**HETA 99-0250-2815**
**University of Kentucky**
**College of Pharmacy**
**Lexington, Kentucky**

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# PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (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 (OSHA) 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.

HETAB also provides, upon request, technical and consultative assistance 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. Mention of company names or products does not constitute endorsement by NIOSH.

# ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Calvin K. Cook, Helga Daftarian, and Vincent Mortimer of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies. Field assistance was provided by Jee Y. Jeong of HETAB. Desktop publishing was performed by Robin Smith. Review and preparation for printing were performed by Penny Arthur.

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# Highlights of the NIOSH Health Hazard Evaluation

## Evaluation of Neurologic Conditions Among Employees at the University of Kentucky College of Pharmacy

This health hazard evaluation was requested by management to investigate neurologic conditions experienced by two research employees at the University of Kentucky College of Pharmacy building in Lexington, Kentucky.

### What NIOSH Did

# We reviewed the chemical hygiene plan for laboratories.

# We reviewed the building's ventilation system.

# We did a tracer gas study of the ventilation system.

# We talked to workers about health problems.

# We looked at employee medical records.

### What NIOSH Found

# Chemical odors can move from labs to other work areas in the building.

# Chemical odors can re-enter the building's ventilation system on the roof.

# Some employees who were interviewed had neurologic health problems, but we could not determine whether they were caused by chemicals in the labs.

### What College of Pharmacy Managers Can Do

# Close off the return-air grille in each lab.

# Balance the ventilation system to maintain a negative pressure in the labs.

# Look further into the design and performance of exhaust stacks on the roof, such as the height and discharge velocity.

# Move the plumbing vent away from the nearby air-intake grille on the roof.

# Enforce rules for safe work practices in labs.

### What the College of Pharmarcy Employees Can Do

# Follow rules for safe work practices in labs.

# Open and use chemical containers only inside a chemical fume hood with sash in the working position.

# If you notice chemical odors outside of the labs, report them immediately to safety management.

# Report work-related health problems to a physician.

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National Institute for Occupational Safety and Health
NIOSH

# Health Hazard Evaluation Report 99-0250-2815
# University of Kentucky
# College of Pharmacy
# Lexington, Kentucky
# November 2000

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## SUMMARY

In June 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request from management at the University of Kentucky Medical Center to conduct a health hazard evaluation (HHE) at the College of Pharmacy building. The request stated that two College of Pharmacy faculty personnel had been diagnosed with chronic neurological conditions (multiple sclerosis [MS] and amyotrophic lateral sclerosis [ALS]), and that there were concerns that the development of these conditions may be work-related. Since the building was first occupied in 1985, faculty personnel often reported smelling chemical odors from research labs on the 4th floor.

NIOSH investigators reviewed the facility's Chemical Hygiene Plan, chemical inventory lists, ventilation blueprints, and floor plans. A tracer gas evaluation of the building's ventilation system was conducted to evaluate potential pollutant pathways and airflow patterns on the 4th floor. The tracer gas study demonstrated how chemical odors generated in labs can enter each floor's common return-air plenum, then disperse to other areas in the building, and how air contaminants released from fume hood exhaust stacks and a plumbing vent could re-enter the building's ventilation system. Some research labs were under positive pressure, which may allow chemical odors to disperse to areas outside the lab.

Medical interviews were conducted and medical records were reviewed. Interviewed were one of the two employees diagnosed as having a neurologic condition and five randomly selected employees. None of the five randomly selected employees reported work-related health problems. The medical records of one employee confirmed the development of a neurologic disorder during the employee's employment at the College of Pharmacy, but this information alone was insufficient to determine whether the condition was work-related. The other employee with a neurologic condition declined to be interviewed or submit medical records.

This investigation could not determine whether occupational exposures could account for neurological disorders experienced by two College of Pharmacy employees. Ventilation problems were identified where the return-air plenum serving each floor can allow air contaminants to recirculate to other areas in the building. Also, the ventilation system was not balanced to maintain a negative pressure in labs. Recommendations are offered to improve work practices and laboratory ventilation.

Keywords: SIC 8211 (Colleges, Universities, and Professional Schools) pharmacy, laboratory safety, ventilation, chemical fume hoods, neurological disorders, multiple sclerosis, MS, amyotrophic lateral sclerosis, ALS, Lou Gehrig's disease, tracer gas, sulfur hexafloride, $SF_6$.

# TABLE OF CONTENTS

# INTRODUCTION

On June 7, 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request from management at the University of Kentucky Medical Center to conduct a health hazard evaluation (HHE) at the College of Pharmacy building. The request stated that two College of Pharmacy faculty employees had been diagnosed with different neurological conditions (i.e., multiple sclerosis [MS] and amyotrophic lateral sclerosis [Lou Gehrig's disease]) over the past four years, and that there were concerns that these conditions may be work-related. These employees were College of Pharmacy professors whose offices and research laboratories were located on the 4th floor.

On September 20, 1999, we conducted a walk-through survey of the building's layout and activities. Information gathered and reviewed included the College of Pharmacy's Chemical Hygiene Plan (CHP), chemical inventory lists for each lab, floor plans and ventilation blue prints. The building's interior and exterior were visually inspected to identify potential chemical sources that may affect the building's air quality. Medical interviews were conducted and medical records were reviewed. Based on the information reviewed during the initial site visit, a follow-up site visit was made on October 18-19th to conduct a tracer gas evaluation that would examine potential pollutant pathways and airflow patterns on the 4th floor.

