HETA 91-254-2186
MARCH 1992
ROPES & GRAY PHOTOCOPY CENTER
BOSTON, MASSACHUSETTS

NIOSH INVESTIGATORS:
Calvin K. Cook
Michael S. Crandall, CIH

I. SUMMARY

In May 1991, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request from a group of employees at Pitney Bowes Management Services, a Ropes & Gray Photocopy Center in Boston, Massachusetts, concerning worker exposure to photocopier emissions. The workers at Pitney Bowes asked NIOSH to conduct an indoor air quality evaluation (IAQ) in the 3000 ft^2 photocopy center. The request stated that a number of employees suffered from a variety of symptoms including eye irritation, headaches, nasal congestion, fatigue, skin irritation, and dizziness which they felt may have been related to the use of six photocopiers located in the photocopy center.

On September 11-12, 1991, NIOSH investigators conducted an IAQ evaluation in the photocopy center. The evaluation included a brief inspection of the facility, air sampling for volatile organic chemicals (VOCs), and real-time measurements for ozone (O_3), carbon dioxide (CO_2), respirable suspended particles (RSP), and carbon monoxide (CO). Ventilation air flow measurements were made to estimate the volume of outside air (OA) and the nature of flow patterns within the photocopy center. Temperature and relative humidity measurements were made to assess comfort parameters. A symptom questionnaire was distributed to all employees present during the two days of the evaluation. Three out of eight employees reported a variety of symptoms, including eye irritation, nasal irritation, nasal congestion, and headaches, which they felt may have been related to the use of six photocopiers in the facility.

Qualitative and quantitative analyses of air samples taken for VOCs revealed trace amounts of 1,1,1-trichloroethane, isooctane, toluene, xylene, and benzene. Real-time ozone concentrations ranged from below the limit of detection (LOD) to 0.08 parts per million (ppm) in the breathing zone; all were below the NIOSH ceiling limit of 0.10 ppm. Ozone concentrations as high as 0.41 ppm were detected at approximately three feet from the exhaust of each photocopier. Carbon dioxide concentrations ranged from 300 to 825 ppm, below the American Society for Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standard for indoor environments (1000 ppm). Respirable dust concentrations ranged from less than 10 to 50 micrograms per cubic meter ($\mu g/m^3$), below the Environmental Protection Agency (EPA) ambient PM_{10} (particulate matter less than 10 micrometers in diameter) standard of 150 $\mu g/m^3$ averaged over a 24-hour period. Carbon monoxide was not detected above the LOD of 5 ppm. Dry bulb temperature and relative humidity measurements were within the ranges recommended by ASHRAE.

Ventilation measurements of air flow revealed an inadequate amount of OA air supplied to the facility. Approximately 290 CFM of OA is supplied to the 3000 ft^2 photocopy center. Based on the ASHRAE guideline specific for photocopy centers, which suggests 0.50 CFM of OA for every square foot of space, the recommended amount of outside air needed to supply the 3000 ft^2 photocopy center is 1500 CFM.

Environmental sampling did not identify a health hazard and did not provide an explanation for the reported symptoms. However, deficiencies in the

ventilation rate may be allowing airborne contaminants to build up to a point where the combination of low levels of individual contaminants may be contributing to the reported symptoms. Recommendations focused on increasing the amount of outside air and preventive maintenance of the photocopy machines.

KEYWORDS: SIC 7334, (Photocopying Service) Indoor Air Quality, Photocopier, Copy Machines, Ozone.

II. INTRODUCTION

In May 1991, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a Health Hazard Evaluation (HHE) from a group of employees at Pitney Bowes Management Services, a Ropes & Gray Photocopy Center in Boston, Massachusetts. The employees asked NIOSH to an conduct an indoor air quality (IAQ) evaluation in the general vicinity of the photocopy center. The request stated that a number of employees suffered from a variety of symptoms including eye irritation, nasal irritation, nasal congestion, fatigue, skin irritation, headaches, and dizziness. A site visit of the facility was conducted on September 11-12, 1991.

