	-

[1]Considered a potential human carcinogen by NIOSH and ACGIH.
- These standards/exposure levels refer to time-weighted averages (TWA) unless otherwise specified as Short term exposure limits (STEL), or ceiling values (C).
- ppm - Parts contaminant per million part air.
- mg/m^3 - Milligrams contaminant per cubic meter of air.
- LFL - Lowest feasible limit.

Some research suggests that industrial exposure criteria may be inappropriate for evaluating IAQ problems in office buildings.(7,8,9) The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) is one organization with environmental criteria designated to maintain acceptable IAQ in office building environments. They define acceptable IAQ as, "air in which there are no known contaminants at harmful concentrations and with which a substantial majority (usually 80%) of the people exposed do not express dissatisfaction."(9,10) ASHRAE recommends that outdoor air acceptable for ventilation (without treatment) meet the requirements established by the U.S. Environmental Protection Agency in the National Ambient Air Quality Standards and Additional Ambient Air Quality Guidelines.(7) These ASHRAE criteria for the contaminants evaluated in this study would include:

	LONG TERM		SHORT TERM	
	level	time	level	time
Carbon Monoxide	-	-	35	1 hr
Formaldehyde	-	-	0.1 ppm	ceiling
Total Airborne Dust	0.075 mg/m^3	1 yr	0.26 mg/m^3	24 hr

ppm - Parts per million parts air.
mg/m^3 - Milligrams per cubic meter of air.
- Long term recommendations are averaged over a 1 year time period.

ASHRAE also recommends criteria[1] for indoor temperatures and ventilation rates for office buildings as detailed below:

Temp./Relative Humidity		Air Changes Per Hour	Minimum Outdoor Air
Winter	Summer		5 cubic feet per min. (CFM)/person (non-smoking)
70-74°F	74-78°F	4 to 10	
20-30% RH	40-50% RH		20 CFM/person (smoking)

[1] ASHRAE is in the process of revising their recommendations on minimum outside air requirements for office buildings; however, the revisions are not final.

The ASHRAE estimated occupancy for offices is 7 persons per 1000 square feet (ft^2) or 143 ft^2 per person.

Carbon dioxide (CO_2) concentrations in indoor air are often used as an indirect measure of a buildings capability to dilute indoor generated odors and irritants. The following CO_2 criteria have been used to assess indoor air quality in office environments:[11,12]

CARBON DIOXIDE (PPM)	COMMENTS
Less than 600	Adequate outside air intake
600 - 800	There may be occasional complaints, particularly if the air temperature rises
800 - 1000	Complaints more prevalent
> 1000	Insufficient make-up air, complaints are general

There are no established standards for occupational exposure to airborne bacteria and fungi suitable to assess potential health effects. Consequently, concentrations of fungi/bacteria measured outdoors and in adjacent office buildings were used as a comparison to airborne fungal levels in the MHHB.

VI. RESULTS

A. Indoor Air Quality Questionnaires

Questionnaires were received from 41 of the 61 MHHB employees for a response rate of approximately 67% (Table 1). Approximately 66% of the employees reported experiencing discomfort related to their work environment; while approximately 34% reported a medical illness believed related to the work environment. The most prevalent symptoms reported by MHHB employees were eye irritation (39%), sore throat (32%), headache (19%), and sinus problems (15%). Problem MHHB conditions reported by the employees included odors (27%), and stuffy indoor air conditions (7%). The building has a no smoking policy and there were no complaints of irritation attributed specifically to tobacco smoke. Only 7% of the questionnaire respondents reported that tobacco products were smoked in their environment.

A larger percentage of the complaints occurred among workers in the high bay area. Approximately 89% of the 19 questionnaire respondents from this area complained of significant discomfort related to their work environment; while 42% reported work related medical illness. Employees from other building areas (buildings 1 and 2 combined) had a lower rate of complaints for work related discomfort (45%) and medical illness (32%). This information was used primarily to direct subsequent industrial hygiene efforts.

B. Environmental

Building Evaluation

Some of the ceiling tiles in the entrance hallway of building #2 were stained indicating past leaks or water incursions. These tiles were dry at the time of our evaluation and we saw no evidence of active leaks in the ceiling space above these tiles. There was no evidence of water damage to the carpet or office furnishing in this area.

