September 8, 2000
HETA 99-0250

Harry Enoch, Ph.D.
Director, Environmental Health and Safety
University of Kentucky
252 East Maxwell Street
Lexington, KY 40506-0314

Dear Dr. Enoch:

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 employees had been diagnosed with a neurological condition (each of a different type) over the last four years, and that there were concerns that the development of these conditions may be work-related.

On September 20, 1999, an initial site-visit was made to gather information about the details of the request, become familiarized with the building's layout, and review the Chemical Hygiene Plan for the College of Pharmacy. Medical interviews were also conducted, and available medical record information was reviewed. Based on the information gathered and reviewed during the walk-through survey, NIOSH investigators decided that a tracer gas study of the building's ventilation system should be done in order to examine potential pollutant pathways and airflow patterns on the 4th floor. On October 18-19th, a follow-up site visit was made by NIOSH investigators to conduct the tracer gas study.

This interim letter summarizes the ventilation evaluation component of the health hazard evaluation (HHE) conducted at College of Pharmacy building located on the campus of the University of Kentucky.

Ventilation System Description

Two main air-handlers (AC-1 and AC-2) serve most of the College of Pharmacy building. A third, smaller, air-handler (AHU-1) provides ventilation to the animal rooms on the first floor. The air supplied by each of these air handlers is a mixture of outside air and air returned from the occupied space. On each floor -- except for the restrooms, janitor's closets, stairwells, and a few special-use rooms, including the animal rooms on the first floor -- the ceiling space above the ceiling panels acts as a shared plenum to collect the air being returned from each room. Air flows into this ceiling-space plenum through a grille in the ceiling in one corner of each room. *(Note: The restrooms, janitor's closets, stairwells and certain special-use rooms do not have grilles for return air. The animal rooms on the first floor have ducted returns to AHU-1.)* A separate fan for each floor draws air from the ceiling plenum and propels it into and upward through the return air shaft to the air handlers in the mechanical penthouse on the roof. Air handlers AC-1 and AC-2 draw some of the air which will be supplied to the occupied space from this return air shaft. Any return air not needed by AC-1 and AC-2 is released through the relief vent on the roof. The outside air for AC-1 and AC-2 is drawn in through intakes on the roof.

The air handler, AHU-1, for the animal rooms is similarly configured, except that since the rooms are all on one floor, there is no return air shaft, but rather a return air duct, and the outside air intake is at ground level. This air handler uses a carbon filter, in addition to the standard filters, on the outside air intake.

Some air is exhausted directly outside the building by fans on the roof. The most common location for these exhaust registers is in the restrooms and the janitor's closets. The other sources for this exhausted air are canopy hoods, such as the one in the instrument room on the fourth floor.

A large amount of air is also exhausted from the building by laboratory exhaust hoods. To prevent the development of a high negative pressure in the building, which would suck unfiltered and untempered air in from outside the building, make-up air is supplied at 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) which have drawn heat from (or released heat to) the exhaust air from the laboratory hoods.

The building is ventilated with variable air volume (VAV) systems. The primary controlling variable for the airflow is the difference of the measured temperature (observed on the thermostat) with respect to the desired temperature (set on the thermostat). When the measured temperature is equal or close to the desired temperature, the supply and return airflows will be at their minimum values. When the measured temperature is significantly greater or less than the desired temperature, the supply and return airflows will be at their maximum values.

The percent of the supply air which comes from outside air is controlled by a variable damper system with return air compensation. The primary controlling variable for the percent outside air is the difference of the outside temperature with respect to the desired supply air temperature. When the outside temperature is equal or close to the supply air temperature, the outside air dampers will be at their maximum setting and less return air will be resupplied to the occupied space. When the outside temperature is significantly greater or less than the supply air temperature, the outside air dampers will shift toward their minimum setting and more return air will be resupplied to the occupied space.