III. BACKGROUND

During the time of the HHE, the Ropes & Gray photocopy center had been in operation at the One International Place building for two years. A total of six full-time employees worked during the day shift in the 3000 ft^2 photocopy center, operating six photocopiers of various models. Workers at the facility spent much of their work day operating photocopiers.

Six photocopiers were used daily, including three Xerox model 1090, one Xerox 5100, and two Kodak Electra 300 Duplicators (Electraprint Finishers). Dry toners were used for each photocopier. It was reported that approximately 1 million copies were generated monthly at the photocopy center.

The heating, ventilating, and air-conditioning (HVAC) needs for the Ropes & Gray copy center were supplied by one of two central system air handling units (AHUs) on the fourth floor. The area serviced by each AHU was divided into 12 zones. Supply air was distributed within each zone through a terminal air distribution box equipped with a constant volume fan. Air supply to the terminal boxes was variable based upon the cooling needs in the space. The central systems provided cooling only with discharge air temperatures between 55 and 59°F depending upon the season. A damper regulating supply air from the central AHU to the terminal box was controlled by a single thermostat in the zone space. The volume of outside air (OA) supplied to the zone boxes was reportedly between 10 and 12% of the central system discharge volume. To maintain a constant supply air volume in the zone when the damper modulated, return air from the common plenum was recirculated. Heat could be provided by electric resistance in the terminal boxes.

The photocopy center comprised an entire zone of the AHU #6. The total supply air output from this AHU was reported to be 15,050 cubic feet per minute (CFM). Total supply to the photocopy center area (or zone) was estimated by direct measurement to be 2900 CFM. With the supply air damper from the central AHU to the terminal box in the 100% open position, the estimated OA amount was 290 CFM (10%). It was reported that this damper could not close completely. The minimum position was 20% open (58 CFM OA). There were 12 supply air diffusers in the zone, eight 2" x 48" slots along the perimeter windows and four 1" x 24" slots next to ceiling light fixtures. Return air exited through slots around the light fixtures to a common plenum. The thermostat for this zone was located in the management office. It was moved from a location in the photocopy center work space to prevent cool air from two auxiliary heating, humidification, and air-conditioning (HHA) units in the copy center from influencing its operation. The two HHA units were used primarily to remove heat added to the space by the six photocopiers. They also helped maintain relative humidity levels required by the paper stock.

When first installed, the HHAs cooled the area to below the central system thermostat set point temperature, which caused the central supply cooling air to shut down completely, allowing only recirculated air. To solve this problem, the thermostat regulating air from the HHAs was raised to 2°F above the central system thermostat, and this thermostat was moved out of the airflow path of the HHA, and into the management office.

IV. ENVIRONMENTAL EVALUATION AND METHODS

In response to the request, NIOSH investigators performed an environmental evaluation on September 12-13, 1991. Ten full-shift area air samples were collected to assess levels of volatile organic chemicals (VOCs) at 5 locations in the facility. Real-time measurements were made to determine O_3 concentrations primarily at two locations: in the breathing zone and approximately 3 ft. from the exhaust of each photocopier. On each day, four serial real-time measurements were made to determine concentrations of CO_2, RSP, CO and temperature and relative humidity (RH) at five locations, beginning in the morning and ending in mid-afternoon. This measurement method allowed trends to be observed throughout the day. Ventilation measurements of air flow were made within the facility. A symptom questionnaire was distributed to all employees present during the two days of the evaluation.

A. Volatile Organic Chemicals (VOCs)

Ten full-shift area air samples for VOCs were collected at five locations during first shift on both days of the evaluation. These were collected by drawing air through 150-milligram charcoal tubes at a sampling rate of 200 cubic centimeters per minute (cc/min) for a period of approximately eight hours. The locations included the customer service desk, the binding area, between photocopiers #3 and #4, a perimeter work area, and the management office.