There were no areas of visibly identifiable mold growth in the MHHB, Building #2. However, we noticed a musty odor in the high bay area. In addition, a second chemical odor, was detected by NIOSH investigators. It smelled similar to a rubbery/solvent odor. Several building employees described it as a "Band-aid" like odor. This odor was strongest near the west entrance door to the high bay area. The source of this odor was detected when a section of the carpet from this area was pulled up for observation. The adhesive used to secure the rubber-backed carpet to the concrete floor was damp/wet and the "Band-aid" odor was strongest at this point. Readings taken at this point with the HNU photoionization meter indicated the presence of organic compound(s) at concentrations above normal room levels (readings). Dry carpet adhesive in another high bay office area was intentionally soaked with water and allowed to stand for several minutes; similar odors and HNU meter readings were then observed at this location when the carpet was lifted. The high bay area was the only location where the orange, rubber-backed carpet was observed.

Areas near the ceiling supply air vents were dirty with accumulated particulate. The ceiling exhaust vent grill in the women's bathroom in the high bay area was almost obstructed with dirt and debris.

The MHHB has a no smoking policy; smoking is not permitted in any of the building offices.

HNU photoionization readings taken in the photocopy room, storage closets, the stairwell, and a number of offices contained no elevated organic gas/vapor concentrations as contrasted to background levels.

Temperature and Relative Humidity

Thirty temperature and relative humidity measurements were taken at the MHHB (Table 2). Indoor temperatures taken during normal business hours with the HVAC operating ranged from a low of 70°F to a high of 78°F, and relative humidity ranged from 51% to a high of 73%.

Ventilation System Evaluation

The MHHB is a modern, relatively air-tight building by design; the windows do not open and the heating, ventilation, and air-conditioning (HVAC) system was designed as the primary source of air supply for building occupants. The high bay area is served by two separate HVAC systems. One large HVAC serves all ground level offices (System #3); while, a smaller HVAC system serves the balcony offices in this area (System #14). These systems were installed during the mid 1970's when the building was constructed. Both systems have heating and air-conditioning (cooling) and dehumidification capabilities but no humidification (humidification is not usually required in Central Florida). The heating system is electric. Cooling capacity is provided through water cooling towers located at a separate facility away from the MHHB. Cold water is piped from this facility to the cooling coils in the HVAC systems serving the MHHB. These HVAC systems were reported (by building engineers) to operate as constant volume systems. (Air supply and outside air supply is constant, independent of thermostat demand.) Supply air from the HVAC system is delivered to office areas through ceiling supply grills. Return air is exhausted through one large return grill located in the north-east corner of the high bay area. This grill was part of HVAC system #3; we were unable to locate any return air grills on the high bay balcony area for HVAC system #14. Each office on the high bay balcony, served by HVAC system #14, had a ceiling supply air grill. The ground floor offices had a different ventilation design reflecting the conversion of this area from a gymnasium/auditorium to office space. The eight supply air grills for the HVAC system (#3) serving this area were located on the high bay ceiling at a height of about 20 ft, the ground floor offices in this area had walls, extending to a height of about 8 ft, but no ceiling cover. This open ceiling area in individual offices was designed to allow supply air from the 20 ft high supply grills to reach office occupants.

The outside air intake for these HVAC systems is located on the roof away from any obvious sources of contamination (exhaust vents, stagnant water, etc.); this one outside air intake serves several HVAC systems including HVAC systems 3 and 14. A fan is used to bring in outside air through this intake and this air is ducted to return air mixing chambers in HVAC systems 3 and 14.

The HVAC operation cycles were controlled by computer. At the time of our survey, HVAC system #14 was operated from 6:30 AM until 9:00 PM every day. HVAC system #3 was operated from 6:25 AM until 9:00 PM Monday through Thursday; on Friday, this system was operated from 6:25 AM until 6:30 PM. On Saturday, HVAC system #3 was operated from 8:00 AM until 6:30 PM; the system was not operated on Sunday.

Roll type pre-filters were used for each HVAC system; these filters have no ASHRAE efficiency rating. HVAC #14 had an additional filter consisting of activated carbon in a cellulose matrix. This filter was designed to remove low level odors; it has no ASHRAE efficiency rating.