Ventilation Evaluation Methods

Sulfur hexafloride (SF_6) is useful as a tracer compound since it is a colorless, odorless gas that is chemically and toxicologically inert. Target concentrations of SF_6 are typically in the range of 1 to 10 parts per million (ppm), well below its time-weighted average of 1,000 ppm. A tracer gas was used to evaluate the possible transmission of chemical vapors from a laboratory to the adjacent offices across the hall. The tracer gas SF_6 was released inside and in front of the fume hood in laboratory #413, at the same corresponding locations in laboratory #419, in the janitor's closet and at the face of the return air plenum inlet duct, and on the roof into the augmentation air fain inlets for heat recovery units 1 and 3, and at the outlet of a plumbing vent on the east side of the penthouse. Monitoring instruments, which measure the instantaneous concentration of the contaminant, were operated at selected locations throughout the day to determine if the SF_6 appeared. How much appeared and how quickly it appeared were indicative of the directness of contaminant dispersion.

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

A thin stream of a visible chemical aerosol resembling smoke was used to visualize the flow of air in selected locations. The "smoke" was released in short bursts by squeezing a rubber bulb attached to one end of a short plastic tube encasing two glass vials containing the chemicals which combine with air to produce the aerosol.

Ventilation Evaluation Results

Tracer gas was not detected at any monitoring location after being released inside chemical fume hood of in laboratory #413. Tracer gas was also not detected at any monitoring location after being released inside the chemical fume hood in laboratory #419.

Tracer gas was, however, detected at all monitoring locations except laboratory #419 make-up air after being released in front of the chemical fume hood in laboratory #413. The nature of the release was such that the velocity of the stream of tracer gas exiting the 1/8-in stainless steel line carried gas outside the capture zone of the lab hood. Note that after some tracer gas was detected immediately inside the lab hood, within 30 seconds tracer gas was detected outside the entry door of laboratory #413, and in less than 2 minutes tracer gas was detected in office #414 and office #418. Tracer gas was also detected in the return air plenum, at the inlet to the return air duct 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.

A release of tracer gas on the roof of the building, into the inlet of the augmentation air fan for heat recovery unit # 3, resulted in tracer gas being detected at the inlet to the return air duct 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.

Tracer gas was next released three times in the vicinity of the inlet to the return air duct in the ceiling plenum above the mechanical space behind the janitor's closet between the rest rooms on the central corridor on the 4th floor. Tracer gas was detected at every monitoring location after at least one of the three releases; only the malfunctioning monitor at the doorway of laboratory #413 did not respond at all. At the monitoring locations at which tracer gas was detected after more than one of the three releases, the times it took for tracer gas to be detected at the monitoring location after the release were similar. 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 2.

Tracer gas was detected at all monitoring locations except the chemical fume hood and make-up air in laboratory #413 after being released in front of the chemical fume hood in laboratory #419. 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 3. Note that after some tracer gas was detected immediately inside the lab hood, it took over 3 minutes until tracer gas was detected outside the entry door in laboratory #419, and over 4 minutes for tracer gas to be detected in office #418. Tracer gas was detected in the return air plenum, at the inlet to the return air duct approximately 6-1/2 minutes after being released in front of the chemical fume hood in laboratory #419.

Releasing tracer gas on the roof of the building, into the inlet of the augmentation air fan for heat recovery unit # 1, again appeared to result 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, such as the chemical fume hood in laboratory #413 and the make up air monitoring locations in #419 and #413, but could not be confirmed at any other monitoring locations from this release.

Another release of tracer gas on the roof, this time at the outlet of a plumbing vent near the 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 were not functioning properly at this point in the survey. Ironically, one of the poorly performing instruments had been moved to the northeast side of the 4th floor of the building to document the appearance of any tracer gas in a small meeting room supplied by AC-2. 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.

A final release of tracer gas, generated in office #418 by disconnecting the regulator from the compressed gas cylinder, resulted in tracer gas being detected at the return air grille in office #418 within 45 seconds. Subsequent appearances of tracer gas from this release were at the inlet to the return air duct within 2-1/2 minutes after being released, and at the monitoring location outside the door to laboratory #419 over 10 minutes after being released.

The flow through the laboratory fume hoods in laboratory #419 and laboratory #413 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 just 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 also created less space for air to flow into the hood, maintaining a higher velocity without increasing the volumetric flow rate. With the sash at working height, the average velocity and almost all component point velocities were greater than 100 feet per minute (ft/min) for both lab hoods. 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 velocity of the downward flow of air from the compensating make-up air supply diffusers panel 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 flow through selected supply diffusers and return air grilles on the southwest side of the 4th 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 airflow in the laboratories #413 and #419 could not be measured.

