HETA 91-158-2161
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IMMACULATE HEART OF MARY CHURCH
CINCINNATI, OHIO

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I. SUMMARY

On March 21, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request from employees of the Immaculate Heart of Mary Church, Cincinnati, Ohio, to conduct a Health Hazard Evaluation (HHE). The requestors were concerned about the indoor air quality in the church office environment. Four out of five office workers reported a variety of symptoms, including headaches, dizziness, confusion, nausea, eye irritation, and dry nose and throat, which they felt may have been related to the use of a photocopier and laser printer.

Environmental sampling was performed at the facility on April 15, 1991, during which time area air samples were collected at five locations for ozone (O_3), carbon dioxide (CO_2), respirable dust, carbon monoxide (CO), and volatile organic compounds (VOCs). The heating, ventilating, and air conditioning system (HVAC) was evaluated, and temperature and relative humidity (RH) measurements were made in several locations. In addition, a symptoms questionnaire was administered to each of the 5 current employees.

Real-time ozone concentrations ranged from below the limit of detection (LOD) to 0.05 ppm in the breathing zone; all were below the NIOSH short-term exposure limit of 0.10 ppm. Ozone concentrations as high as 0.56 ppm were detected at the laser printer exhaust. Carbon dioxide concentrations ranged from 400 to 850 ppm. Respirable dust concentrations ranged from below the LOD to 90 micrograms per cubic meter ($\mu g/m^3$), below the Environmental Protection Agency (EPA) ambient PM_{10} standard of 150 micrograms per cubic meter of air ($\mu g/m^3$) averaged over a 24-hour period. Carbon monoxide was not detected above the LOD of 5 ppm. No VOCs were detected in qualitative analysis of 4 charcoal tube air samples using gas chromatography and mass spectrometry (GC-MS) techniques. Temperature and RH values were within the range recommended by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE).

Concentrations of O_3 measured at the exhaust of the laser printer exceeded the NIOSH recommended short-term exposure limit (STEL) of 0.10 ppm by nearly 6 times. However, concentrations of O_3 measured at breathing zone height ranged from below the LOD to 0.05 ppm. Although the concentrations of O_3 at the worker's desk and at breathing zone height near the laser printer were much lower than the evaluation criteria, some of the symptoms reported on the questionnaires are consistent with symptoms associated with O_3 exposure, as described in the evaluation criteria section of this report. While we cannot confirm that O_3 exposures caused the reported health symptoms, efforts should be made to reduce O_3 exposures in an effort to minimize potential health complaints.

Recommendations are made in the report to 1) relocate the laser printer and photocopier to a better ventilated location, preferably to a room with exhaust to the outdoors; (2) to consult a qualified heating, ventilating, and air-conditioning (HVAC) contractor to discuss providing outside air to the building at all times during occupancy; and (3) to contact the manufacturer of the laser printer to have the O_3 filter checked for possible overloading or inefficiency.

KEYWORDS: SIC 8661 (Churches) Office Environment, Laser Printer, Photocopier, Ozone, Indoor Air Quality, Church.

II. INTRODUCTION

On March 21, 1991, a representative of the Immaculate Heart of Mary Church requested that the National Institute for Occupational Safety and Health (NIOSH) conduct a Health Hazard evaluation (HHE) to evaluate employee exposure to laser printer and photocopier emissions. The request stated that employees were suffering from a variety of symptoms including headaches, dizziness, confusion, nausea, eye irritation, and dry nose and throat.

On April 15, 1991, NIOSH investigators conducted an initial survey at the facility. An opening meeting was held with a representative of the church administration and background information was obtained regarding the request. Following the opening meeting, environmental monitoring was conducted. During that time, a symptoms questionnaire was administered to employees. On April 30, 1991, a verbal report addressing the preliminary results of the environmental monitoring was provided, along with recommendations for reducing employee exposures.

III. BACKGROUND

The Immaculate Heart of Mary Church was built in 1945 for the purpose of providing general religious services. One year prior to the HHE request, the church office had been remodeled. A wall was built, dividing the office into two separate rooms, and a partition was removed from one of the employee workstations.

There are five people (3 full-time and 2 part-time) who work in the church office. Day-shift employees work eight-hour shifts performing general office duties, often using a 3M 6040 photocopier and Panasonic KX-P4450 laser printer that had been in use for approximately two years. Working hours are from 9:00 a.m. to
5:30 p.m. daily for day-shift workers, while part-time employees work from 4:00 p.m. to 8:00 p.m. daily.