The HVAC ducts were lined on the interior with an insulation material which was visibly dirty. PLM analysis indicated that this material consisted of glass fibers similar to mineral wool.

Both HVAC system #3 and #14 has standing water in the condensate pan below the cooling coils; although, the water did not appear contaminated with obvious biological growth. The cooling coils and aluminum air deflection fins in these two systems were dirty with a brown/green grime. We noticed a musty odor similar to the musty odor in the high bay area, in both HVAC systems.

HVAC fan flow rates for the system serving the high bay area are reported in Table 3. These measurements were made in the HVAC fan rooms. The volumetric flow rate for the supply fan from HVAC #3 met design flow at approximately 12,600 CFM. HVAC #14 was separated into two separate sides, each sharing a common fan, cooling coils, return air mixing plenum, and outside air intake. One side of HVAC #14 served the high bay balcony, with a volumetric flow rate of about 3000 CFM; the other side of HVAC #14 served other MHHB areas.

The outside air intake measurements for these two systems (Table 3) were taken with the outside air supply fan operating. On initial attempts to measure outside air supply, we discovered the supply fan was not operating. MHHB engineers explained that the fan motor overheats on occasion and this trips an electrical breaker shutting off the outside air supply fan. The outside air supply for HVAC system #3 was approximately 1900 CFM or about 15% of the total air flow. The outside air supply to HVAC system #14 was approximately 630 CFM. This outside air was split between both sides of HVAC #14; it included about 11% of the total air flow for this system.

The total volumetric air supply delivered to the high bay office areas was measured from ceiling grills (Figure 1 and Table 4). The sum of air flow measurements taken from ceiling diffusers was below design volume for these grills as determined from building blueprints. The 18 MHHB occupants on the ground level of the high bay area received approximately 7350 CFM of air through the 8 ceiling diffusers in this area.[1] The estimated outside air supply to this area, 1100 CFM, would provide 61 CFM of outside air per ground level employee assuming adequate distribution. The six occupants in the high bay balcony area received 1100 CFM of supply air through ceiling supply grills. The estimated outside air supply to these employees would be approximately 120 CFM; this would provide on average outside air supply of 20 CFM/employee. However, there was some imbalance in air supply to individual offices/work stations on the balcony as indicated on Figure 1.

General office air flow patterns evaluated with smoke tubes and a heated element anemometer indicated that air turbulence and mixing in the high bay areas was greatest near the 20 ft high ceiling and above individual ground level offices. Air flow/mixing at desk level in these office areas was greatly reduced, due largely to the location of HVAC air supply and return grills. A large portion of the supply air form the HVAC system does not penetrate to employees in individual office areas with the existing HVAC design. This supply air is largely delivered, mixed, and exhausted in the open area above individual offices thereby bypassing building employees in ground level offices.

During our evaluation, MHHB employees in the high bay area operated large floor fans to bring in additional unconditioned outside air through two entrance doors on the west side of the building. The doors were propped open with chairs and fans were placed in front of these entrances. One additional floor fan was used to help direct/mix outside air brought in through these two doors. This was described as a normal operation, done on a daily basis.

Airborne Gases/Vapors

Formaldehyde concentrations inside the MHHB high bay area ranged from 0.02 parts per million parts air by volume (ppm) to 0.05 ppm (Table 5). The mean concentration from the seven samples taken inside the MHHB was 0.04 ppm with a standard deviation (STD) of 0.01 ppm. The mean concentration from the two ambient formaldehyde samples was 0.009 ppm with a STD of 0.001. The formaldehyde sample collected from the eye bank has a concentration of 0.02 ppm.

[1] We could not reach 2 of the ceiling diffusers on the south side of the high bay ground level; we used design flow estimates in place of actual readings from these diffusers to calculate total air supply.

Bulk airborne samples taken for qualitative identification of organic gases and vapors contained trace amounts of toluene and 1,1,1-trichloroethane. The additional charcoal tube samples, taken for subsequent quantification of any airborne organic gases/vapors were not analyzed since the bulk air samples contained only trace amounts of organic gases/vapors. Several additional organic compounds were detected in the solid samples of bulk carpet glue. These compounds included diazinon (an insecticide), a cresol isomer, substituted phenols, phthlates, and a series of trixylylphosphate isomers.