# BACKGROUND

## College of Pharmacy Building Description

The College of Pharmacy building is a six-level structure of approximately 95,000 square foot that was constructed in 1985 to serve both academic and research functions. The basement level includes laboratories, offices, and storage for equipment. The 1st floor is comprised of the general manufacturing area, the animal facility, and laboratories. The 2nd and 3rd floors primarily contain administrative offices and lecture rooms, while the 4th and 5th floors are comprised mostly research laboratories, offices, and conference rooms. About 150 people, including college faculty, research staff, administrative staff, and students, work in the building. Research labs have a chemical fume hood and an area for chemical storage and disposal. Hundreds of different chemicals were stored in labs. Faculty researchers and research assistants are personnel authorized to perform lab activities. One faculty researcher, who has been diagnosed with a neurological condition, worked in an office and a lab, of which both were on the 4th floor. This particular faculty researcher reported that chemical odors could be smelled in hallways and offices. According to discussions with faculty members, they often reported smelling chemical odors in offices and hallways since the building was first occupied in 1985. Chemical odors, described as organic solvents, occurred infrequently for brief periods.

## Ventilation System Description

The heating, ventilating, and air-conditioning (HVAC) needs of the College of Pharmacy building are primarily served by two main air-handlers (AC-1 and AC-2). A third, smaller air-handler (AHU-1) is dedicated to the animal rooms on the 1st floor. Air supplied by these air-handlers is a mixture of outside-air and return-air from individual rooms in the building. This HVAC system is a variable-air-volume (VAV), by which each air-handler has an internal damper that modulates the outdoor supply-air flow rate, under the control of a thermostat. The primary controlling variable for the amount of outside air provided (10% minimum) is the difference of the outside temperature with respect to the desired supply-air temperature. Air-handlers AC-1 and AC-2 are equipped with standard air filters, while AHU-1 is equipped with standard air filters and odor-absorbing charcoal filters. Heating and cooling are provided by a centralized power plant on campus that provides steam and chilled water, respectively, to coils in air-handling units. Scheduled inspection and maintenance procedures are performed on the HVAC system every six months.

Laboratories, offices, lecture rooms, conference rooms, and hallways all have a supply-air and a return-air grille located on the ceiling. Supply-air is delivered to these areas through grilles ducted from air-handlers AC-1 and AC-2. Outside-air for AC-1 and AC-2 is drawn through intake grilles on the roof, mixed with air returned from all floors of the building, then delivered to occupied spaces. On each floor the space above ceiling panels serves as a common plenum for return-air. A separate return-air fan for each floor draws air from the common plenum and forces it upward through the return-air shaft to air-handlers located in the mechanical penthouse on the roof.

The restrooms, janitor's closets, stairwells, and a few special-use rooms have supply-air grilles but no return-air grilles. Instead, these areas have dedicated exhaust fans ducted to the roof outdoors. A 4$^{th}$ floor instrument room has exhaust canopy hoods but no return-air grilles. The animal rooms have both supply-air and return-air grilles ducted to AHU-1.

Chemical fume hoods are static pressure sensitive and have a horizontal-type sash. They are served by three dedicated exhaust ventilation systems that discharged air contaminants directly to the outdoors through three roof top exhaust stacks (approximately 12 feet in height from the roof line). These exhaust stacks are equipped with heat-recovery units for energy conservation. In response to previous complaints of chemical odors in the building that were believed to be caused by air contaminants recirculating from these exhaust stacks, each stack was fitted with an auxiliary fan to increase the discharge velocity that would exhaust air contaminants above the recirculation region on the roof.

A large amount of air is exhausted directly from the building by chemical fume hoods. To prevent a high negative pressure in the building, which would draw unfiltered and untempered air in from the outdoors, make-up air is supplied through a diffuser above the face of each lab hood from fans on the roof. Each make-up air system (MUA-1, MUA-2, MUA-3) is tempered (heated or cooled) by passing the 100-percent outside air over coils in heat-recovery units (RTU-1, RTU-2, RTU-3) that draw heat from (or release heat to) the exhaust air from the laboratory hoods. At least once each year, air velocity measurements are made across the face of fume hoods to ensure adequate performance.

# METHODS

During the initial site visit NIOSH industrial hygienists reviewed the College of Pharmacy's building ventilation blue-prints and overhead floor plans to identify potential pollutant pathways. Elements of the written CHP were reviewed that included chemical inventory lists; these included chemical storage and handling procedures, waste disposal procedures, fume hood performance information, employee training guidelines, HVAC system maintenance schedule, and previous air sampling for air contaminants. During the follow-up visit on October 19, 1999, a NIOSH ventilation engineer conducted a tracer gas evaluation that focused on the ventilation serving offices and labs on the south end of the building. Review of previous air sampling results showed very little chemical concentrations in labs. Because chemical odors were infrequent and occurred only for brief periods, it has been difficult to document specific chemicals responsible for the odors reported by employees. For these reasons, and because chemical odors were not reported by faculty personnel during NIOSH visits, air sampling was not conducted by NIOSH investigators.

