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## **SUMMARY**

On August 3, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from Central Penn Anesthesiology, Ltd., personnel who work at the Polyclinic Medical Center facility in Harrisburg, Pennsylvania. The requestors asked NIOSH to evaluate complaints of severe headaches and rashes among four Central Penn staff members, which they believed were related to working in the Pain Clinic at Polyclinic. NIOSH investigators conducted an environmental and medical survey at this facility on November 15 and 16, 1990.

The environmental survey included an inspection of the relevant areas of the facility and the ventilation system serving those areas, air sampling for possible chemical contaminants, and discussions with Polyclinic staff members about the ventilation system and other facilities issues. A total of 14 general-area air samples were collected, each in one of three sampling locations, and analyzed for possible chemical contaminants. The medical investigation included employee interviews, a review of medical records, and consultation with the physicians who cared for the affected employees.

An inspection by the NIOSH investigators of various components of the heating, ventilating, and air-conditioning (HVAC) system serving the Pain Clinic revealed no visual evidence of microbiological growth, maintenance deficiencies, or other apparent problems. However, an evaluation of this system's design and performance did identify potential problems. A visual inspection of the Pain Clinic rooms revealed no evidence of environmental hazards such as microbial growth, improperly stored chemicals, etc. Air sampling was conducted, and trace levels of a variety of aliphatic and aromatic organic compounds were detected in the air of a Pain Clinic room, the "indoor background" sampling location, and the "outdoor background" sampling location. No aldehydes were detected in any of these locations. The compounds detected are all commonly found in trace concentrations in both indoor and outdoor air. All measured concentrations are multiple orders of magnitude below all industrial evaluation criteria.

A variety of health symptoms were reported, including nausea, lightheadedness, dizziness, and urticarial rash. Although significant health symptoms were reported by the affected employees, the results of medical tests which were available to the NIOSH investigators did not demonstrate abnormalities which suggested an acute exposure to environmental toxicants that could cause these symptoms.

The NIOSH investigators have concluded that no chemical contaminants were detected in the air of Pain Clinic Treatment Room #1 during the NIOSH survey in concentrations which could account for the reported symptoms of Central Penn Anesthesiology personnel. Also, the NIOSH investigators identified no other specific environmental causes for the reported symptoms. In addition, two consulting firms had previously been unable to identify chemical contaminants or other factors which were plausible causes. Consequently the NIOSH investigators were unable to identify the cause of the employees' symptoms. Although the investigators did not identify specific causes for the reported symptoms, the evaluation of the ventilation system revealed other factors that, potentially, could intermittently degrade the general quality of the indoor air. Recommendations are made for ventilation system improvements to address these concerns.

Keywords: SIC 8062 (general medical and surgical hospitals), secondary SIC 8011 (offices and clinics of doctors of medicine), headache, rash, urticaria, neurologic symptoms, ventilation.

## **INTRODUCTION AND BACKGROUND**

On August 3, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from Central Penn Anesthesiology, Ltd., personnel who worked in the Pain Clinic at the Polyclinic Medical Center in Harrisburg, Pennsylvania. The requestors asked NIOSH to evaluate complaints among Central Penn personnel of severe headaches and rashes which they believed were related to working in the Pain Clinic at Polyclinic. NIOSH investigators conducted an initial environmental and medical survey at this facility on November 15 and 16, 1990.

Polyclinic Medical Center is a general medical and surgical hospital with several separate buildings. The hospital's Pain Clinic, located near the northwest corner of the Landis Building, on Level 1 off the Pre-Admission Testing area, consists of three rooms that are accessible from a common area. This common area also provides access to several other rooms which are used for various purposes related to pre-admission testing, including patient waiting rooms, interview rooms, and administrative and clerical offices. The three Pain Clinic rooms are used for conducting outpatient medical interview of patients who will later be admitted to the hospital for surgery, and for outpatient treatment of pain. The requestors asked that this evaluation focus on these three rooms, especially Pain Clinic Treatment Room #1; they stated that their reported symptoms were most highly related to working in this room.

The Pain Clinic was opened in December 1989. Its three rooms were occupied intermittently by anesthesiologists, nurses, secretaries, and patients during the time period when episodes of acute symptoms were reported; typically, one to two people occupied each of these rooms at any given time. All three rooms were used from 9 a.m. to 5 p.m. daily. At the time of the NIOSH survey, however, these rooms were closed off and unused due to the reported health effects.

## **EVALUATION METHODS**

### **Environmental**

The environmental survey included an inspection of the relevant areas of the facility and the ventilation system serving those areas, and air sampling for possible chemical contaminants. It also included discussions with Polyclinic facilities-staff members about the design and operation of the ventilation system, and about other facilities issues. The NIOSH investigators also reviewed, and discussed with Polyclinic and Central Penn personnel, the findings from prior investigations of the reported problems conducted by Polyclinic's facilities staff and by two consulting firms which the hospital had retained (identified in this report as Consultants A and B).