The six airborne samples taken from isocyanate compounds were all below the limit of detection (LOD). The LOD for the isocyanate compounds evaluated during this survey include: toluene - 2,4-diisocyanate (2 micrograms per cubic meter - $\mu g/m^3$); toluene - 2,6-diisocyanate (3 $\mu g/m^3$) and methylene-diphenylisocyanate (1 $\mu g/m^3$).

Carbon dioxide (CO_2) measurements from short-term detector tube samples collected in the high bay area ranged from 300 ppm to 500 ppm. The six samples from this area had a mean of 440 ppm and a STD of 82. The ambient CO_2 measurement taken outside the MHHB had a concentration of 350 ppm. Three short-term detector tube samples for carbon monoxide were all below the limit of detection, (approximately 1 ppm).

Airborne Dust

The two airborne total dust concentrations measured in the high bay area had concentrations of 0.015 milligrams of dust per cubic meter of air (mg/m^3) and 0.02 mg/m^3. These samples were time-weighted over 2 workshifts, approximately 15 hours. The outside airborne dust concentration collected during our survey was 0.05 mg/m^3; while the dust sample collected at the eye bank office had a concentration of 0.01 mg/m^3.

Settled Dust

Glass fibers, similar to those observed in HVAC dust lining, were detected in some of the bulk dust samples collected from the HVAC ceiling diffusers; although, they were present only at trace concentrations. The most common items detected in these bulk samples included cellulose materials/fibers and silicate mineral particles.

Airborne Microorganisms

Airborne concentrations of microorganisms (bacteria and fungi) measured inside the MHHB, high bay area, during routine operations ranged from a low of 280 colony forming units per cubic meter of air (CFU/m^3) to 670 CFU/m^3. The mean concentration from the 6 samples collected in the high bay area was 420 CFU/m^3 with a STD of 144. The 3 samples collected outside the MHHB had a higher mean concentration of microorganisms, 1870 CFU/m^3 with a STD of 153. The 3 samples collected in a nearby office setting, the eye bank, had a mean concentration of 363 CFU/m^3 with a STD of 125.

VII. DISCUSSION

Building Odors

One of the primary concerns raised during this evaluation involved the presence of odors in the MHHB high bay area as indicated by the questionnaire results. Approximately 53% of the 19 questionnaire respondents in this area cited odors as a problem of concern in their work environment. The two distinct odors noticed by NIOSH investigators were almost exclusively from the high bay area.

There was no visible evidence of fungal contamination problems in MHHB office areas to suggest a potential source of the musty/moldy odors. Areas of excessive or obvious microbiological growth were not observed in any of the MHHB offices. Flooding and water incursion into office areas can be a source of excessive fungal/bacterial growth and odors,[13,14] however, there was no evidence of major flooding at the MHHB.

Airborne fungal and bacterial concentrations measured at the MHHB during normal office operations were lower than those measured outdoors and similar to those from a nearby office building. There are no adequate health standards or guidelines to assess potential health hazards from exposure to the nonpathogenic bacteria/fungi common to office settings. However, MHHB employees are exposed to higher airborne bacterial and fungal concentrations outdoors than in the building.

Some MHHB conditions observed during our evaluation can contribute to increased growth of bacteria and fungi and related musty odors. These include high indoor relative humidity, damp carpeting, standing water in the HVAC system condensate pans, inadequate cleaning of the cooling coils/deflector veins in HVAC systems, and dirty, glass wool lining inside the HVAC system.