## Medical Evaluation

NIOSH staff conducted individual, confidential medical interviews with six employees of the College of Pharmacy. Five of the employees were selected at random from an employee roster list provided by the College. The sixth employee was one of the two referred to in the request as having a neurological disorder. The other employee reported to have a neurological disorder declined to be interviewed. Of the six employees interviewed, four were College of Pharmacy faculty, one was a staff employee, and one was a graduate student. Information from the structured interviews addressed occupational work history (including a description of current work duties), workplace chemical exposures, personal protective equipment (PPE) worn, history of health problems/symptoms, and history of chemical exposures outside of the workplace.

Medical records for one College of Pharmacy employee were also reviewed. The Occupational Safety and Health Administration (OSHA) Logs and Summary of Occupational Injuries and Illnesses (Form 200) were reviewed.

## Tracer Gas Evaluation

Sulfur hexafloride ($SF_6$) is useful as a tracer compound because it is a colorless, odorless gas that is chemically and toxicologically inert, and is seldom present in the work area. Target concentrations of $SF_6$ are typically in the range of 1 to 10 parts per million (ppm), well below its time-weighted average (TWA) exposure limit of 1,000 ppm.[1,2,3]

The primary purpose of the tracer gas evaluation was to evaluate the possible transmission of chemical vapors from laboratories to other areas in the building. From a compressed gas cylinder with a 1/8-inch stainless steel line, tracer gas was released inside and in front of the two fume hoods in laboratories #413 and #419. The tracer gas was also released at three other primary locations: (1) the 4th floor's main return-air inlet located above the mechanical space behind a janitor's closet near the central corridor, (2) the auxiliary fan inlets for exhaust stacks #1 and #3 on the roof, and (3) the outlet of a plumbing vent on the east side of the penthouse. Monitoring instruments, which instantaneously measured the tracer gas, were operated at selected locations on the 4th floor throughout the day to determine if the $SF_6$ appeared. How quickly and how much $SF_6$ appeared were indicative of the directness of contaminant dispersion.

## General Airflow Measurements

In addition to tracer gas dispersion tests, the volumetric airflow rate through selected supply-air and return-air grilles was measured. Depending on the size and accessibility of the grille or diffuser, either a flow hood (TSI AccuBalance®, TSI® Instruments, Inc. Minneapolis, Minnesota) was used to measure the volumetric airflow directly, or a hot-wire anemometer (TSI Velocicalc®, TSI Instruments, Inc. Minneapolis, Minnesota) was used to determine an average velocity from which the flowrate was calculated using the measured area of the diffuser or grille.

In labs #413 and #419, a micromonometer was used to measure pressure differences at doorways between each lab and the adjacent hallway while the fume hood fan was on and the exit door was shut. Ventilation (Draeger®) smoke tubes were also used to visually observe airflow patterns at doorways and ceiling plenums in each lab.

# EVALUATION CRITERIA

## Laboratory Safety

OSHA's general industry regulation (Code of Federal Regulation [CFR]1910.1450)[2] for laboratory safety requires all employers engaged in laboratory use of hazardous chemicals to develop and carry out the provisions of a written Chemical Hygiene Plan CHP. The following summarizes important aspects of a CHP.

- Personnel Designation. Assignment of personnel who are responsible for implementation of the CHP including the assignment of a Chemical Hygiene Office. If appropriate, a Chemical Hygiene Committee should be established.

- Employee Training and Information. Educate employees about the nature of chemical hazards in the laboratory, prudent work practices, emergency procedures, and equipment that can be used to protect themselves from hazards.

- Operating Procedures. Establish standard operating procedures relevant to safety and health considerations to be followed when laboratory work involves the use of hazardous chemicals.

- Procedure Approvals. The CHP should identify any procedures or operations that require special supervisory approval before they are performed.

Procedures involving unstable chemicals, highly toxic gases (e.g., hydrogen cyanide), or special equipment operating at elevated pressures may all require special authorization prior to the performance of any work.

- Control Criteria. Establish control measures to reduce employee exposures to hazardous chemicals, including engineering controls, the use of PPE, and hygiene practices.

- Equipment Performance. Require that all safety equipment (i.e., fume hoods, portable fire extinguishers) are functioning properly and specific measures are taken to ensure proper and adequate performance of such equipment. The OSHA Laboratory Safety Standard only requires that fume hoods prevent the escape of contaminants into the labs below permissible exposure limits (PEL's) or at a level that does not pose a health hazard. The American National Standards Institute (ANSI) recommends a face velocity range of 60 to 120 feet per minute (fpm) across the face of fume hoods.[4]

- Special Precautions. Implement special precautions to be taken when working with reproductive toxins, human carcinogens, and substances which have a high degree of acute toxicity. Precautions to be taken may include:

  - establishment of a designated area;
  - use of fume hoods or glove boxes;
  - procedures for safe removal of contaminated waste; and decontamination procedures.

- Medical Consultation. Provide medical consultation to workers in any of the three following situations:

  - whenever an employee develops signs and symptoms associated with chemicals he or she may have been working with; or
  - whenever an employee is exposed above the threshold for medical monitoring established by a substance-specific occupational standard; or
  - after an unforseen release, such as a leak, spill or explosion, which results in exposure.