A total of 14 general-area air samples were collected and analyzed for possible chemical contaminants using several methods, the specifics of which are subsequently described. Sampling times ranged from about 1½ hours [hr] to over 7 hr, and all samples were collected using battery-powered "low-flow" air-sampling pumps drawing air at measured rates through collection media appropriate for the specific method. Each sample was collected in one of three locations: (1) Pain Clinic Treatment Room #1, since the requestors' complaints focussed on this room; (2) the Dietary Department office area, considered an "indoor background" location, since this area is served by the same ventilation system as the Pain Clinic but is not directly adjacent to

it; and, (3) an "outdoor background" location about 40 ft from the same ventilation system's outside-air intake. Background samples are important when evaluating potentially "trace" concentrations of contaminants, because they may illustrate differences in trace contaminants between the areas being investigated and the ambient background.

The air samples were collected for two complementary analytical purposes. Some were collected for qualitative analysis to identify any organic compounds which may have been present in the air sampled; the remainder were collected to allow for subsequent quantitative determination of the airborne concentrations of the compounds identified.

Five sampling and analytical methods (three qualitative and two quantitative) were used which were sensitive to a wide variety of organic compounds, including aldehydes. More specifically, samples were collected for qualitative and quantitative analyses of general volatile organic compounds (VOCs) using tubes packed with activated-charcoal adsorbent ("charcoal tubes"), for the qualitative identification (only) of general organic compounds using special adsorbent-containing tubes called thermal-desorption tubes (TD tubes), and for qualitative and quantitative analysis of aldehydes using special reagent-containing tubes.

Charcoal-tube samples for VOCs and reagent-tube samples for aldehydes were collected for a period of approximately 7 hr on November 16. With respect to airborne chemical contaminants present, and their time-weighted average (TWA) concentrations, these samples are representative of environmental conditions during working hours on that day. To maximize the chances of detecting any intermittently present, or otherwise elusive, chemical contaminants, the sampling with the highly sensitive TD-tube method, with its shorter collection duration (about 1 $\frac{1}{3}$  to 2 $\frac{1}{4}$  hr), was conducted on both days of the survey.

**DETAILS OF AIR SAMPLING AND ANALYTICAL METHODS.** Charcoal-tube samples for VOCs, whether for qualitative or quantitative analyses, were collected using an air-flow rate of 200 milliliters per minute (mL/min). The analyses of both types of these samples includes desorption with carbon disulfide followed by some type of gas chromatography (GC). The qualitative analysis requires GC with mass-spectrometry detection (MSD), while the quantitative determination may be accomplished, depending on the compound being measured, by GC with flame-ionization detection (FID), similar to NIOSH Methods 1500, 1501, and 1550,<sup>1</sup> or by GC with nitrogen-phosphorus detection (NPD) or other appropriate detection system.

TD tubes called Carbotrap<sup>TM</sup> 300 Multi-bed Thermal Desorption Tubes were used, with an air-flow rate of 20 mL/min, to collect samples for the qualitative identification of general organic compounds. The analysis of these samples includes desorption by heating in a special oven, with the effluent fed directly to GC with MSD. This method is much more sensitive than the charcoal-tube method described above, and may be able to identify more substances. However, it is not quantitative, and only the quantitative charcoal-tube method is available for determination of the airborne concentrations of the compounds identified.

The special reagent tubes used to collect samples for aldehydes, whether for qualitative or quantitative analyses, contain XAD-2 resin coated with (2-hydroxymethyl)piperidine (2-HMP), and were used with an air-flow rate of 80 mL/min. Each type of aldehyde present reacts with the 2-HMP to form its oxazolidine derivative. The qualitative aldehyde samples were collected and analyzed in accordance with NIOSH Method 2539.<sup>1</sup> The analysis of this type of sample includes

desorption of the oxazolidine derivatives with toluene, followed by GC with FID for the initial identification of any oxazolidine derivatives present. This is followed by GC-MSD to confirm any initial identifications made. A variety of analytical methods are available for the quantitative determination of specific aldehydes, but, as subsequently discussed in this report, none of these compounds were detected with the qualitative sampling so quantitative analyses were not needed.

### **Medical**

The medical survey consisted of an inspection of the facility, a review of the relevant medical records, and interviews with employees. The employees interviewed included those who had reported symptoms as well as other employees working in the area served by the same ventilation system. The physician who saw the three employees reporting symptoms in the emergency room on July 24, 1990, was contacted by telephone, as was the physician caring for two of these employees.

## **EVALUATION CRITERIA**

A number of published studies have reported high prevalences of health complaints and symptoms among occupants of office buildings and other types of structures.<sup>2,3,4,5,6</sup> In response to complaints of this kind, NIOSH investigators have completed over 700 investigations of the indoor environment in a wide variety of settings. The majority of these investigations have been conducted since 1979.

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

Scientists investigating indoor environmental problems believe that, in cases such as these, there may be multiple factors contributing to building-related occupant complaints.<sup>7,8</sup> Among these factors are imprecisely defined characteristics of heating, ventilating, and air-conditioning (HVAC) systems, cumulative effects of exposure to low airborne concentrations of multiple chemical pollutants, elevated airborne concentrations of particulate matter, odors, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.<sup>9,10,11,12,13,14</sup> Reports have not been conclusive as to whether increases of outdoor-air delivery rates to indoor spaces above currently recommended levels (which are discussed subsequently in this section) are beneficial.<sup>15,16</sup> However, rates lower than these appear to increase the prevalence of complaints and symptoms in some studies.<sup>17,18</sup> Design, maintenance, and operation of HVAC systems are critical to their proper functioning and to the provision of healthy and thermally comfortable indoor environments. Indoor environmental pollutants can arise from either outdoor sources or indoor sources.<sup>19</sup>