The chemical "Band-aid" odor is likely due to carpet solvents used in the high bay area based. Qualitative air samples for organic compounds (taken on both silica gel and charcoal substrates) did not identify the chemical agent(s) responsible for these odors. Only trace amounts of formaldehyde, toluene, and 1,1,1-trichloroethane were detected in room air; of these, toluene is the only chemical that can produce a rubbery odor.[15] It is possible that other organic compounds from the carpet glue present in air at very low concentrations below the analytical detection limits of our sampling methods, were responsible for these chemical odors. Many materials can produce nuisance odors with odor thresholds below existing health standards or analytical detection limits.[15,16]

Other Health/Comfort Concerns

Other predominant health/comfort complaints reported by MHHB employees after relocating to their new building included eye irritation, sore throat, headache, sinus problems, and stuffy indoor air. Many of the these complaints have been commonly reported in other office environments with HVAC system problems. Often, the reported symptoms cannot be

attributed to overexposure to any specific environmental contaminant.[11-13, 17,18] This is consistent with the results of our evaluation, as well as past environmental results, from the MHHB. None of the NIOSH industrial hygiene sampling results from the MHHB exceeded existing OSHA PEL's or the exposure guidelines of NIOSH and ACGIH. All of the environmental analyses sampled at the MHHB were substantially below these evaluation criteria.

Reduced ventilation rates, inadequate outside air supply, or altered air distribution are commonly associated with building related health/comfort problems.[11,12,17] It is well-recognized that fresh outside air must be added to closed-circuit building ventilation systems, in adequate amounts, to provide sufficient oxygen for respiration and to dilute the numerous low-level contaminants generated in occupied spaces. The reduction in outside air intake, or distribution, can result in occupant discomfort and complaints similar to many of those reported at MHHB.[11-13,17,18]

Carbon dioxide (CO_2) concentrations are often used as a marker for adequate outside air intake and distribution. CO_2 is generated in an office environment through human respiration, tobacco smoke, combustion processes, etc. As the CO_2 concentrations increase above the normal ambient levels (approximately 330 ppm in non-polluted locations) there is evidence of reduced outside air intake. Increased CO_2 levels can indicate insufficient outside air intake (with increased air recirculation) and have been associated with increased discomfort/complaints. Carbon dioxide concentrations in the 600-1000 ppm range are associated with occupant complaints.[11-12] In these criteria, carbon dioxide is not believed to be a direct cause of the problems/complaints; instead, CO_2 concentrations are an indirect measure of the potential for problems/complaints due to the inadequate removal/dilution of numerous low level chemical irritants in the office environment. In our evaluation, CO_2 concentrations in the MHHB high bay area were low by comparison to the these criteria. Although, in this instance, these low CO_2 concentrations may reflect, in part, low indoor CO_2 sources (e.g. low occupant density and the no smoking policy) and large room volume.

The HVAC measurements taken during our evaluation indicate that the HVAC systems are taking in adequate amounts of outside air for building occupants by ASHRAE standards, assuming uniform/equal air distribution to all workers, however, air distribution was a problem due to poor HVAC design. Before conversion to office space, this area served as a gymnasium/auditorium; the current HVAC design reflects this past use. The placement of supply and return grills resulted in poor HVAC supply air distribution to individuals in ground level offices. Most of the air from this HVAC system is delivered, mixed, and exhausted in a zone above the individual ground level employee work stations. There was a supply air grill in every balcony office; but we could not locate a return air grill in this area (HVAC #14). This design does not promote good distribution/mixing. Air flow measurements from the supply grills in this area were imbalanced; some offices/work stations received a much greater air supply than others. (See Figure 1)

MHHB employees in the high bay area improvised a second method of outside air intake; large floor fans were used to bring in unfiltered outside air through two ground level entrance doorways on the west side of the building. This introduced large quantities of outside air into the building; although, there were no provisions for dealing with the high indoor relative humidity caused by this practice. The problems resulting from high indoor humidity, caused by this practice, likely offset any benefit provided by increased outside air intake.

VIII. CONCLUSIONS

1. Two distinct nuisance odors were noticed in the MHHB high bay area. One of these odors (unidentified source) was a musty/moldy odor. The second, a rubber, "Band-aid" like odor, is likely a product of the carpet glues used to secure the rubber backed carpet to the concrete floor. The chemical(s) responsible for this odor are likely present in the air at trace concentrations below the detection limits of the sampling/analytical methods we used. Both of these odors were largely confined to areas with the orange, rubber-backed carpet and it is possible that this carpet may be the source for both odors.