IV. ENVIRONMENTAL EVALUATION AND METHODS

Full-shift area air samples were collected to assess levels of volatile organic compounds (VOCs) at four locations in the building: near the copy machine (2 feet [ft]) from the exhaust); at the computer terminal (1 ft from laser printer); in Hageman Hall (control area); and outside the building. The material safety data sheet indicates that the copy machine dry toner contains 90.7% styrene acrylate copolymer, 4.5% carbon black, and
3.0 polypropylene. Residual acrylic monomers which may be present in the product or potentially generated during processing were of concern because these substances are known irritants. The material

safety data sheet for the laser printer toner was not available at the time of the survey.

Real-time measurements were made for ozone (O_3), carbon dioxide (CO_2), carbon monoxide (CO), respirable dust, temperature, and relative humidity (RH) at the locations indicated above. Four serial measurements were made at each location, beginning in the morning and ending in mid-afternoon. The purpose of this measurement strategy was to allow trends to be observed throughout the day.

The ventilation system was evaluated with respect to its design and performance. The inspection focused on the location of the supply and exhaust diffusers; air movement in the office environment (using ventilation smoke tubes), the amount of fresh outside air supplied by the system, and the general cleanliness and maintenance of the air handling system.

A. Volatile Organic Compounds (VOCs)

Four area air samples for VOCs were collected on standard 150-milligram charcoal tubes at a sampling rate of 200 cubic centimeters per minute (cc/min) for a period of 6 hours. Qualitative analyses were performed on these charcoal tube samples using gas chromatography and mass spectrometry (GC-MS) techniques. Bulk samples of both toners were collected for possible analysis at a later time.

B. Ozone (O_3)

Real-time O_3 concentrations were measured using a calibrated Mast Model 727-3 Ozone Monitor. Its limit of detection LOD is 0.02 parts per million (ppm), with a range of 0.02 to 9.99 ppm. Five colorimetric detector tube measurements were taken for O_3 at the exhaust of the laser printer, and in the breathing zone of an employee who worked adjacent to the laser printer. The purpose for the colorimetric detector tube measurements was to compare results obtained using the different sampling techniques.

C. Carbon Dioxide (CO_2)

Real-time CO_2 concentrations were determined using Gastech Model RI-411A, Portable CO_2 Indicators. This portable, battery-operated instrument monitors CO_2 (range 0-4975 ppm) via non-dispersive infrared absorption with a sensitivity (LOD) of 25 ppm. Instrument zeroing and calibration was performed prior to use with zero air and a known CO_2 span gas (800 ppm).

D. Respirable Dust

Real-time respirable dust concentrations were measured using GCA Environmental Instruments Model RAM-1 monitors. This portable, battery-operated instrument assesses changes in particle concentrations via an infrared detector, centered on a wavelength of 940 nanometers. Air is sampled (2 liters per minute) first through a cyclone preselector which restricts the penetration of particles greater than 9 micrometers in diameter. The air sample then passes through the detection cell. Operating on the 0 to 2000 micrograms per cubic meter ($\mu g/m^3$) range with a 32-second time constant yields a LOD of 1 $\mu g/m^3$.

E. Temperature and Relative Humidity (RH)

Real-time temperature and RH measurements were conducted using a Vista Scientific, Model 784, battery-operated psychrometer. Dry and wet bulb temperature readings were monitored and the corresponding RH calculated.

F. Carbon Monoxide (CO)

Short-term CO measurements were made during the first series of measurements using Draeger gas detector tubes yielding an LOD of 5 ppm. Two measurements were made in the center of the main office and near the photocopier.

V. EVALUATION CRITERIA

NIOSH investigators have responded to approximately 700 complaints of indoor air quality problems in a wide variety of settings. The majority of these investigations have been conducted since 1979, paralleling the "energy efficiency" concerns of building operators and architects.

Commonly, the symptoms and health complaints reported by building occupants have been diverse and not suggestive of any particular medical diagnosis or readily associated with a causative agent. Typical symptoms have included headaches, varying degrees of itching or burning eyes, irritations of the skin, including rashes, sinus problems, dry and irritated throats and other respiratory irritations. The workplace environment has been typically implicated because workers' symptoms reportedly disappear when they are away from the office.

Less often the symptoms are more severe and are found to be specifically related to something in the building environment. Examples of these building-related illnesses, or BRI, not all of which have been found during NIOSH investigations, are environmental

allergy (allergic rhinitis, allergic asthma, and hypersensitivity pneumonitis), caused by exposure to spores, organic dusts, animal "danders," bacteria and fungi, and bacterial infections (Legionnaires' disease, and Pontiac fever). In previous NIOSH investigations, microbial contamination has resulted from water damage to carpets or furnishings, and standing water in ventilation system components.