## Health Effects Related to Organic Solvent Exposure

A number of studies reported in the literature have described an association between chronic, relatively low level exposure to organic solvents and solvent mixtures and the development of neuropsychologic deficits. The neuropsychologic deficits most commonly reported following chronic solvent exposure include alterations in psychomotor function, increased fatigue, difficulty concentrating, short-term memory deficits, impaired visual motor performance, and decreased reaction time.[5] Effects on the central nervous system could include histologic changes in central nervous system tissue, cerebellar syndrome, and alterations identifiable on computerized tomography (CT) scanning or magnetic resonance imaging (MRI) of the brain.[5] Other neurologic effects include loss of smell, loss of visual acuity, optic neuropathy, cerebral and cerebellar demyelination, cerebral atrophy, and dementia. Peripheral neuropathy with axonal degeneration has been described from a number of solvent exposures, including hexane, methylbutyl ketone, and trichloroethylene. Other conditions which are suspected to result from organic solvent exposure include benzene-induced hemopathy, leukemia, Hodgkin's disease, chronic glomerulonephritis, cirrhosis, halothane-induced hepatitis, and histiocytic lymphoma and lymphosarcoma.[6] Several studies have also shown altered function of the immune system on both the cellular and molecular levels.[6]

### *Multiple Sclerosis*

In a case-control study of automobile plant workers, Nelson *et al* found an association between exposure to organic solvents and chronic neurologic disease.[7] Epidemiologic studies of workers in various industries where exposure to organic solvents is common have been inconclusive in establishing a direct association between solvent exposure and the development of specific degenerative neurologic diseases, such as MS. It is believed that the pathogenesis for MS and other inflammatory central nervous system diseases is a complex one; both genetic and environmental factors may be involved and interact.[8] The first published study addressing the question of MS and solvent exposure was a prevalence survey from Italy in 1982, which compared the prevalence of MS among workers in the shoe and leather industry in Florence with the prevalence of MS among the general population in Florence. The study showed an elevated prevalence ratio in shoe and leather workers relative to each control group.[6]

Souberbielle *et al* reported results of a case-control study examining the professions of persons with and without MS. The study did not find a predominance of occupations with a likely solvent exposure among the case group.[9] A case-control study by Hopkins *et al* investigated complete occupational histories, but there was little correlation between MS and "exposure to various chemicals, radiation, or potentially toxic gases".[10] In a prospective cohort study consisting of 124,766 "solvent-exposed" Danish men and 87,501 "solvent-unexposed" Danish men, both groups were followed over a period of 20 years. After 20 years of follow-up, the number of MS cases among men presumed to be exposed to organic solvents was similar to the number of cases expected on the basis of the rates in all Danish men. The number of cases was also comparable to the expected number of MS cases based on the incidence in the comparison group.[11]

In conclusion, although one epidemiologic study found an increased prevalence of MS in an industry where organic solvent use is prevalent, other studies have not linked solvent exposure to MS.

### *Amyotrophic Lateral Sclerosis*

Amyotrophic lateral sclerosis (ALS), otherwise known as Lou Gehrig's disease, is a disease of the motor neurons, which are those nerve cells that control voluntary muscle movement.[12] ALS affects approximately 30,000 people in the United States, with approximately 5,000 new cases occurring each year.[12] Commonly, onset of the disease occurs between the ages of 40 and 70.[12] Men are slightly more likely to develop ALS than women.[12, 13] There is no known cure for ALS, and there is as yet no effective treatment that can significantly alter the course of the disease.[12, 13]

Although there are many causes of motor neuron degeneration which are thought to be possible causes for ALS, no individual cause has been proven.[12,13] While we do not know what causes ALS, current theories about the source of this disease include free radical production inside motor neuron cells (causing neuronal cell death), autoimmune factors, premature aging, viral agents, and environmental toxins.[12,13] Epidemiologic studies have demonstrated weak associations between ALS and occupational and/or environmental exposures to factors such as electromagnetic fields, solvents, and heavy metals (such as lead and mercury).[14,15] Genetic factors also appear to play a role in the development of ALS.[13] However, as in other neurodegenerative disease processes, it is difficult to implicate any specific agent as a causative factor for ALS. This is due to the fact that there are a broad range of substances which have the potential for damaging neurons. In addition, since diseases such as ALS typically affect individuals later in life, there may be a long delay that occurs between exposure and effects on nerve function.

# RESULTS

## Medical Evaluation

The six employees who were interviewed had worked for the University of Kentucky College of Pharmacy for an average of 12 years (range: 6 months to 25years). All generally worked during the day.

Five of the six employees interviewed stated that they did work involving research in a laboratory environment. Laboratory chemicals utilized by each employee in the lab were variable, depending on the nature of the research being undertaken. Among the chemicals employees reported using in their research laboratories were various solvents (such as methylene chloride, ether compounds, toluene, xylene, glycol ether, paraformaldehyde, acetonitrile), liquid nicotine, as well as chemicals used in high performance liquid chromatography (i.e., methanol, acetonitrile, and dioxanes). Two employees reported occasional chemical odors in office areas. One employee stated that there had been problems with the temperature regulation of laboratories in the past, but that the problems were later rectified. Other than the employee previously identified with a chronic neurologic condition, the interviewed employees denied having experienced health problems related to their work at the College of Pharmacy. One of these five employees, however, did mention that some of the research assistants working in the animal labs had developed an allergy to rat dander during the course of their work.