Less often, an illness may be found to be specifically related to something in the building environment. Some examples of potentially building-related illnesses are allergic rhinitis,

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

There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related to the occurrence of symptoms than the measurement of any indoor contaminant or condition.<sup>20,21,22</sup> Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.<sup>22,23,24,25</sup>

Problems NIOSH investigators have found in the non-industrial indoor environment mirror those discussed in the preceding paragraphs, and have included poor air quality due to ventilation system deficiencies, overcrowding, volatile organic chemicals from office furnishings, machines, structural components of the building and contents, tobacco smoke, microbiological contamination, and outside air pollutants; comfort problems due to improper temperature and relative humidity conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job-related psychosocial stressors. In most cases, however, no specific cause of the reported health effects could be determined.

Standards for exposures to chemical substances specifically for the non-industrial indoor environment do not exist. NIOSH, the Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards or recommended limits for occupational exposures.<sup>26,27,28</sup> With few exceptions, airborne pollutant concentrations observed in the office work environment fall well below these published occupational standards or recommended exposure limits. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended building ventilation design criteria and thermal comfort guidelines.<sup>29,30</sup> The ACGIH has also developed a manual of guidelines for approaching investigations of building-related complaints that might be caused by airborne living organisms or their effluents.<sup>31</sup>

### **Ventilation Rates**

The ASHRAE standard "Ventilation for Acceptable Indoor Air Quality" generally specifies an outside-air (o.a.) intake rate of 20 ft<sup>3</sup>/min (cubic feet per minute, or cfm) per person for office spaces and 15 cfm/person for medical-procedures rooms.<sup>29</sup> However, when more than one space is served by a common supply system, the ratio of outdoor to supply air required to satisfy the ventilation and thermal control requirements may differ from space to space, and, if so, the system's o.a.-intake rate determined from the preceding criteria must be corrected as specified in Section 6.1.3.1, Multiple Spaces, in the ASHRAE standard. Of the spaces served, the one with the highest ratio of outdoor to supply air required is defined as the "critical space," and the numerical value of this ratio, for the critical space, is used when determining the corrected o.a.-intake rate needed for the system. The ASHRAE standard also specifies that variable-air-volume systems (these have variable total-supply-air flowrates, to individual spaces served and for the system overall) must be able under minimum-flow conditions to supply adequate o.a. to maintain

acceptable indoor air quality to each space served. The most certain way to assure this is to employ the minimum supply-air flowrate to each space when determining the required effective o.a. needs and the critical space, and then consider the resulting required proportion of o.a. in the system supply air to be a minimum if variable o.a.-intake dampers are used.

Carbon dioxide (CO<sub>2</sub>) is a normal constituent of exhaled breath; measurement of CO<sub>2</sub> concentrations can be used as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. Indoor-air CO<sub>2</sub> concentrations are normally higher than the generally constant ambient-air CO<sub>2</sub> concentration, which ranges from 300 to 350 parts per million (ppm). When indoor CO<sub>2</sub> concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated CO<sub>2</sub> concentrations suggest that other indoor contaminants may also be increased.

## RESULTS AND DISCUSSION

### Environmental

**VENTILATION SYSTEM ASSESSMENT (GENERAL).** The ventilation system serving the Pain Clinic is system AH-1-LG, which serves Levels 2, 1, and G (ground) of the northwest section of the Landis Building. System AH-1-LG is a dual-supply-duct variable-air-volume (VAV) system with an air-handling unit (AHU) located in the building's basement. The AHU conditions a mixture of outside air and air returned from the occupied spaces, and then supplies the conditioned air to these spaces. The Appendix contains a full description of system AH-1-LG and how it operates.

Any moist or wet surfaces inside HVAC-system components (e.g., standing water in an AHU condensate tray) could lead to microbial growth from which bioaerosols could be released into the airstream. Key components of system AH-1-LG were examined for such problems, as fully discussed in the second section of the Appendix. A summary of the findings follows.

A visual inspection of the AHU revealed no evidence of microbiological growth, or any other apparent problems with its condition or operation. A problem at the AHU would most likely affect more of the area served by the system, rather than only the three Pain Clinic rooms. As Consultant A indicated, it is unlikely that the ventilation system is delivering contaminated air from the AHU and/or main supply ducts to the Pain Clinic alone. If there is a contamination source, it is in the Pain Clinic area. An inspection of the visible portions of the ventilation system serving the Pain Clinic rooms also revealed no apparent problems. Most of the portion of the ventilation system serving the Pain Clinic has also been examined by Polyclinic facilities-staff members as well as Consultant A investigators, and no evidence of problems has been reported. Based on all of the above findings, the delivery of bioaerosols by the ventilation system to the Pain Clinic is unlikely to be the cause of the reported acute symptoms. However, it is uncertain if the earlier investigators fully examined the mixing-box discharge ducts which lead to the ceiling-mounted supply-air diffusers. Access was not available for viewing much of these ducts' internal surfaces during the NIOSH visit.