The causes of comfort and health problems among building occupants are typically multifactorial, which makes determination of an environmental cause difficult. The problems found during NIOSH investigations include the following: inadequate ventilation, contamination from inside the building, contamination from outside the building, microbiological contamination, and contamination from the building materials. In most cases, the cause of the health complaints could not be determined, although one or more of the problems was identified.

Inadequate ventilation, a category which includes insufficient outside air, poor air distribution, and short-circuiting of supply air, has been reported in the NIOSH building investigations. These ventilation problems make it difficult to control heating and cooling and allow contaminants to accumulate in the occupied space. The resulting conditions may cause occupants to become uncomfortable or experience adverse health effects.

Some scientists suspect that work-related complaints may be attributable not to individual environmental contaminants, but to the cumulative effect resulting from exposures to low concentrations of multiple pollutants, work environments outside of comfort ranges, and other factors. Exposure criteria specific for indoor air quality in office buildings do not exist. NIOSH, the Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards and recommended limits for occupational exposures. With few exceptions, pollutant concentrations observed in the office work environment fall well below these published occupational standards or Recommended Exposure Limits (RELs). The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended building ventilation design criteria and thermal comfort guidelines.[1,2]

A. Carbon Dioxide (CO_2)

Carbon dioxide, a normal constituent of exhaled breath, can be used as an indicator of whether adequate quantities of outdoor air are being introduced into an occupied space. The ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality[1], recommends outdoor air supply rates of 20 cubic feet

per minute per person (cfm/person) for office spaces and conference rooms, 15 cfm/person for reception areas, and
60 cfm/person for smoking lounges, and provides estimated maximum occupancy figures for each area.

Indoor CO_2 concentrations are normally higher than the generally constant outdoor CO_2 concentration (range 300-350 ppm). When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. CO_2 concentrations in this range do not represent a health hazard. However, they do indicate that the air concentrations of other contaminants normally present in office environments may also be elevated.

B. Temperature And Relative Humidity[2]

The perception of thermal comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures. Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. ANSI/ASHRAE Standard 55-1981 specifies conditions in which 80% or more of the occupants will find the environment thermally comfortable.

C. Carbon Monoxide (CO)[3]

CO is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials. Major sources of exposure to CO are engine exhaust, tobacco smoking, and inadequately-ventilated combustion products from appliances and heaters that use natural gas, propane, kerosene, or similar fuels. On inhalation, CO acts as a metabolic asphyxiant, causing a decrease in the amount of oxygen delivered to the body tissues. CO combines with hemoglobin (the oxygen carrier in the blood) to form carboxyhemoglobin, which reduces the oxygen-carrying capacity of the blood. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered.

D. Other Potential Contaminants

At this facility the office workers were primarily concerned with photocopier and laser printer emissions, by which potential contaminants include O_3, respirable dust, and VOCs. In office settings, airborne concentrations of these substances rarely exceed NIOSH RELs and OSHA Permissible Exposure Levels (PELs) that are specific for industrial environments. In addition,

there are no current exposure criteria for O_3, respirable dust, or VOCs that are specific for office environments. Indicated below are NIOSH RELs and OSHA Permissible Exposure Levels (PELs) which are used in industrial environments.

1. Ozone (O_3)

   Ozone is a highly reactive and unstable gas composed of three oxygen atoms rather than the usual two. In photocopiers it is formed from the interaction of oxygen and the oxides of nitrogen in the presence of the corona discharger wire. O_3 reverts to oxygen quite rapidly, particularly on contact with surfaces such as office furnishings.[4]

   O_3 has a pungent odor at 0.01 to 0.02 ppm in air. At 0.25 ppm, O_3 can cause irritation to the eyes and upper respiratory tract. Symptoms of chronic exposure include headache, weakness, shortness of breath, drowsiness, reduced ability to concentrate, slowing of heart and respiration rate, and confusion.[3]

   NIOSH recommends that O_3 exposures should not exceed 0.10 ppm for a short-term exposure limit (STEL).[5] The OSHA PEL and ACGIH threshold limit value (TLV) for O_3 are 0.10 ppm as an 8-hour time-weighed average (TWA), and 0.30 ppm as a STEL.[6,7]

2. Volatile Organic Compounds (VOCs)

   VOCs, including formaldehyde and other aldehydes, are emitted in varying concentrations from numerous indoor sources (e.g., carpeting, fabrics, adhesives, solvents, photocopier toners, paints, cleaners, waxes, cigarettes, kerosene heaters, and other combustion heating products). Studies conducted in newly constructed office buildings have identified hundreds of these organic compounds present in the indoor air. Some organic species (e.g., formaldehyde and benzene) have been determined to be carcinogenic in animal studies. Total indoor VOCs and aldehyde concentrations typically exceed corresponding outdoor levels except in locations immediately impacted by industrial or combustion source emissions. Recent laboratory studies evaluating human responses to controlled exposures during varying VOC mixtures reported test subject health symptoms similar to those reported by workers in large office buildings.[8,9]