Qualitative and quantitative analyses were performed. Gas chromatography with a flame ionization detector (GC/FID) was used for quantitation and mass spectrometry detection (GC/MS) for qualitative analyses. Two charcoal tube samples collected near the exhaust of two photocopiers located near the middle of the photocopy center were analyzed qualitatively. Based on this information, analyses were performed on the eight remaining samples.

B. Ozone (O_3)

Real-time ozone concentrations were measured using a calibrated Mast Model 727-3 Ozone Monitor. During operation, air is continuously drawn into the cells within the instrument. The instrument has a limit of detection (LOD) of 0.02 parts per million (ppm), with a range of 0.02 to 9.99 ppm. Concentrations of ozone were measured near the worker breathing zone and approximately three feet from the exhaust of each photocopier in the facility while workers performed their routine job duties.

C. Carbon Dioxide (CO_2)

Real-time carbon dioxide concentrations were measured using a Gastech Model RI-411A portable CO_2 meter. This portable, battery-operated instrument monitors CO_2 (range 0 to 4975 ppm) by non-dispersive infrared absorption with a sensitivity of 25 ppm. Instrument zeroing and calibration were performed before use.

D. Carbon Monoxide (CO)

Real-time concentrations of carbon monoxide were measured using a battery-operated PhD Atmospheric Monitor model 1605 DL. The instrument measures CO concentrations with electrochemical detection. The LOD is 1 ppm.

E. Respirable Suspended Particles (RSP)

Real-time RSP concentrations were measured by using GCA Environmental Instruments Model RAM-1 monitor. This portable, battery-operated instrument assesses changes in airborne particle concentrations via an infrared detector, centered on a wavelength of 940 nm. Indoor air is sampled (2 L/min) first through a cyclone preselector, which passes through the detection cell. Operating on the 0-2 mg/m^3 range with a 32-s time constant yields a resolution of 0.001mg/m^3.

F. Temperature and Relative Humidity (RH)

Real-time temperature and RH measurements were taken with a Vaisala HM #34 Humidity and Temperature meter. A series of measurements were made to evaluate thermal comfort parameters at various locations of the facility.

G. Ventilation Air Flow

The ventilation air flow within the facility was evaluated with respect to its design and performance. The inspection focused on the location and the amount of air flow for each supply and exhaust diffuser, the nature of the air movement in the facility, the amount of fresh air supplied by the system, and the general cleanliness and maintenance of the ventilation system. A series of ventilation measurements were made using a Shortridge Flow Hood model MN 86BP to determine the amount of air supplied and exhausted by each diffuser in the facility. Using ventilation smoke tubes, general air flow patterns were observed at various locations of the facility.

V. EVALUATION CRITERIA

A number of published studies have reported high prevalences of symptoms among occupants of office buildings.[1-5] 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 there are multiple factors contributing to building-related occupant complaints .[6,7] Among these factors are imprecisely defined characteristics of heating, ventilating, and air-conditioning (HVAC) systems, cumulative effects of exposure to low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.[8-13] Reports are not conclusive as to whether increases of outdoor air above currently recommended amounts ($\geq$15 cubic feet per minute per person) are beneficial.[14,15] However, rates lower than these amounts appear to increase the rates of complaints and symptoms in some studies.[16,17] Design, maintenance, and operation of HVAC systems are critical to their proper functioning and provision of healthy and thermally comfortable indoor environments. Indoor environmental pollutants can arise from either outdoor sources or indoor sources.[18]

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.[19-21] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[21-24]

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 and inadequately ventilated kerosene heaters or other fuel-burning appliances. Exposure to boiler additives can occur if boiler steam is used for humidification or is released by accident.

Problems NIOSH investigators have found in the non-industrial indoor environment 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 cause of the reported health effects could be determined.