2. None of the gases/vapors sampled during the industrial hygiene survey exceeded the OSHA PEL's, ACGIH TLV's, NIOSH criteria, or ASHRAE standards.[5,6,7] This is consistent with the findings from the previous evaluations in the MHHB. Average airborne total dust concentrations measured inside the MHHB were not in excess of ASHRAE recommendations.[7]

3. Workers in the MHHB reported symptoms consistent with those commonly attributed to office settings with poor ventilation practices. These types of complaints including irritation of the eyes and upper respiratory tract, headache, nausea, tiredness, sinus problems, and others are commonly associated with inadequate outside air supply/distribution in conjunction with low level indoor pollutants.[11-13,17,18]

4. Some aspects of HVAC design and operation were suboptimal:

   A. Due to poor location of HVAC supply and return grills, much of the supply air, including HVAC outside supply air, did not penetrate to breathing zone levels.

   B. The condensate pans in both HVAC systems had poor drainage and standing water. This condition affords potential for growth of microorganisms and related odor/exposure problems.[14]

   C. The HVAC cooling coils/air deflection fins contained a moist, dirt/grime. Dirty, wet HVAC components are less effective and can afford a suitable substrate for the growth of microorganism and related odor/exposure problems.[14]

D. The outside air supply fan shut down at one point during our evaluation reportedly due to the problem of overheating. This occurrence greatly reduces outside air supply to building occupants by the HVAC.

E. The glass fiber insulation inside the duct work in this building provides a substrate for accumulation of dirt/moisture and subsequent growth of microorganisms. Additionally, damaged fiberglass insulation can also release glass fibers into the office environment causing irritation of the eyes, skin, and throat. Water damaged fiberglass dust insulation has been a source of increased growth of microogramism and related odors in other NIOSH IAQ evaluations.

5. The use of floor fans to bring in additional (unconditioned) outside air creates problems of high indoor relative humidity. All of the relative humidity measurements taken during normal building operation exceeded the ASHRAE recommendations for indoor relative humidity. High indoor humidity can cause increased fungal growth and moldy/musty odors.[14] Outside air intake and distribution should be accomplished through proper HVAC practices.

IX. RECOMMENDATIONS

1. The HVAC systems should be operated according to ASHRAE standards; some HVAC design/operation changes are needed:

A. The 20 ft high ceiling air supply grill in the high bay area should be restructured (lowered) to deliver supply air into the breathing zone level of workers in ground floor offices. The use of ceiling fans would be an acceptable alternative, provided they have sufficient volumetric air flow capacity to pull ceiling supply air to ground level.

B. Return air grills should be added to HVAC #14 in the high bay balcony area to help promote better air mixing/distribution to workers in this area. Rebalance the supply air delivered to this area to ensure a more uniform distribution among the different offices/work stations.

C. Reduce relative humidity to a range between 20-50% as specified by ASHRAE.[10,13] Discontinue the use of large floor fans to bring unconditioned humid outside air into the building through ground level entrances.

D. HVAC condensate pan drainage should be improved to provide continuous drainage and eliminate standing water.[13,14]

E. More frequent cleaning of the HVAC cooling coils and deflector fins is needed to remove the buildup of dirt/debris. This task

would be simplified by providing a more convenient access panel to the HVAC unit that could be opened without removal of numerous screws.[13,14]

F. Corrective action should be taken to ensure that the outside supply air fan does not shut down during HVAC operating hours.

G. Any glass fiber ductwork scheduled for replacement should be changed to a ductwork with a nonporous interior free from glass fiber lining. Lining the duct exterior with fiberglass would be an acceptable alternative. HVAC ductwork lining should be inspected periodically where possible to guard against water damage, biological growth/odors, and glass fiber release. Any ductwork with damaged glass fiber lining materials should be replaced.

2. Consideration should be given to replacing the carpet and carpet glue in the high bay area based on employee complaints of odors. This action should remove one of the problem odors in the area (the rubbery, "Band-aid" like odor) and possibly the moldy/musty odor. If the carpet is replaced, the old carpet glue should be scraped/removed and the floor should be treated with a concrete sealer. New carpet with padding could then be added with only minimal use of glues. It should be noted that the addition of any new carpets can often introduce new odors into a building and these odors could be equally offensive to building occupants; this should be discussed with building employees prior to replacement of the carpet.