3. Respirable Dust

Respirable dust particles smaller than 2.5 micrometers (μm) in diameter are associated with combustion source emissions. The greatest contributor to indoor respirable dust is environmental tobacco smoke (ETS). In buildings where smoking is not allowed, respirable dust levels are influenced by outdoor particle concentrations and by minor contributions from other indoor sources. In buildings with oil, gas, or kerosene heating systems, increased dust concentrations associated with the heating source may be important. Respirable particles, defined as particles smaller than 10 μm in diameter (PM_{10}), are a combined result of combustion, soil, dust, and mechanical source particle contributions. The larger particles are associated with outdoor particle concentrations, mechanical processes, and human activity. When indoor combustion sources are not present, indoor particle concentrations generally fall well below the Environmental Protection Agency (EPA) ambient PM_{10} standard of 150 micrograms per cubic meter of air ($\mu g/m^3$) averaged over a 24-hour period.[10]

VI. RESULTS AND DISCUSSION

A. Environmental

Results for real-time air monitoring for respirable dust, CO_2, temperature, and RH are shown in Table 1. Real-time measurements for respirable dust revealed airborne concentrations ranging from none detected to 90 $\mu g/m^3$, below the Environmental Protection Agency 24-hour PM_{10} standard of 150 $\mu g/m^3$. CO_2 measurements ranged from 425 to 850 ppm, with the highest values obtained during the afternoon. Outdoor CO_2 concentrations ranged from 400 to 425 ppm. All CO_2 concentrations were below the NIOSH guideline of 1000 ppm throughout the day of the evaluation. In this case, however, since only a small group of people work in the office, CO^2 may not be the best indicator for ventilation adequacy. Dry bulb temperatures and RH ranged from 70 to 74°F in the office areas and from 46 to 62% RH, respectively. On the day of the survey, weather conditions were wet and cool during morning hours, then later became sunny and warm by mid-afternoon. The outdoor temperature ranged from 61 to 70°F, and the RH ranged from 73-38%. The temperature and RH measurements made inside and outside the building fall within the ranges recommended by ASHRAE.

No VOCs were detected on the 4 charcoal tube air samples analyzed by GC-MS.

Results for O_3 are shown in Table 2. Real-time measurements for O_3 taken at the exhaust of the laser printer revealed concentrations of 0.56 ppm (nearly 6 times higher than the NIOSH STEL of 0.10 ppm), while only traces of O_3 could be detected at the exhaust of the photocopier. Real-time measurements for O_3 taken at breathing zone height (two feet from the exhaust) near both the laser printer and photocopier were both below the NIOSH and OSHA STELs, ranging between 0.01 to 0.05 ppm. Additionally, colorimetric detector tubes were used to measure airborne concentrations of O_3 to compare the results obtained with the O_3 monitor. Results indicated an O_3 concentration of 0.60 ppm O_3 at the laser printer exhaust, which compares with an O_3 concentration of 0.56 ppm using the O_3 monitor.

Breathing zone concentrations of O_3 were measured at 0.01 ppm at one employee's desk, below the NIOSH STEL of 0.10 ppm. It is important to note that prior to the NIOSH evaluation, the laser printer had been moved to a location away from the office due to employees' health concerns, and that a change in the office layout was made which may have affected airflow patterns. Ozone emissions may have been more of a problem in the past, prior to removal of a floor to ceiling partition enclosing the printer and an employee's desk. Also, not all workers are protected from adverse health effects if their exposures are maintained below the NIOSH and OSHA exposure criteria. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

Following the survey, real-time O_3 monitoring was conducted at NIOSH on a 2½-year old Panasonic KX-P4450 laser printer (an identical model of the one used at the Immaculate Heart of Mary Church) to compare the O_3 emissions of the two printers. Results showed that O_3 could not be detected at the exhaust of the NIOSH laser printer, indicating that O_3 emissions can be controlled with this type of printer.

CO was not present above the LOD of 5 ppm in 2 area air samples obtained using Draeger gas colorimetric detector tubes specific for CO.

Review of the completed questionnaires indicated that 4 of 5 office workers were experiencing one or more symptoms (such as nausea, headaches, dizziness, eye irritation, confusion, and dry nose and throat) which have been associated with O_3 exposure. However, some of these symptoms are non-specific and have also been commonly reported in other indoor air quality investigations where no source of O_3 was identified.