The medical records of one employee diagnosed with a neurological disorder indicated that the condition developed while the person was employed at the College of Pharmacy. This employee attributed exacerbation of symptoms to exposure to chemicals that had migrated from other laboratories.

## Ventilation Evaluation

### *Tracer Gas Evaluation*

After tracer gas was released inside the chemical fume hood in laboratory #413, none was detected at any of the locations monitored. Tracer gas was also not detected at any monitoring location after being released inside the chemical fume hood in laboratory #419.

Following a release in front of the chemical fume hood in laboratory #413, tracer gas was detected at all monitoring locations, except at the make-up air diffuser above the chemical fume hood in lab #419. A stream of the tracer released from the compressed gas cylinder was discharged outside the capture zone of the lab hood. While tracer gas was detected immediately inside the lab hood, within 30 seconds it was detected outside the entry door of laboratory #413, and detected in less than 2 minutes in offices #414 and #418. Tracer gas was also detected at the inlet of the main return-air plenum within 3-1/2 minutes after being released in front of the chemical fume hood in laboratory #413. These results were duplicated by a second release approximately 1 hour and 20 minutes after the first release of tracer gas, with the exception of the monitoring location outside the entry door of laboratory #413, at which the monitor seemed to malfunction approximately 5 minutes after the first release. The times required for tracer gas to appear at a monitoring location and to rise to a peak value, as well as the height of the peak, are presented for both releases in Table 1.

After a release in front of the chemical fume hood in laboratory #419, tracer gas was detected at all monitoring locations, except at two locations in laboratory #413 (inside the chemical fume hood and at the make-up air diffuser). The times required for tracer gas to appear at a monitoring location and to rise to a peak value, as well as the height of the peak, are presented in Table 2. Note that after some tracer gas was detected immediately inside the lab hood, it took over 3 minutes until it was detected outside the entrance door in laboratory #419, and over 4 minutes before being detected in office #418. Tracer gas was measured at the inlet of the main return-air plenum approximately 6-1/2 minutes after being released in front of the chemical fume hood in laboratory #419.

Tracer gas was released three times at the inlet to the main return-air plenum. It was detected at every monitoring location after at least one of the three releases (only a malfunctioning monitor at the doorway of laboratory #413 did not respond), and the detection times were similar following each release. The times required for tracer gas to appear at a monitoring location and to rise to a peak value, as well as the height of the peak, are presented for all three releases in Table 3.

A release into the inlet of the auxiliary fan for hood exhaust stack #1 resulted in a small amount of tracer gas being detected inside the building, this time in the chemical fume hood in laboratory #419, approximately 2 minutes and 15 seconds after being released. The appearance of tracer gas was suspected at other locations, but could not be confirmed from this release.

Tracer gas was released on the roof of the building into the inlet of the auxiliary fan for hood exhaust stack # 3. This resulted in tracer gas being detected at the inlet main return-air plenum approximately

1 minute and 40 seconds after being released. No other monitoring locations detected tracer gas from this release; however, no monitors were set-up in the northeast portion of the building served by AC-2, which may have been the route of entry.

A final release of tracer gas on the roof, this time at the outlet of a plumbing vent 3 feet from outside-air intakes for AC-1 and AC-2 (closer to and, at the time of the release, upwind of AC-2) again resulted in tracer gas being detected inside the building, this time at all monitoring locations except two at which the monitoring instruments malfunctioned. The times required for tracer gas to appear at a monitoring location and to rise to a peak value, as well as the height of the peak, are presented in Table 4.

## *General Airflow Measurements*

Airflow through the laboratory fume hoods in laboratories #413 and #419 was checked by measuring the velocity at selected points across the face of the hood. The readings were taken with the sliding glass-paneled sash in two positions, fully open and at "working height." The working height was a position (approximately 12 inches above the working surface) marked on the side of the hood opening which allowed a person to comfortably insert his or her arms into the hood to work with chemicals while keeping the upper body, neck and face protected behind the glass panel. This height created less space for air to flow into the hood, thus maintaining a higher velocity without increasing the volumetric flow rate. With the sash at working height, the average capture velocity and nearly all measurement point velocities for labs #413 and #419 were within ANSI's recommended range of 60-120 ft/min.[4] With the sash fully open, the average velocity and many of the component point velocities were less than 100 ft/min for both lab hoods. The average air velocity of the downward airflow from the compensating make-up air diffusers above the lab hood openings was a little less than 50 ft/min for both lab hoods. The results are presented in Table 5.

The volumetric airflow through selected supply-air and return-air grilles on the southwest side of the 4$^{th}$ floor (where the labs and offices of interest were located) was measured and compared with the design values specified on the mechanical drawings. The results are presented in Table 6. Note that the return-air in lab #419 has a value of "zero" because airflow was too low to be measured by the flow hood, and ventilation smoke tubes showed no air movement. Also, the return-air in lab #413 could not be determined because filing cabinets blocked the access to take measurements; however, smoke tubes showed that there was some return-air flow.