Standards 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.[25-27] With few exceptions, 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.[28-29] 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.[30]

Measurement of indoor environmental contaminants has rarely proved to be helpful, in the general case, in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proved relationship between a contaminant and a building-related illness. However, measuring ventilation and comfort indicators such as carbon dioxide (CO_2), and temperature and relative humidity, is useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems. The basis for the measurements made in this investigation are presented below.

A. Volatile Organic Chemicals (VOCs)

Volatile organic chemicals 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 VOC 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.[4,31,32]

B. 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. Ozone reverts to oxygen quite rapidly, particularly on contact with surfaces such as office furnishings.[33]

Ozone 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.[34] Symptoms of chronic exposure include headache, weakness, shortness of breath, drowsiness, reduced ability to concentrate, slowing of heart and respiration rate, and confusion.[35]

NIOSH recommends that O_3 exposures should not exceed 0.10 ppm for a short-term exposure limit (STEL).[36] 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.[27,37]

C. Carbon Dioxide (CO_2)

CO_2 is a normal constituent of exhaled breath and, if monitored, may be useful as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. The ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, 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.[28]

Indoor CO_2 concentrations are normally higher than the generally constant ambient 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. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased.

D. Respirable Suspended Particles (RSP)

Respirable particles smaller than 2.5 micrometers are associated with combustion source emissions. The greatest contributor to indoor respirable particulate is environmental tobacco smoke (ETS). In buildings where smoking is not allowed, respirable particulate 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 micrometers (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.[38]

E. Carbon Monoxide (CO)

Carbon monoxide is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials. Major sources of exposure to CO are engine exhaust, tobacco smoke, 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.[33]

F. Temperature and Relative Humidity

The perception of 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 would be expected to find the environment thermally comfortable.[29]

VI. RESULTS AND DISCUSSION

A. Environmental

Quantitative analyses of 8 area air samples taken within the facility for VOCs revealed trace amounts of 1,1,1-trichloroethane, isooctane, toluene, and xylene, below the limit of quantitation (LOQ) of 0.03 milligrams for each compound (less than 0.33 mg/m^3).

Results for real-time O_3 measurements are shown in Tables 1 and 2. The values presented in the tables represent the highest O_3 concentrations measured in the described location at the indicated time. Ozone concentrations were measured at the exhaust and at the breathing zone area of each photocopier in the facility. Ozone measurements taken near the exhaust and in the breathing zone of photocopiers #1 and #2 revealed concentrations that range from none-detected to 0.41 ppm and none-detected to 0.08 ppm, respectively. Ozone measurements taken near the exhaust and in the breathing zone areas of photocopiers #3, #4, #5, and #6 revealed air concentrations that range from none-detected to 0.35 ppm and none-detected to 0.02 ppm, respectively. All ozone measurements made in the breathing zone of each photocopier revealed concentrations below the NIOSH ceiling limit of 0.10 ppm. Even though the airborne levels of these individual substances would not be expected to cause adverse health effects, it is possible that their combined effect may be contributing to the reported symptoms.

Real-time measurements for CO_2, RSP, temperature and RH are shown in Tables 3 and 4. Carbon dioxide concentrations ranged from 300 to 825 ppm, with the highest values obtained in the binding area. Outdoor CO_2 concentrations ranged from 325 to 375 ppm. All CO_2 measurements taken within the facility were below the ASHRAE consensus standard of 1000 ppm for indoor environments (ASHRAE 62-1989). Real-time measurements for respirable suspended particles revealed airborne concentrations ranging from none-detected to 0.05 milligram per cubic meter (mg/m^3), below the EPA 24-hour PM_{10} standard of 0.15 mg/m^3. Dry bulb temperatures and RH ranged from 75 to 79°F and from 34 to 43% in the photocopy center, respectively. Outdoor temperatures ranged from 55 to 72°F, and the RH ranged from 26 to 49%. The indoor temperature and RH measurements taken fall within the ranges recommended by ASHRAE in standard 55-1981, Thermal Environmental Conditions[2] for Human Occupancy (see Figure 1). Real-time CO measurements revealed levels that could not be detected above the LOD of 1 ppm. Measurements taken in the binding area for temperature, O_3, RSP, and CO_2 concentrations revealed values that were consistently higher than the values found in other locations.