3. All interior water leaks should be repaired promptly and permanently. If water leaks occur, all porous, water damaged materials should be discarded. Nonporous surfaces should be vacuumed with a vacuum cleaner using high efficiency particulate filters and then sanitized with a bleach or biocide agent.[13,14]

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TABLE 1
INDOOR AIR QUALITY QUESTIONNAIRE RESULTS
UNIVERSITY OF SOUTH FLORIDA, MHH BUILDING 104
MHETA 88-020

RESPONSE: 41 - (67%)
SEX: Male (44%)
Female (56%)
BY AREA: High Bay Area - 46%
Other MHHB Areas - 54%

Questions	Total Responses (%)			High Bay Area Responses (%)		
	Yes	No	NR	Yes	No	NR
Do you currently smoke tobacco?	15	85	0	5	95	0
Are tobacco products smoked at your work area?	7	93	0	5	95	0
Have you experienced any significant discomfort related to your current work environment?	66	34	0	89	10	0
Have you changed your usual work activities because of this discomfort?	33	67	0	41	59	0
Have you changed your usual work location because of this discomfort?	30	70	0	41	59	0
Have you requested a change because of this discomfort?	18	78	4	29	65	6
Have you had a medical illness which you suspect is related to your current work environment?	37	63	0	42	58	0
Have you missed work because of this illness?	67	33	0	62	38	0
Have you seen a doctor for this illness?	67	33	0	62	38	0
Have you been treated for this illness?	53	40	7	62	38	0
Have you noticed a hazardous condition in your current work environment?	20	66	5	47	42	10
Have you changed your usual work activities because of this hazardous condition?	25	67	8	33	56	11
Have you changed your usual work location because of this hazardous condition?	17	75	8	22	67	11
Have you requested a change because of this hazardous condition?	42	58	0	44	56	0

NR - No Response

TABLE 1 (cont)
INDOOR AIR QUALITY QUESTIONNAIRE RESULTS
UNIVERSITY OF SOUTH FLORIDA, MHH BUILDING 104
MHETA 88-020

Symptoms Reported	Percent (%)
Eye Irritation/Problems	29
Sore Throat	22
Headaches	19
Stuffy Nose/Sinus Problems	15
Metalic Taste in Mouth	7
Cough	5
Nausea/Vomiting	5
Upper Respiratory Infection	5
Fatigue	2
Dry Throat	2
Nose Bleeds	2
Sneeze	2
Muscle Aches	2
Swelling Face	2
Ear Infection	2
Congestion	2
Bronchial Constriction	2

Problem Conditions	Percent (%)
Odors (Moldy or Chemical)	29
Too Noisy	5
Stuffy	7
Too Cold	2
Too Dusty	2

TABLE 2
TEMPERATURE AND RELATIVE HUMIDITY MEASUREMENTS
UNIVERSITY OF SOUTH FLORIDA, MHH BUILDING 104
MHETA 88-020

Date	Time	Location[1]	Temperature (°F)	Relative Humidity (%)
01/07/88	0940	Station A	74	51
01/07/88	0945	Station B	70	56
01/07/88	0948	Outside	68	69
01/07/88	1145	Station A	75	58
01/07/88	1155	Station B	74	56
01/07/88	1200	Outside	76	64
01/07/88	1355	Station B	76	59
01/07/88	1400	Outside	78	64
01/07/88	1403	Station A	77	59
01/07/88	1545	Outside	74	82
01/07/88	1550	Station A	78	64
01/07/88	1559	Station B	77	58
01/08/88	0900	Station B	73	73
01/08/88	0903	Station A	74	67
01/08/88	0907	Outside	70	90
01/08/88	1245	Station B	71	68
01/08/88	1250	Outside	70	80
01/08/88	1255	Station A	72	64
01/08/88	1512	Station B	75	66
01/08/88	1515	Outside	75	66
01/08/88	1520	Station A	76	60
01/10/88*	0933	Station B	65	57
01/10/88*	0937	Station A	69	47
01/10/88*	0941	Outside	52	87
01/10/88*	1100	Station A	67	50
01/10/88*	1130	Outside	55	82
01/10/88*	1201	Station B	65	58
01/10/88*	1540	Outside	55	85
01/10/88*	1545	Station A	67	54
01/10/88*	1550	Station B	67	56

[1] Station A - High Bay Area on Balcony
Station B - High Bay Area Ground Floor Offices

°F Degrees Fahrenheit

% Percent Relative Humidity

* The HVAC system was not operating on Sunday, 01/10/88.