Ventilation smoke tubes showed how the airflow contained potential air contaminants within the hoods. However, the downward airflow from the compensating make-up air diffusers above the lab hoods created some turbulence that would allow some air contaminants generated in front of the hood opening to escape being captured by the hood.

The general airflow pattern within the laboratories was downward across the exterior wall (where the supply-air grille was located), across the floor to the opposite wall, then back toward the exterior end of the room through the top half of the room. In less than a minute this circulating pattern of airflow could carry air from the supply-air grille to the lab hood, and from the lab hood to the area in front of the door where the return-air grille was located in a ceiling panel. This provided mixing and recirculation of any contaminant released in the lab.

The airflow through the opening between the bottom of the closed entrance door to the lab indicated a positive pressure for laboratory #413 and a negative pressure for lab #419. With the entrance doors open, both labs had some airflow into the lab and some airflow out of the lab into the corridor. Labs #415 and #417 were determined to be under positive and negative pressure, respectively, through similar measurements.

A comparison, presented in Table 7, of the supply-air, exhaust, return-air and make-up air flowrates for the two laboratories reveals that the net flow of air, both measured and as designed, was negative for laboratory #419 and positive for laboratory #413. That is, air would tend to flow into laboratory #419 from the hallway with the door closed. However, air would tend to flow out of laboratory #413 into the hallway with the door closed.

# DISCUSSION

Beyond the two employees with chronic neurological conditions described in the initial HHE request, we found no evidence of possible work-related health problems among the five randomly selected employees who were interviewed during the survey. The two employees diagnosed with neurological conditions had different diagnoses, neither of which have been clearly linked to occupational exposures. Although one employee was diagnosed with a neurologic disorder while employed by the College of Pharmacy, this information alone is insufficient to determine whether the condition is work-related.

The ventilation evaluation revealed several pollutant pathways that can affect the overall indoor environmental quality (IEQ) of the College of Pharmacy building. The College of Pharmacy building has an inherent ventilation design problem by which the common return-air plenum will allow air contaminants in labs to move to other areas (i.e., other labs, offices, conference rooms). Also, because the ventilation system was not properly balanced to ensure that labs maintained a negative pressure, air contaminants migrated into adjacent hallways. The detection of tracer gas inside the building after it was injected into the inlet of the auxiliary fans for the hood exhaust stacks suggests that the height of the stacks and the velocity of the exhaust discharge may be insufficient to prevent reentrainment. A plumbing vent located only 3 feet from an air intake will introduce sewer odors into the building.

The most important safety equipment in a laboratory to control chemical airborne concentrations is the chemical fume hood. When fume hoods are not used during experiments and procedures, even for brief moments, chemicals may migrate to other laboratories and work areas, thus potentially affecting other personnel. Although fume hoods in labs #413 and #419 performed in accordance with ANSI guidelines, it should be noted that the OSHA Laboratory Safety standard only requires that fume hoods perform well enough to prevent the escape of contaminants into the laboratory environment below their respective PEL, or at a level that does not pose a health hazard. OSHA has not established face velocity criteria for fume hood performance, but ANSI and other safety organizations recommend guidelines of providing face velocities that generally range from 60 to 120 fpm.[4] Providing these recommended face velocities alone, however, will not assure worker protection. If substances were to be released from a fume hood and concentrations exceed their respective PELs, the fume hood would not be functioning properly as OSHA requires, and the laboratory employer would be in violation no matter what face velocity is provided. Therefore, in addition to establishing minimum face velocities, air sampling for potentially released substances may be necessary to confirm compliance and effectiveness of fume hoods.

In accordance with the facility's CHP, all laboratory personnel are trained before initial assignment and before new exposure situations. Based on discussions with laboratory personnel, however, there was a problem with some research assistants improperly handling chemicals outside fume hoods. According to the management, it is the responsibility of the principal research investigator to ensure that assistant laboratory workers were properly trained about chemical hazards in the laboratory.

# CONCLUSIONS

The tracer gas evaluation showed how chemical odors from labs can enter each floor's common return-air plenum, then disperse to other occupied areas. The tracer gas evaluation also showed how air contaminants from two fume hood exhaust stacks and a plumbing vent could re-enter the building's ventilation system on the roof. Also, some research labs were under positive pressure, allowing chemical odors to disperse to adjacent hallways.

The two employees diagnosed with neurologic conditions had different diagnoses, neither of which have been clearly linked to occupational exposures. It is not possible to determine the cause of disease in this situation.

## RECOMMENDATIONS

1. The ventilation system serving each laboratory should be modified to prevent air in labs from entering the return-air plenum. One way (but not limited to) would be to close access to the return-air plenum from all laboratories, narrow the range of the variable supply-air flow rates to the labs (or convert the laboratory supply-air systems to a constant-air-volume) and, if necessary, add additional heating and cooling to maintain thermal comfort. This should be done by a qualified ventilation engineer.

2. Balance the laboratory fume hood exhaust and make-up air flows to the laboratories to maintain a negative pressure in each lab with respect to the hallway. Airflow should move from the hallway into the labs.

3. Consult a ventilation engineer with experience in discharge design to review the height of the exhaust stacks and their discharge velocities.