B. Ventilation

Direct ventilation measurements show the AHU delivered a total air capacity of approximately 2900 CFM to the photocopy center. The volume of outside supplied to the photocopy center was approximately 290 CFM based on an estimate of 10% OA. According to the ASHRAE guideline specific for photocopy centers, which suggests 0.50 CFM of OA for every square foot of space (see summary and recommendations), the recommended amount of outside air needed to supply the 3000 ft^2 photocopy center is 1500 CFM. A visual inspection of the AHU supplying the photocopy center found no signs of standing water, biological growth, or overloaded particulate filters.

VII. SUMMARY AND RECOMMENDATIONS

1. Based on reported percentages of OA from the central HVAC system and direct ventilation measurements taken throughout the photocopy center, the NIOSH investigators suspect an insufficient amount of OA is supplied to the facility. Generally ASHRAE-required ventilation rates are prescribed in cubic feet per minute per person (CFM/person) occupying the space, and are based upon estimated occupant densities listed in the Standard. These ventilation rates are specified to reflect the consensus that the provision of acceptable outdoor air at these rates would achieve an acceptable level of indoor air quality by reasonably controlling CO_2 and other bioeffluents. However, in the case of the photocopy center the contamination is presumed to be due to other sources (e.g. photocopy machines) and the ventilation rates are given in more appropriate parameters, cubic feet per square foot of space (CFM/ft^2). The HVAC system should be modified to provide the minimum amount of OA recommended by ASHRAE at all times during occupancy.

2. With the exception of the binding area, air distribution throughout the facility appeared to be good. Additional ventilation (consistent with current ASHRAE guidelines) and improvements in the distribution of air in the binding area will likely improve the overall indoor air quality, thereby reducing symptoms.

   To increase air distribution in the binding area, a side grill could be installed on the supplemental air-conditioning unit located nearest to the area of concern. As an alternative, providing a portable or ceiling fan would help increase air circulation in this area.

3. The manufacturers of the photocopiers were contacted to determine whether each photocopier model has a built-in ozone filter, and if so, how frequent it should be replaced. A XEROX representative reports that the XEROX model 1090 photocopier has a built-in lifetime ozone filter. For the XEROX model 5100, XEROX recommends replacing each filter after every 100,000 copies produced. A Kodak representative reported that their Kodak Electra 300 Duplicator is equipped with a built-in ozone filter, and also suggested replacing the filter after every 100,000 copies produced. In accordance with the manufacturers' recommendations, each photocopier should be monitored on the number of copies made. Ozone filters should be checked for effectiveness or replaced periodically based on the manufacturers' recommendations.

VIII. REFERENCES

1. Kreiss KK, Hodgson MJ [1984]. Building associated epidemics. In: Walsh PJ, Dudney CS, Copenhaver ED, eds. Indoor air quality. Boca Raton, FL: CRC Press, pp 87-108.

2. Gammage RR, Kaye SV, eds. [1985]. Indoor air and human health: Proceedings of the Seventh Life Sciences Symposium. Chelsea, MI: Lewis Publishers, Inc.

3. Woods JE, Drewry GM, Morey PR [1987]. Office worker perceptions of indoor air quality effects on discomfort and performance. In: Seifert B, Esdorn H, Fischer M, et al, eds. Indoor air '87, Proceedings of the 4th International Conference on Indoor Air Quality and Climate. Berlin Institute for Water, Soil and Air Hygiene.

4. Skov P, Valbjorn O [1987]. Danish indoor climate study group. The "sick" building syndrome in the office environment: The Danish town hall study. Environ Int 13:399-349.