The outside-air (o.a.) intake opening for system AH-1-LG is located in a pit alongside the rear alleyway, near the loading dock. As discussed by both consultants in their reports, this creates the potential for vehicular engine exhaust products (from both gasoline and diesel engines) to be

inducted into this o.a.-intake opening and the areas served by this system. As the Consultant B investigators noted in their report, this induction of pollutants would probably occur on an intermittent basis depending on atmospheric conditions, the number of vehicles present during a given time period, and their positioning. Also affecting the potential for induction of pollutants would be the position of the ventilation system's variable o.a. "economizer" damper. The Consultant B investigators reported detecting traces of compounds found in engine-exhaust emissions in the air of areas served by ventilation system AH-1-LG when an idling vehicle was parked near the system's o.a.-intake opening (although they did not monitor the air for these types of compounds in the Pain Clinic rooms). Although truck drivers have been instructed to shut off engines while stopped in that area to avoid contaminating the intake air, such a policy is hard to enforce. In fact, idling vehicles were observed there during the NIOSH survey. This policy faces further resistance in the winter because many of the vehicles are diesel-powered; since diesel engines are hard to start in cold weather, operators often prefer to leave engines idling when the vehicles are parked. Although the induction of engine-exhaust-contaminated o.a. is a potential problem, it is unlikely to be the cause of the reported acute symptoms because the ventilation system cannot supply contaminated o.a. to the Pain Clinic alone. As indicated previously, if there is a contamination source causing the reported symptoms, it is in the Pain Clinic area.

**VENTILATION SYSTEM ASSESSMENT (OUTSIDE-AIR-INTAKE RATE).** To determine if ventilation system AH-1-LG delivers outside air to the spaces of interest at a sufficient rate, its design and performance may be compared with the guidelines in the ASHRAE ventilation standard discussed previously. Consultant B investigators measured the supply-air (s.a.) flowrates to each room in the Pain Clinic using an airflow hood. The NIOSH investigators used the results of these measurements, as well as the design and actual system s.a.-flowrates and minimum o.a.-intake rates, to assess the adequacy of the effective rate that the system delivers o.a. to the Pain Clinic rooms. This assessment is fully described in the last section of the Appendix. Based on all the information presented there, the NIOSH investigators conclude that insufficient outside air delivery cannot be ruled out as a problem in the Pain Clinic area.

Although airborne concentrations of CO<sub>2</sub>, which may be elevated by occupants' exhaled breath, are often measured as a screening technique to evaluate whether o.a. is being delivered into an occupied space at an adequate rate, the concentration of CO<sub>2</sub> is of limited significance when the space in question is unoccupied. Acceptable CO<sub>2</sub> levels detected during unoccupied periods do not necessarily suggest an o.a.-delivery rate adequate for the normal occupancy level. The Consultant A investigators used Gastec® detector tubes to collect four air samples for CO<sub>2</sub> in Pain Clinic Treatment Room #1 and two samples in the Pain Clinic Office, while the entire Pain Clinic was unoccupied. For each of two samples (one collected in each room monitored), they reported that the measured concentration ranged between 300 and 500 ppm, and for each of the remaining four samples they reported that it ranged between 500 and 1000 ppm. These are not considered elevated levels under the evaluation criteria cited previously. The Pain Clinic rooms were also unoccupied at the time of the NIOSH survey, and the CO<sub>2</sub> measurements were not repeated by the NIOSH investigators.

**POSSIBLE CHEMICAL AND MICROBIAL CONTAMINANTS.** The visual inspection of the Pain Clinic rooms by the NIOSH investigators revealed no apparent problems in the rooms themselves. Treatment Room #1 contained a sink, the drainpipe of which had been previously considered by Consultant B investigators. They determined that this was not likely the source of

any contaminants, since the trap in this drain was not dry, and the drain stack servicing it did not service fixtures in other areas that were noteworthy in terms of possible contaminants.

Except for the potential induction of vehicle-engine exhausts into the ventilation system, addressed previously in this report, the only possible source of irritant substances in the Pain Clinic identified by Consultant A investigators was an air-freshener disk which seemed to be the source of a strong, soapy odor. The investigators removed it, and after a short time the odor dissipated from one of two Pain Clinic rooms where it had been evident. Prior to their visit, an odor described as possibly like a pesticide had been reported on July 10, 1990, during the first incidence of acute health effects reported by workers in the Pain Clinic. A day earlier, a different odor had been reported at the start of this 2-day incidence of reported acute health effects, and it was determined that a solvent had been in use that day elsewhere in the facility for an asbestos-removal project. No odors were evident during the NIOSH survey.

Previous investigators of the reported health effects have conducted air monitoring in the Pain Clinic. At the opening meeting of the NIOSH evaluation, Polyclinic management representatives stated that a member of the Polyclinic engineering staff collected air samples on July 24, 1990, for xylene, formaldehyde (HCHO), ethylene oxide, and carbon monoxide (CO) with Gastec® detector tubes, and detected none of these gases. Consultant A investigators also used Gastec® detector tubes to sample the air for HCHO, CO, ammonia, and acetic acid, and again, none of these were detected. They also collected wipe samples from supply-air diffusers in the Pain Clinic. These samples were analyzed for heavy metals and chlorinated pesticides; none were detected.