TABLE 3
HVAC VOLUMETRIC FLOW MEASUREMENTS[1]
UNIVERSITY OF SOUTH FLORIDA, MHH BUILDING 104
MHETA 88-020

HVAC	Area Served	Volmetric Flow (CFM) Design Flow	Measured Flow	Outside Air Intake[2]	Outside Air (%)
#3	High Bay Ground Level	12,400	12,600	1,900	15
#14-Side A*	High Bay Balcony	3,440	3,000		
Side B*	Other MHHB Areas	?	2,800		
			5,800	630	11

[1] Measurements taken with a pitot tube/inclined manometer

[2] Measurements made with outside air intake fan operating

* HVAC #14 has two sides, one side serves the high bay balcony and the other supplies other MHHB areas. Both side of HVAC #14 share one common outside air source supplying 630 CFM to a common mixing chamber.

CFM Cubic Feet Per Minute

TABLE 4
VOLUMETRIC AIR FLOW MEASUREMENTS FROM CEILING SUPPLY GRILLS
UNIVERSITY OF SOUTH FLORIDA, MHH BUILDING 104
MHETA 88-020

HVAC System	Area Served	Design[1]	Measured	Outside Air(CFM)[2]	Employees/ Area	Area Sq. Feet[3]	CFM Outside Air/Employee	Sq. Feet Office Area/Employe
#3	High Bay Area Ground Level	10,700	7,350	1,100	18	5,200	61	290
#14	High Bay Area Balcony	1,530	1,100	120	6	600	20	100

CFM - Cubic feet per minute
[1]Design Flow -obtained by summing the design flow rate for each ceiling air supply grill as determined from building blueprints.
[2]Outside Air Supply - measurements were estimated by multiplying the percent outside air intake for each system by the total air flow as determined from ceiling supply grills.
[3]Area Values in Square Feet - should be considered an approximate.

TABLE 5
FORMALDEHYDE CONCENTRATION IN AIR
UNIVERSITY OF SOUTH FLORIDA, MHH BUILDING 104
MHETA 88-020

SAMPLE	DATE	LOCATION	CONCENTRATION (PPM)
1	1/07/88	High Bay-Balcony	0.04
2	1/07/88	High Bay-Ground Level Office	0.03
3	1/07/88	Eye Bank	0.02
4	1/07/88	Outside	0.01
5	1/08/88	High Bay-Balcony	0.05
6	1/08/88	High Bay - Ground Level Office	0.04
7*	1/10/88	High Bay-Balcony	0.03
8*	1/10/88	High Bay-Balcony	0.04
9*	1/10/88	High Bay-Ground Level Office	0.02
10*	1/10/88	Outside	0.008

Health Standards/Guidelines

OSHA Standard (TWA) - 3 ppm
ACGIH Recommendation (TWA) - 1 ppm
NIOSH* Recommendation (C) - 0.1 ppm
ASHRAE Standard (C) - 0.1 ppm

PPM - parts per million parts air
OSHA - Occupational Safety and Health Administration
ACGIH - American Conference of Governmental Industril Hygienist
TWA - Time weighted average
C - ceiling exposure limit

*Samples taken when the HVAC systems were off.

TABLE 6
AIRBORNE CONCENTRATIONS OF MICRORGANISMS
UNIVERSITY OF SOUTH FLORIDA, MHH BUILDING 104
MHETA 88-020

SAMPLE	LOCATION	CONCENTRATION (CFU/M^3)
1	High Bay-Balcony	440
2	High Bay-Balcony	670
3	High Bay-Balcony	280
4	High Bay-Balcony	440
5	High Bay-Ground Level Offices	280
6	High Bay-Ground Level Office	390
7	Outside	1700
8	Outside	2000
9	Outside	1900
10	Eye Bank Office	360
11	Eye Bank Office	490
12	Eye Bank Office	240

CFU/M^3 - colony form units per cubic meter of air
Samples collected on 1/7/88