B. Ventilation

During the evaluation of the air handling system, NIOSH investigators were assisted by the grounds person at the church. The air handling system did not appear to provide a mechanical supply of outside air as recommended by ASHRAE for office environments during times of occupancy. During the renovation of the office one year prior to the HHE, a false ceiling was installed, perhaps affecting the capability of the ventilation system to supply outside air to the building. It appeared that outside air intakes had been blocked. The air handling system in current use was located in a room within the office area and appeared to recirculate the air throughout the office, with outside air entering by way of infiltration, leaks in the building envelope, and through open doors and windows. In addition, it was observed that the fan of the air handling system did not run continuously. Ventilation smoke tubes were used to determine general air flow patterns and direction in the main office area and other surrounding areas. Air movement within the main office area appeared stagnant during periods when the fans were not running. The grounds person stated that there was no maintenance program for the air-handling system. The air filter located in the furnace was heavily soiled with particulates and needed to be changed.

VII. SUMMARY AND RECOMMENDATIONS

Based on information obtained during this health hazard evaluation, and in consideration of current ASHRAE standards, the following recommendations are offered. Although breathing zone measurements of the contaminants evaluated during the survey indicated that none exceeded existing evaluation criteria, it is recommended that actions be taken to minimize O_3 exposure. The following recommendations, addressing these issues, were offered during the closing meeting.

1. Most laser printers are equipped with filters that serve to reduce O_3 emissions. Contact the manufacturer of the laser printer to have the O_3 filter checked for possible overloading or inefficiency.

2. Until the ozone filter is checked for effectiveness by the manufacturer, relocate the laser printer to a better ventilated location, preferably to a room with an exhaust to the outdoors.

3. Consult a qualified Heating, Ventilating, and Air Conditioning (HVAC) contractor to discuss the provision of outside air to the building at all times during occupancy.

4. Until a qualified HVAC contractor is contacted, run the air handling system fan throughout the working hours to provide continuous air circulation in the office area.

5. The air handling system should be visually inspected and maintained on a regular basis, to keep it in proper working condition. Persons inspecting the system should observe for dampness, standing water, air leaks, particulate filter condition, and biological growth.

VIII. REFERENCES

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IX. AUTHORSHIP AND ACKNOWLEDGEMENTS

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Copies of this report have been sent to:

1. Immaculate Heart of Mary Church
2. Requestor
3. Department of Labor - OSHA, Region V

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1

Indoor Air Quality Data

Immaculate Heart of Mary Church
Cincinnati, Ohio
April 15, 1991

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Location	Time	CO_2 (ppm)*	Temp (F)	RH (%)	Resp. Dust (mg/m^3)**	Comments
	9:29	450	69	68	0.01	no occupants
Hageman	11:17	425	67	60	0.02	" "
Hall	1:00	425	68	53	N/D ***	" "
	2:32	450	68	48	0.01	" "
	9:52	525	70	62	0.07	at photo copier,
Main	11:20	525	71	55	0.02	2 occupants
Office	1:05	600	72	45	0.02	" "
	2:37	850	73	47	0.02	" "
	9:58	625	73	59	0.01	at laser printer,
Main	11:20	525	71	55	0.02	2 occupants
Office	1:07	750	74	46	0.03	" "
	2:42	645	74	46	0.03	3 occupants
	10:02	525	74	57	0.09	1 occupant
Second	11:27	500	74	51	0.02	" "
Office	1:10	600	74	45	0.02	" "
	10:06	425	61	73	N/D ***	cloudy, wet
Outdoors	11:31	425	64	54	0.02	cloudy, warmer
	1:15	400	66	45	0.01	sunny, warm
	2:54	400	70	38	0.01	" "

* ppm= parts per million parts of air
** mg/m^3 = milligrams per cubic meter of air
*** none detected

Table 2

Results of Ozone Measurements

Immaculate Heart of Mary Church
Cincinnati, Ohio
April 15, 1991

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Location	Time	Ozone (ppm)*	Comments
BZ Ht.** of photocopier (3 ft. from exhaust)	11:13 11:20	0.05 0.04	100 copies made 100 copies made
At exhaust of photocopier	10:40 11:32 11:49	0.04 0.05 0.05	50 copies made 100 copies made 200 copies made
At exhaust of	1:52 2:10 2:15 2:20	0.56 0.56 0.50 0.56	laser printer laser printer running continuously
BZ Ht. of laser printer (2 ft. from exhaust)	1:40	0.03	" "
At desk of an employee	2:30	0.01	" "

* ppm= parts per million parts of air
** BZ ht. = breathing zone height