The Consultant A investigators reported detecting a halogenated anesthetic gas, Forane, in the Pain Clinic air using a Photovac 10S70 portable gas chromatograph. Forane, as well as two other halogenated anesthetic gases which reportedly were not detected, are normally present in operating rooms and recovery rooms elsewhere in the Landis Building. However, the instrument used employs a photoionization detector which is unlikely to respond to any of these three highly halogenated compounds, and it does not have the capability (e.g., mass spectrometry detection) to confirm the identity of detected compounds. Therefore, it is unlikely that the compound detected was Forane. Consultant B did detect low levels of another anesthetic gas, nitrous oxide (N<sub>2</sub>O), in Pain Clinic Treatment Room #1. This likely occurs due to the partial recirculation of the recovery room air into HVAC system AH-1-LG. However, at the November 15, 1990, opening meeting, all parties present agreed that exposure to the anesthetic gases does not produce the symptoms reported by the requestors.

**AIR SAMPLING RESULTS.** The results of the air sampling conducted indicate that trace levels of a variety of aliphatic and aromatic organic compounds were present in the air of Pain Clinic Treatment Room #1, the "indoor background" sampling location (the Dietary Department office area), and the "outdoor background" sampling location during the sampling periods. No aldehydes were detected in any of these locations (a limit of detection for the aldehyde sampling was not determined because only the qualitative samples were analyzed, but typical limits of detection are listed in the published aldehyde methods discussed earlier). The compounds detected with the qualitative sampling and analyses methods are: C<sub>6</sub> and C<sub>7</sub> alkanes, isooctane, and other aliphatics, perchloroethylene, 1,1,1-trichloroethane (methyl chloroform), benzene, toluene, siloxane compounds, xylene isomers, styrene, 1-ethyl-2-hexanol, limonene,

C<sub>9</sub>H<sub>12</sub> aromatic compounds (with molecular weights of 120), naphthalene, and an unidentified aliphatic alcohol. These compounds are all considered common trace air contaminants.

The primary constituents identified in the qualitative air samples were chosen for quantitative determination. The results of the quantitative analyses indicate that 1,1,1-trichloroethane and benzene were present at concentrations which were below these analyses' limits of detection, and therefore were less than 0.002 ppm and less than 0.004 ppm, respectively, in all three sampling locations. Xylene isomers were measured in all three areas at nearly equal concentrations of approximately 0.005 ppm (for all three of these samples, the measured concentration is only an estimate because it is below the analytical limit of quantitation). Toluene was measured in both indoor locations at equal concentrations of approximately 0.0060 ppm, about twice the outdoor level of approximately 0.0031 ppm (for all three of these samples, the measured concentration is only an estimate because it is below the analytical limit of quantitation). Limonene, sometimes used as a scent in cleaning agents, was measured in the Dietary Department office area at a concentration of 0.010 ppm, several times greater than the concentration measured in Treatment Room #1 or outside. Total aliphatic hydrocarbon concentrations were as follows: 0.091 milligrams per cubic meter of air (mg/m<sup>3</sup>) in Treatment Room #1, 0.080 mg/m<sup>3</sup> in the Dietary Department office area, and about 0.024 mg/m<sup>3</sup> (below the limit of quantitation) outside.

All measured concentrations are multiple orders of magnitude below all relevant industrial evaluation criteria, even the relatively stringent NIOSH REL of 0.1 ppm for full-shift time-weighted-average exposures to benzene, and are considered fairly typical for indoor-air-quality evaluations. The chromatograms from the qualitative analyses suggest that most of the other constituents, that were not quantitatively measured, were actually more prevalent and present at higher levels in the Dietary Department office area, and even outside, than in Treatment Room #1.

Neither the compounds detected in the concentrations measured, nor the relative prevalence of air contaminants in Pain Clinic Treatment Room #1 compared to other areas sampled, is indicative of a problem due to airborne chemicals.

## **Medical**

**CHRONOLOGY AND SYMPTOM HISTORY.** A detailed chronology of employee symptoms was constructed as part of the NIOSH medical investigation. Because only four employees are involved, however, it is possible that individuals could be identified from specific histories. In order to protect employee confidentiality, therefore, only a general review of symptoms will be presented in this report.

On Monday, July 9, 1990, three employees working in the Pain Clinic area and in the early afternoon noted the onset of a variety of symptoms. Although no employee reported all of the symptoms, each reported some symptoms, including nausea, vomiting, involuntary trembling, and a sensation of heaviness of the lower limbs accompanied by fatigue. Employees reported smelling an odor "like anesthetic gas" or an undefinable odor. Subsequently, one employee's physician diagnosed viral labyrinthitis (a temporary viral inflammation of the inner ear) as the cause of dizziness. The other employees did not report a physician's diagnosis.

On July 10 and 11, employees working in the Pain Center experienced the onset of varied symptoms including nausea, headache, vertigo, light-headedness, confusion, difficulty walking, and burning of the eyes and throat, and the appearance of an urticarial rash ("hives"). One employee noted an "insecticide" odor.

No additional symptoms were reported until Tuesday, July 24. All employees present that day developed symptoms of headache and dizziness. The employees also reported that houseflies in the area were sluggish and slow to respond to motion, unlike a fly's normal flight response to threats. All three employees went to the emergency room for evaluation. At that time the Pain Clinic ceased operations in the Landis building and the employees stopped going there; all subsequent patient services have been provided in other areas or in a building owned by Central Penn Anesthesiology and located a block away from the hospital.

In addition to the symptoms described above, one employee reported feelings of fatigue, slurred speech and tingling of the fingertips. These symptoms resolved over the next 3 days.