The visualized flow of air at the face of the lab hoods revealed that air at the face of the hoods was captured and contained within the hoods. However, the downward flow of air from the compensating make-up air supply diffuser panel above the lab hood opening created some turbulence around the outstretched arms of a person working at the lab hood, and some escaped capture by the lab hood exhaust flow.

The general pattern of airflow with the laboratories was downward across the wall with the window, above which was located the supply air diffuser slots, outward from this wall to the door end of the room in the lower half of the room and back towards the window end of the room through the top half of the room. This circulating pattern of airflow could carry some air from the supply to 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 in less than a minute, and provided continued mixing and recirculation of any contaminant released in the lab.

The airflow through the opening between the bottom of the closed entry door and floor was shown to be inward for laboratory #419 and outward for laboratory #413. With the entry doors open, both labs had some airflow into the lab and some airflow out of the lab into the corridor.

A comparison, presented in Table 7, of the supply, return, exhaust and make-up air flow rates 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 corridor with the door closed; and little, if any, air would be drawn out of the room into the return air plenum. However, air would tend to flow out of laboratory #419 into the corridor with the door closed; and air would be drawn out of the room into the return air plenum.

Ventilation Evaluation Discussion

- The circulation of air within laboratory #413 would quickly move throughout the room and any contaminant not captured or exhausted by the lab hood would be carried not only into the corridor from which it could enter offices and other labs but also into the return air plenum from which it could be spread (albeit much diluted) to all parts of the building.

- The appearance of tracer gas inside the building when injected into the inlet of the augmentation air fans on the heat recovery units suggests that the height of the stacks and the velocity of the discharge for the heat recovery units may be insufficient to prevent reentrainment.

- The detection of some tracer gas in the building after being released in the vicinity of the end of the plumbing vent on the roof is of some concern for the possible introduction of unpleasant sewer odors into the building. This is very likely since a plumbing vent is located only 3 feet away from an air intake.

- Based on discussions with laboratory personnel indicates that there may be a problem with some research assistants improperly handling. Although all laboratory personnel are provided training about laboratory hazards and the importance of prudent practices, there have been case reports of workers who have continued to handle chemicals outside of chemical fume hoods. The most important safety equipment in a laboratory to control chemical airborne concentrations is the chemical fume hood. When chemical fume hoods are not used during experiments, even for brief moments, chemical odors may migrate to other laboratories and work areas, thus potentially affecting other building occupants.

Ventilation Recommendations

1. Block off access to the return air plenum from the laboratories, and 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) adding additional heating and cooling, if necessary, to maintain thermal comfort in the laboratories.

2. Balance the laboratory fume hood exhaust and make-up air flows to the laboratories to create a negative pressure in each lab with respect to the corridor, so that air only flows into the labs from the corridors.

3. Consider having a competent ventilation engineer with experience in discharge design should be consulted for the review of the height of the stacks and velocity of the discharges for the heat recovery units.

4. Extend the height of the plumbing vent in front the outside air intakes for AC-1 and AC-2 above the level of the mechanical penthouse. The same ventilation engineer mentioned in recommendation # 3 should be consulted for the specification of the height of the vent.

A final report of the complete evaluation is forthcoming that will include the medical and industrial hygiene components with additional recommendations. If you have any questions, please do not hesitate to contact me at (513) 841–4374.

Sincerely,

Calvin K. Cook, M.S., C.S.P.
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Table 1. Times (in seconds) for tracer gas to appear and peak, along with the height of the peak, for two releases (1st/2nd) outside the chemical fume hood in laboratory #413.			
Monitoring Site	***Time to Appear (sec)***	***Time to Reach Peak (sec)***	***Peak Height (ppm)***
Chemical Fume Hood in #413 (direct path)	1/1	12/24	1.5/7.4
Chemical Fume Hood in #413 (after circulation in room)	103/85	96/126	4.0/6.0
Make-Up Air in #413	108/90	732/504	0.028/0.045
Outside Doorway in #413 (at bottom of door)	29/*NA**	24/*NA**	8.0/*NA**
Supply Air in Office #414	115/61	324/282	0.053/0.28
Return Air in Office #414	101/113	636/264	3.6/1.9
Chemical Fume Hood in #419	349/319	2028/1272	0.017/0.030
Make-Up Air in #419	*NR*/NR**	*NR*/NR**	*NR*/NR**
Ceiling Plenum Return Air Inlet	215/209	198/246	0.091/1.68
** NR - No Response *NA - Not Available due to instrument malfunction*			