5. Burge S, Hedge A, Wilson S, Bass JH, Robertson A [1987]. Sick building syndrome: a study of 4373 office workers. Annals of Occupational Hygiene 31:493-504.

6. Kreiss K [1989]. The epidemiology of building-related complaints and illness. Occupational Medicine: State of the Art Reviews. 4(4):575-592.

7. Norbäck D, Michel I, Widstrom J [1990]. Indoor air quality and personal factors related to the sick building syndrome. Scan J Work Environ Health. 16:121-128.

8. Morey PR, Shattuck DE [1989]. Role of ventilation in the causation of building-associated illnesses. Occupational Medicine: State of the Art Reviews. 4(4):625-642.

9. Mendell MJ, Smith AH [1990]. Consistent pattern of elevated symptoms in air-conditioned office buildings: A reanalysis of epidemiologic studies. Am J Public Health. 80(10):1193-1199.

10. Molhave L, Bachn B, Pedersen OF [1986]. Human reactions to low concentrations of volatile organic compounds. Environ Int 12:167-176.

11. Fanger PO [1989]. The new comfort equation for indoor air quality. ASHRAE J 31(10):33-38.

12. Burge HA [1989]. Indoor air and infectious disease. Occupational Medicine: State of the Art Reviews. 4(4):713-722.

13. Robertson AS, McInnes M, Glass D, Dalton G, Burge PS [1989]. Building sickness, are symptoms related to the office lighting? Annals for Occupational Hygiene 33(1):47-59.

14. Nagda NI, Koontz MD, Albrecht RJ [1991]. Effect of ventilation rate in a health building. In: Geshwiler M, Montgomery L, and Moran M, eds. Healthy buildings. Proceedings of the ASHRAE/ICBRSD conference IAQ'91. Atlanta,

GA. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

15. Menzies R, et al. [1991]. The effect of varying levels of outdoor ventilation on symptoms of sick building syndrome. In: Geshwiler M, Montgomery L, and Moran M, eds. Healthy buildings. Proceedings of the ASHRAE/ICBRSD conference IAQ'91. Atlanta, GA. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

16. Jaakkola JJK, Heinonen OP, Seppänen O [1991]. Mechanical ventilation in office buildings and the sick building syndrome. An experimental and epidemiological study. Indoor Air 1(2):111-121.

17. Sundell J, Lindvall T, and Stenberg B [1991]. Influence of type of ventilation and outdoor airflow rate on the prevalence of SBS symptoms. In: Geshwiler M, Montgomery L, and Moran M, eds. Healthy buildings. Proceedings of the ASHRAE/ICBRSD conference IAQ'91. Atlanta, GA. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

18. Levin H [1989]. Building materials and indoor air quality. Occupational Medicine: State of the Art Reviews. 4(4):667-694.

19. Wallace LA, Nelson CJ, Dunteman G [1991]. Workplace characteristics associated with health and comfort concerns in three office buildings in Washington, D.C. In: Geshwiler M, Montgomery L, and Moran M, eds. Healthy buildings. Proceedings of the ASHRAE/ICBRSD conference IAQ'91. Atlanta, GA. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

20. Haghighat F, Donnini G, D'Addario R [1992]. Relationship between occupant discomfort as perceived and as measured objectively. Indoor Environ 1:112-118.

21. NIOSH [1991]. Hazard evaluation and technical assistance report: Library of Congress Madison Building, Washington, D.C. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 88-364-2104 - Vol. III.

22. Skov P, Valbjørn O, Pedersen BV [1989]. Influence of personal characteristics, job-related factors, and psychosocial factors on the sick building syndrome. Scand J Work Environ Health 15:286-295.

23. Boxer PA [1990]. Indoor air quality: A psychosocial perspective. J Occup Med 32(5):425-428.

24. Baker DB [1989]. Social and organizational factors in office building-associated illness. Occupational Medicine: State of the Art Reviews. 4(4):607-624.