Other employees reported suffering: dizziness, increased salivation and urination; urticaria; bloody stools for 2 days; abdominal pain; dizziness, disorientation, headache, tremor, and difficulty composing a sentence; and, dark, smelly urine. One employee was tested for heavy metal and organophosphate screens, and cholinesterase levels, which were normal.

The emergency room physician who saw all three affected employees on July 24 said that although all three described symptoms, he did not see corroborative signs. The affected employees described abnormalities of speech and gait, but this physician reported observing normal gait and speech in all three. He did not observe neurologic abnormalities (although he did not perform a detailed neurological examination) or skin abnormalities during the initial presentation.

During the July 24 episode, the emergency room physician also obtained blood for heavy metal screens, urine for mercury levels, and blood for pesticide screens from all three employees; the analyses were performed by outside contract laboratories. The blood levels of arsenic, lead, and mercury for all three workers were well below the reference ranges of the laboratory, as were the urine mercury levels. None of the 41 pesticides and metabolites tested in the pesticide screens were detected except for DDE, a metabolite of DDT (DDT was not detected). The detected levels of DDE, which ranged from 1 to 4 parts per billion (ppb), most likely represent exposure to trace levels in the general environment. Traces of DDE are very commonly found in serum; in one nationwide survey, quantifiable DDE levels were present in the sera of 99.5% of the 4089 people tested.<sup>32</sup>

Three other Polyclinic employees who worked in adjacent areas of the Pre-Admission Testing Area were interviewed in the NIOSH investigation. One employee reported that on one of the days when the anesthesia personnel were affected (but did not specify July 10 or 24), this employee and other employees smelled "an odd smell;" this employee felt eye and nose irritation, chest tightness, and nausea. The only symptom noted the next day was occasional chest tightness, and all symptoms had resolved by the time of the NIOSH interview. Another employee reported occasional headaches and lightheaded feelings during this period, and occasionally smelling "different fumes." The third employee reported having an occasional headache but ascribed this symptom to job-related stress.

**INTERPRETATION OF RESULTS.** The affected employees described symptoms in both neurologic and dermatologic categories. These will be discussed separately.

- **Neurologic symptoms:** The neurologic symptoms described by the employees include headache, dizziness, vertigo, difficulty walking, and nystagmus. Some of these symptoms, such as lightheadedness or disorientation, are compatible with an exposure to some agents such as organic solvents; the acute onset and recovery of the affected workers is also compatible. But the gastrointestinal and dermatologic symptoms are not typically associated with acute solvent intoxication, and it is difficult to explain why a solvent vapor would so profoundly affect the Pain Clinic employees and yet spare the employees in the rest of Pre-Admission Testing Center, which receives the same air supply. Although significant absorption of solvents can occur through skin contact, none of the affected employees reported using any unusual chemical agents on the days when symptoms appeared. None of the investigations have detected any solvents in quantities sufficient to produce such symptoms.

One employee expressed concern that the symptoms might have resulted from acute heavy metal intoxication. Although acute intoxication by elemental mercury vapor can present with headache and gastrointestinal symptoms, these are usually accompanied by dyspnea (difficulty breathing) due to erosive bronchitis and bronchiolitis (inflammation of large and small air passages in the lung) and interstitial pneumonitis (inflammation of the lung tissue).<sup>33,34</sup> The affected employees did not report pulmonary symptoms, and their blood mercury levels (a better indicator of acute mercury intoxication than urine levels) were normal. Lead intoxication, which can present suddenly with weakness and gastrointestinal symptoms, is equally unlikely given the employees' normal blood lead and zinc protoporphyrin levels.<sup>35</sup> In addition, neither of these metals was found during environmental sampling conducted by Consultant A.

- **Dermatologic symptoms:** Urticaria (hives) are caused by release of histamine, a chemical released by certain cells in the body; the potential causes of urticaria from histamine release include a wide range of drug, food, plant, and inhalant exposures as well as infections and physical stimuli.<sup>36</sup> Urticaria can also result from an occupational exposure involving either an allergic response to the substance, or a non-allergic response in which a substance directly affects the walls of blood vessels in the skin or causes the release of substances such as histamine.<sup>37</sup> Although urticaria were described by two employees, this symptom was not noted by the other two employees, who gave detailed descriptions of their symptoms and histories. This suggests that if the urticarial rash resulted from an occupational exposure, it was not due to one of the nonallergic causes because these tend to affect nearly all exposed individuals.

Substances found in hospitals which have been reported as causes of allergic contact urticaria include antibiotics, topical preparations of benzocaine, rubber gloves (usually due to natural latex), cornstarch powder in rubber gloves, and formaldehyde.<sup>37</sup> Determination of whether these or other substances may have caused the symptoms reported by the affected workers would require evaluation and testing by a dermatologist or allergist. Materials which were used in the Landis building and are currently used in the new Pain Center (for example, if the same brand of rubber gloves is being used) are unlikely to have been the cause in one setting and leave workers unaffected after moving to a new location.

## CONCLUSIONS

The NIOSH investigators have concluded that no chemical contaminants were detected in the air of Pain Clinic Treatment Room #1 during the NIOSH survey in concentrations which could account for the reported symptoms of Central Penn Anesthesiology personnel. Also, the NIOSH investigators identified no other specific environmental causes for the reported symptoms. In addition, neither of the consultants identified chemical contaminants or other factors which were plausible causes. Although significant health symptoms were reported by the affected employees, the results of medical tests which were available to the NIOSH investigators did not demonstrate abnormalities which suggested an acute exposure to environmental toxicants. Consequently the NIOSH investigators were unable to identify the cause of the employees' symptoms. However, this does not rule out the possibility that some of the reported health effects could have been work-related.