4. To reduce the chance of sewer odors entering the building, the plumbing vent that is within 3 feet of an outside air-intake grille should be relocated (preferably at a distance of at least 25 feet down-wind of prevailing winds).

5. Laboratory personnel should be reminded to open and use all chemical containers exclusively inside fume hoods with the sash in the "working position", and how unsafe practices may affect other personnel.

6. The CHP should clearly state that principal investigators should periodically review and correct their laboratory assistants' work practices to ensure prudent practices are performed.

7. In accordance with OSHA's Laboratory Safety Standard (29 CFR 1910.1450), if there is reason to believe that exposure levels to a substance routinely exceed exposure limits, initial air monitoring should be made on laboratory personnel while performing laboratory activities to determine their exposure to any substance regulated by a recognized standard. Air sampling should be done after testing or redesigning chemical fume hoods before their use, particularly for special laboratory procedures involving highly toxic substances. The ANSI/ASHRAE 110-1995 Method of Testing Performance of Laboratory Fume Hoods can be used to confirm fume hood performance.[16] If possible, air sampling should also should be done immediately following reports of chemical odors. A qualified industrial hygienist should be consulted.

8. In accordance with the CHP, employees with work-related medical concerns should be evaluated by an occupational medicine provider, or by their personal physician.

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Table 1
Times (In Seconds) for Tracer Gas to Appear and Then Peak, along with the Height of the Peak†
University of Kentucky Medical Center, College of Pharmacy
Lexington, Kentucky (HETA 99-0250-2815)

† Note: The tracer gas sulfur hexafluoride ($SF_6$) was released outside the chemical fume hood in lab #413

| ***Monitoring Site*** | ***First Release of $SF_6$*** | | | ***Second Release of $SF_6$*** | | |
|---|---|---|---|---|---|---|
| | Time to appear (seconds) | Time to peak (seconds) | Peak height (ppm) | Time to appear (seconds) | Time to peak (seconds) | Peak height (ppm) |
| Inside chemical fume hood in lab #413 (initial release) | 1 | 12 | 1.5 | 1 | 24 | 7.4 |
| Inside chemical fume hood in lab #413 (after circulation in room) | 103 | 96 | 4.0 | 85 | 126 | 6.0 |
| Make-up air diffuser above chemical fume hood in lab #413 | 108 | 732 | 0.028 | 90 | 504 | 0.045 |
| Outside doorway of lab #413 (at bottom of door) | 29 | 24 | 8.0 | *NA** | *NA** | *NA** |
| Supply-air grille in office #414 | 115 | 324 | 0.053 | 61 | 282 | 0.28 |
| Return-air grille in office #414 | 101 | 582 | 3.6 | 113 | 264 | 1.9 |
| Inside chemical fume hood in lab #419 | 349 | 2028 | 0.017 | 319 | 1272 | 0.03 |
| Make-up air diffuser above chemical fume hood in lab #419 | *NR** | *NR** | *NR** | *NR** | *NR** | *NR** |
| Inlet of main return-air plenum for 4th floor. | 215 | 198 | 0.091 | 209 | 246 | 1.68 |

*NR* = no response from instrument
*NA* = data not available due to instrument malfunction
ppm = parts per million

Table 2
Times (In Seconds) for Tracer Gas to Appear and Then Peak, along with the Height of the Peak†
University of Kentucky Medical Center, College of Pharmacy
Lexington, Kentucky (HETA 99-0250-2815)

†Note: The tracer gas sulfur hexafluoride ($SF_6$) was released outside the exhaust hood in Lab #419

| ***Monitoring Site*** | ***Release of $SF_6$*** | | |
|---|---|---|---|
| | Time to appear (seconds) | Time to peak (seconds) | Peak height (ppm) |
| Inside chemical fume hood in lab #419 (initial release) | 3 | 48 | 10.7 |
| Inside chemical fume hood in lab #419 (after circulation in room) | 147 | 144 | 4.2 |
| Make-up air diffuser above chemical fume hood in lab #419 | 6 | 54 | 0.12 |
| Outside doorway of lab #419 (at bottom of door) | 186 | 66 | 4.2 |
| Supply-air grille in office #418 | NR* | NR* | NR* |
| Return-air grille in office #418 | 253 | 972 | 0.068 |
| Inside chemical fume hood in lab #413 | NR* | NR* | NR* |
| Make-up air grille above chemical fume hood in lab #413 | NR* | NR* | NR* |
| Inlet of main return-air plenum for $4^{th}$ floor | 387 | 285 | 0.004 |

NR = no response from instrument
NA = data not available due to instrument malfunction
ppm = parts per million

Table 3
Times (In Seconds) for Tracer Gas to Appear and Then Peak, along with the Height of the Peak†
University of Kentucky Medical Center, College of Pharmacy
Lexington, Kentucky (HETA 99-0250-2815)