Table 2. Times (in seconds) for tracer gas to appear and peak, along with the height of the peak, for the three releases (1st/2nd/3rd) near the inlet to the return air duct inlet.			
Monitoring Site	***Time to Appear (sec)***	***Time to Reach Peak (sec)***	***Peak Height (ppm)***
Ceiling Plenum Return Air Inlet	5/5/17	6/6/90	0.79/3.2/0.33
Supply Air in Office #414	37/25/37	24/32/12	0.006/0.074/0.14
Return Air in Office #418	*NR**/83/59	*NR**/81/90	*NR**/0.002/0.004
Make-Up Air in #419	*NR**/76/*NR**	*NR**/18/*NR**	*NR**/0.78/*NR**
Chemical Fume Hood in #419	*NR**/79/79	*NR**/84/72	*NR**/0.009/0.011
Make-Up Air in #413	54/66/66	30/42/42	0.002/0.046/0.003
Chemical Fume Hood in #413	*NR**/85/73	*NR**/18/42	*NR**/0.024/0.017
Outside Doorway in #413 (at bottom of door)	*NA*/NA*/NA**	*NA*/NA*/NA**	*NA*/NA*/NA**

** NR - No Response   *NA - Not Available due to instrument malfunction*

Table 3. Times (in seconds) for tracer gas to appear and peak, along with the height of the peak, for the release outside Dr. Howard's Lab exhaust hood.

Monitoring Site	*Time to Appear (sec)*	*Time to Reach Peak (sec)*	*Peak Height (ppm)*
Chemical Fume Hood in #419 (direct path)	3	48	10.7
Chemical Fume Hood in #419 (after circulation in room)	147	144	4.2
Make-Up Air in #419	6	54	0.12
Outside Doorway of #419 (at bottom of door)	186	66	4.2
Supply Air in Office #418	*NR**	*NR**	*NR**
Return Air in Office #418	253	972	0.068
Chemical Fume Hood in #413	*NR**	*NR**	*NR**
Make-Up Air in #413	*NR**	*NR**	*NR**
Ceiling Plenum Return Air Inlet	387	285	0.004
** NR - No Response *NA - Not Available due to instrument malfunction*			

Table 4. Times (in seconds) for tracer gas to appear and peak, along with the height of the peak (in pm), for the release at the outlet of a plumbing vent on the roof.

Monitoring Site	*Time to Appear (sec)*	*Time to Reach Peak (sec)*	*Peak Height (ppm)*
Conference Room #442	*NA**	*NA**	*NA**
Ceiling Plenum Return Air Inlet	75	633	0.13
Outside Doorway of #419 (at bottom of door)	120	168	0.50
Chemical Fume Hood in #419	141	525	0.010
Make-Up Air in #419	798	810	0.054
Supply Air in #418	*NA**	*NA**	*NA**

Return Air in #418	205	517	0.056
Chemical Fume Hood in #413	290	1106	0.019
** NR - No Response* **NA - Not Available due to instrument malfunction*			

Table 5. Average velocities (ft/min) through the open area of the laboratory hood and down across the face from the make-up air supply diffuser located above the hood.

	Chemical Fume Hood in #413	*Chemical Fume Hood* in #419
Sash Fully Open	74	68
Sash at Working Height	119	130
Make-Up Air	47	46

Table 6. Measured and Design Flow Rates, and Percent of Design for Southwest Portion of 4th Floor.

	Design CFM	*Measured CFM*	*Percent Design*
Supply Air in Office #418	100	62	62 %
Corridor Supply Air Outside Offices	150	89	59 %
Photo Lab	110	61	56 %
Corridor Supply Air Outside Photo Lab	120	63	52 %
Corridor Supply Air Outside Restrooms	180	136	76 %
Corridor Supply Air in front of Stairwell	100	51	51 %
Corridor Supply Air along side Stairwell	95	45	47 %
Supply Air in #419	305	345	113 %
Make-Up Air in #419	1090	240	22 %
Chemical Fume Hood in #419	-1560	-645	41 %
Supply Air in #413	350	540	154 %
Make-Up Air in #413	665	150	23 %
Chemical Fume Hood in #413	-950	-435	46 %
Net Flow Rate in #413	65	255	392 %

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