## RECOMMENDATIONS

1. The outside-air-intake opening for ventilation system AH-1-LG should be moved from its current location, near the loading dock, because of the potential for vehicles' engine-exhaust products to be inducted to the areas served by this system. The intake opening could be placed above the rooftop level by constructing a duct from the current intake opening to the roof, as suggested by Consultant B. If this location is selected, refer to Figures I, II, and III (from ACGIH's ventilation manual<sup>38</sup>), and Enclosure I for guidance in the proper location of exhaust and intake openings, and be certain that some provision (such as a side-mounted air opening at the top of the new duct) is provided to keep rainwater from entering the new intake opening and collecting in the current below-ground o.a.-intake area ("pit"). Filtration of the outside air entering the system, suggested by Consultant B as an alternative to relocating the o.a.-intake opening, is not recommended as an alternative since some of the major hazardous constituents of engine-exhaust emissions, such as CO, cannot be removed from the airstream by any of the commercially available filtration and/or adsorbent-bed systems.
2. A mechanical firm with engineering capability should be retained to evaluate the existing design of ventilation system AH-1-LG (serving the Pain Clinic rooms and other areas) to determine if it is adequate to ensure the provision of o.a. to the Pain Clinic rooms in the required effective proportions; insufficient information was available at the time of the survey to make this determination. This firm should then recommend any modifications needed to ensure that the system performs in accordance with the guidelines in the ASHRAE ventilation standard discussed previously, particularly the provisions regarding VAV systems, and regarding multiple spaces served by the same system. The system was not operating to design specifications at time of survey, leaving its minimum system-o.a.-intake proportion below that specified in the design. Therefore, even if the design is found to be adequate, performance must at least be restored to design-specified levels to assure an adequate rate of o.a. delivery to the Pain Clinic area.

As part of the system-design evaluation, the mechanical firm should also determine what, if any, system modifications are needed to properly effect the changes advocated in Recommendation No. 1. Specifically, the capability of the current air mover (fan) in the system's AHU to overcome the additional resistance to airflow from the added outside-air-

intake duct should be assessed. Also, the maximum and minimum system outside-air-intake rates should be compared with the total rate air is exhausted from the system's service area via all exhaust systems. Generally, it is good practice for the building as a whole to be kept under "positive pressure" compared to the outside environment. Once the existing design is found to be adequate or an adequate modified design is determined, the mechanical firm should then assure that the system satisfactorily performs at the design-specified levels for all relevant parameters.

3. Maintenance procedures should specify the periodic inspection, cleaning, and testing of HVAC system AH-1-LG (as well as the other HVAC systems in this building and in the entire Polyclinic complex). These procedures should specifically include the proper maintenance of the HVAC-system controls, such as thermostats. The AHU, as well as the "pit" area in front of the current outside-air-intake opening, should be periodically checked for the accumulation of water and/or dirt that could be favorable to the growth of microorganisms which could be introduced into the air stream, and the areas should be cleaned as necessary. Correct air flowrates should be verified periodically (particularly the minimum and maximum hot- and cold-supply-air flowrates at the VAV mixing boxes), as should the proper operation of the o.a.-intake dampers.
4. Since it is uncertain if the earlier investigators of problems reportedly related to the Pain Clinic area fully examined the mixing-box discharge ducts which lead to the ceiling-mounted supply-air diffusers in the Pain Clinic rooms, these ducts' internal surfaces should be inspected. Any access openings created for this inspection should be securely sealed upon completion of this procedure.
5. A health and safety committee should be established to address the health concerns of the workers and promote a safer workplace. This committee should have both non-management and management representation.

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## APPENDIX

### VENTILATION SYSTEM DESCRIPTION AND ASSESSMENT

#### Description

The ventilation system serving the Pain Clinic is system AH-1-LG, which serves Levels 2, 1, and G (ground) of the northwest section of the Landis Building. System AH-1-LG is a dual-duct variable-air-volume (VAV) system. The area served by this system is divided into numerous zones (usually a room or two in size), each of which has a VAV mixing box with a thermostatic control. The mixing box is supplied with hot air from one supply duct, and cold air from another. In response to the thermostat, dampers in the box regulate the flowrates of incoming hot and cold air, thereby controlling the temperature of the resulting mixture; this mixture is supplied to a third duct for discharge through ceiling-mounted diffusers into the occupied space of the zone.

The maximum air flowrate allowed by each hot- or cold-air-supply VAV damper may be adjusted by a service technician to match the system design specifications, which are based upon anticipated thermal loads. The minimum air flowrate allowed by each such damper may also be adjusted, and some airflow is supposed to be maintained at all times through each damper. When the thermostat calls for cooling, the cold-air-supply VAV damper will modulate to provide cold-air flow at an appropriate rate (between the minimum and maximum settings), while the hot-air-supply VAV damper will allow hot-air flow at the pre-set minimum rate. When the thermostat calls for heating, the opposite will occur, and when the thermostat calls for neither heating or cooling, both VAV dampers will allow flow at the pre-set minimum rates only.