†Note: The tracer gas sulfur hexafluoride ($SF_6$) was released near the inlet of the main return-air plenum for 4th floor

| ***Monitoring Site*** | ***First Release of $SF_6$*** | | | ***Second Release of $SF_6$*** | | | ***Third Release of $SF_6$*** | | |
|---|---|---|---|---|---|---|---|---|---|
| | Time to appear (seconds) | Time to peak (seconds) | Peak height (ppm) | Time to appear (seconds) | Time to peak (seconds) | Peak height (ppm) | Time to appear (seconds) | Time to peak (seconds) | Peak height (ppm) |
| Inlet of the main return-air plenum | 5 | 6 | 0.79 | 5 | 6 | 3.2 | 17 | 90 | 0.33 |
| Supply-air grille in office #414 | 37 | 24 | 0.006 | 25 | 42 | 0.074 | 37 | 12 | 0.14 |
| Return-air grille in office #418 | NR* | NR* | NR* | 83 | 81 | 0.002 | 59 | 90 | 0.004 |
| Make-up air grille above chemical fume hood in lab #419 | NR* | NR* | NR* | 76 | 18 | 0.078 | NR* | NR* | NR* |
| Inside chemical fume hood in lab #419 | NR* | NR* | NR* | 79 | 84 | 0.009 | 79 | 72 | 0.011 |
| Make-up air grille above chemical fume hood in lab #413 | 54 | 30 | 0.002 | 66 | 42 | 0.046 | 66 | 42 | 0.003 |
| Inside chemical fume hood in lab #413 | NR | NR* | NR* | 85 | 18 | 0.024 | 73 | 42 | 0.017 |
| Outside doorway of lab #413 (at bottom of door) | *NA** | *NA** | *NA** | *NA** | *NA** | *NA** | *NA** | *NA** | *NA** |

NR = no response from instrument
NA = data not available due to instrument malfunction
ppm = parts per million

Table 4
Times (In Seconds) for Tracer Gas to Appear and Then Peak, along with the Height of the Peak†
University of Kentucky Medical Center, College of Pharmacy
Lexington, Kentucky (HETA 99-0250-2815)

†Note: The tracer gas sulfur hexafluoride ($SF_6$) was released at the outlet of a plumbing vent on the roof

| ***Monitoring Site*** | ***Release of $SF_6$*** | | |
|---|---|---|---|
| | Time to appear (seconds) | Time to peak (seconds) | Peak height (ppm) |
| Conference Room #442 | NA* | NA* | NA* |
| Inlet of main return-air plenum for 4th floor | 75 | 633 | 0.13 |
| Outside doorway of lab #419 (at bottom of door) | 120 | 168 | 0.50 |
| Inside chemical fume hood in lab #419 | 141 | 525 | 0.010 |
| Make-up air diffuser above chemical fume hood in lab #419 | 798 | 810 | 0.054 |
| Supply-air diffuser in office #418 | NA* | NA* | NA* |
| Return-air diffuser in office #418 | 205 | 517 | 0.056 |
| Inside chemical fume hood in lab #413 | 290 | 1106 | 0.019 |

* NR = no response from instrument
* NA = data not available due to instrument malfunction
ppm = parts per million

Table 5
Average Air Velocities (Feet/minute) Through the Open Area of the Laboratory Hood and from the Make-up Air Supply Diffuser Located above the Hood
University of Kentucky Medical Center, College of Pharmacy
Lexington, Kentucky (HETA 99-0250-2815)

| **Position of Sash or Make-up Air Location** | Chemical Fume Hood in Lab #413 | Chemical Fume Hood in Lab #419 |
|---|---|---|
| Sash Fully Open | 74 | 68 |
| Sash at Working Height (≈12 inches) | 119 | 130 |
| Make-Up Air (air is supplied above laboratory hood) | 47 | 46 |

Table 6
Measured and Design Flow Rates, and Percent of Design for Southwest Portion of 4th Floor
University of Kentucky Medical Center, College of Pharmacy
Lexington, Kentucky (HETA 99-0250-2815)

| **Location** | Design CFM | Measured CFM | Percent Design |
|---|---|---|---|
| Supply-air in lab #419 | 305 | 345 | 113 % |
| Return-air in lab #419 | unknown | 0 | 0 |
| Make-up air above chemical fume hood in lab #419 | 1090 | 240 | 22 % |
| Chemical fume hood in #419 | -1560 | -645 | 41 % |
| Supply-air in lab #413 | 350 | 540 | 154 % |
| Return-air in lab #413 | unknown | ND* | ND* |
| Make-up air above chemical fume hood in lab #413 | 665 | 150 | 23 % |
| Chemical fume hood in lab #413 | -950 | -435 | 46 % |
| Supply-air in office #418 | 100 | 62 | 62 % |
| Hallway supply-air outside offices | 150 | 89 | 59 % |
| Supply-air in photo lab | 110 | 61 | 56 % |
| Hallway supply-air outside photo lab | 120 | 63 | 52 % |
| Hallway supply-air outside restrooms | 180 | 136 | 76 % |
| Hallway supply-air in front of stairwell | 100 | 51 | 51 % |
| Hallway supply-air along side stairwell | 95 | 45 | 47 % |

ND* = not determined

Table 7
Actual and Design Net Flow Rates, and Percent of Design,
Calculated from Measured and Design Values Presented in Table 6, for Southwest Portion of 4th Floor
University of Kentucky Medical Center, College of Pharmacy
Lexington, Kentucky (HETA 99-0250-2815)

| **Location** | Design CFM | Measured CFM | Percent Design |
|---|---|---|---|
| Net Flow Rate in #419 | -165 | -60 | 36 % |
| Net Flow Rate #413 | 65 | 255 | 392 % |

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