The air-handling unit (AHU) for system AH-1-LG is located in the building's basement. Air enters the AHU from the main return-air duct and from the outside-air-intake duct; "economizer" dampers are used to modulate the proportion of outside air handled by the unit, from the reported design minimum of 70%, up to 100% when advantageous to save energy. Air entering the AHU passes through the filters and the fan; then the airflow is split. A portion moves through the "hot deck," where the steam-filled heating coils are located, and into the main hot-air-supply duct for distribution to VAV mixing boxes throughout the system's service area. The remainder moves through the "cold deck" across cooling coils supplied with cold water, and into the main cold-air-supply duct for similar distribution.

Air supplied in this manner to the occupied areas replaces air which is removed from the areas by discharge to the outside (e.g., by exhaust systems in certain parts of the service area such as restrooms, by exfiltration, etc.) and/or by the return-air system. Return-air grilles are located in the ceilings of most rooms, and returning air enters the above-ceiling plenum through these openings. Once inside this plenum, the air moves toward the return-air duct openings which are located above the ceilings.

### Assessment (General)

Any moist or wet surfaces inside HVAC-system components could lead to microbial growth from which bioaerosols could be released into the airstream. In system AH-1-LG, the primary sources of moisture (such as the cooling coils and condensate tray, potential leaks from steam heating coils, etc.) are located in the AHU. A visual inspection of the AHU revealed no evidence of microbiological growth, or any other apparent problems with its condition or operation.

An inspection of the visible portions of the ventilation system serving the Pain Clinic rooms, such as the supply-air mixing boxes, ducts, and diffusers, and the return-air inlet grilles and above-ceiling plenum, also revealed no apparent problems. Interior surfaces of much of the ventilation system supplying air to the Pain Clinic rooms (specifically, the hot- and cold-air-supply ducts and VAV mixing boxes, near the points where these items connect together) have reportedly been inspected by Polyclinic facilities-staff members during maintenance and repair procedures. They reported that no evidence of microbiological growth (a problem with which they reported familiarity from past experience) or other problems was observed. Consultant A investigators also observed no contamination or dust during their inspection, and they noted that the portion of the ventilation system serving the Pain Clinic seemed to be working and the ductwork appeared to be in good condition. The cold-air and hot-air ducts between the AHU and the mixing boxes are at nearly constant temperatures year-round, so there is little potential for moisture condensation on their interior surfaces.

### Assessment (Outside-air-intake rate)

To determine if ventilation system AH-1-LG delivers outside air (o.a.) to the spaces of interest at a sufficient rate, its design and performance may be compared with the guidelines in the ASHRAE ventilation standard discussed previously. Consultant B investigators measured the supply-air (s.a.) flowrates to each room in the Pain Clinic using an airflow hood. The results of these measurements were: Treatment Room #1, 65 cfm; Clinic Office, 175 cfm; and, Anesthesia Office, 50 cfm. The most "critical" of these under the Multiple Spaces provisions of the ASHRAE Standard is the Anesthesia Office, which was typically occupied by up to two people when the Pain Clinic was in use. At 20 cfm/person, this office needs 40 cfm of effective o.a., or an effective o.a. proportion in its s.a. of 80% at a s.a. flowrate of 50 cfm.

Consultant B, in its report, did not specify whether the s.a. flowrates measured represent the minimums or maximums allowed by the VAV-dampers. As discussed previously, the minimum supply-air flowrate to each space should be employed when determining the required effective o.a. needs. If this was done, then the needed effective o.a. proportion in the s.a. to this office may properly be considered as 80% for the purposes of determining the appropriate o.a. proportion in the system s.a. As stated previously, the design-specified minimum o.a.-intake proportion for this system was 70%. Insufficient information is available to determine if this is adequate to provide an effective o.a. proportion of 80% to the Anesthesia Office, but example calculations indicate that it likely would be adequate. (Specifically, if the uncorrected system o.a.-intake proportion during the design of the system was found to be no more than 47%, which is not atypical, an actual system o.a.-intake proportion of 70% would be adequate.) Therefore, if 50 cfm is the minimum s.a. flowrate to the Anesthesia Office, the design of the system may be adequate in terms of o.a. intake. However, the system reportedly was not operating to design specifications at time of survey. The maximum system s.a. flowrate was about 10% below the design-specified rate, and partly as a consequence the system o.a.-intake proportion reportedly

was only about 64%. Therefore, even if the design is adequate in this regard, the o.a.-intake rate at the time of the survey may have been inadequate.

Often, s.a. flowrates are measured with VAV dampers at maximum-flow positions. The design-specified minimum flow through a VAV box is typically less than half of the design maximum. If Consultant B measured the maximum s.a. flowrates, the minimums are likely less than 25 cfm for the Anesthesia Office and 30 cfm for Treatment Room #1. Each of these areas needs 40 cfm of o.a. (effective) alone, so in this case their needed effective o.a. proportions in the s.a. would exceed 100%. This cannot be achieved even if the system s.a. is 100% o.a. (actual). Therefore, if the measured s.a. flowrates to these rooms are maximums, then o.a. delivery to them is insufficient according to current ASHRAE criteria. Based on all the information presented in this subsection, the NIOSH investigators conclude that insufficient outside air delivery cannot be ruled out as a problem in the Pain Clinic area.