25. CDC [1988]. NIOSH recommendations for occupational safety and health standards 1988. Atlanta GA: U.S. Department of Health and Human Services,

Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. MMWR 37(suppl S-7).

26. Code of Federal Regulations [1989]. OSHA Table Z-1-A. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

27. ACGIH [1991]. 1991-1992 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

28. ASHRAE [1990]. Ventilation for acceptable indoor air quality. Atlanta, GA: American Society of Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 62-1989.

29. ASHRAE [1981]. Thermal environmental conditions for human occupancy. Atlanta, GA: American Society for Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 55-1981.

30. ACGIH [1989]. Guidelines for the assessment of bioaerosols in the indoor environment. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

31. Molhave L, Bach B, Pedersen, OF [1986]. Human reactions during controlled exposures to low concentrations of organic gases and vapors known as normal indoor air pollutants. Environ. Int 12, 167-175.

32. Bach B, Molhave L, Pedersen, OF [1984]. Human reactions during controlled exposures to low concentrations of organic gases and vapors known as normal indoor air pollutants: Performance tests. Proceedings of the 3rd international indoor air quality and climate conference, World Health Organization, Stockholm, Sweden, 397-402.

33. Jensen M, Roed-Petersen, J [1979]. Itching erythema among post office workers caused by a photo copying machine with wet toner. Contact Dermatitis. Vol. 5.

34. Canadian Center for Occupational Health and Safety [1983]. Photocopiers -Do They Pose a Health Hazard? Hamilton, Ontario.

35. NIOSH [1977]. Occupational Diseases - A Guide to Their Recognition. Revised Edition. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 77-l8l.

36. CDC [1988]. Recommendations for Occupational Safety and Health Standards 1988. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. MMWR 37 S-7): 1-29.

37. Code of Federal Regulations [1989]. OSHA Table Z-1. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

38. Ambient PM^{10} standard [1987]. Environmental Protection Agency, Washington, DC. U.S. Government Printing Office, Federal Register 52:24634.

IX. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared by: Calvin K. Cook
Industrial Hygienist
Industrial Hygiene Section

Michael S. Crandall, CIH, M.S.
Supervisory Industrial Hygienist
Industrial Hygiene Section

Originating Office: Hazard Evaluations and Technical Assistance Branch
Division of Surveillance, Hazard Evaluations and Field Studies

Report Typed By: Tammy Lykins
Office Automation Assistant

X. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report may be freely reproduced and are not copyrighted. Single copies of this report will be available for a period of 90 days after the date of this report from the NIOSH Publications Office, 4676 Columbia Parkway, Cincinnati, OH 45226. To expedite your request, include a self-addressed mailing label along with your written request. After this time, copies may be purchased from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

Copies of this report have been sent to:

1. Pitney Bowes Photocopy Center
2. Confidential requestor
3. NIOSH, Region IV
4. OSHA, Region IV

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

Results of Real-time Ozone Measurements

Pitney Bowes Photocopy Center
Boston, Massachusetts
September 11, 1991

HETA 91-254

Location	Time	Ozone (ppm)*	Comments
3' from exhaust of PC** #1	9:18	0.15	PC #1 running
	9:30	0.18	" "
	10:12	0.29	" "
BZ Ht.*** of PC # 1	10:40	0.03	PC #1 and #2 running
	10:44	0.04	" "
	10:53	0.05	PC #1 and #3 running
3' from exhaust of PC #2	10:19	0.08	PC #2 and #3 running
	10:27	0.12	" "
	10:35	0.11	PC #2, #3, & #4 running
BZ Ht. of PC #2	11:00	0.01	PC #4 running
	11:06	0.02	PC #2 and #4 running
	11:10	0.03	PC #2 running
3' from exhaust of PC #3 and #4	1:20	0.29	PC #3 and #4 running
	1:30	0.27	PC #3 and #4 running
	1:45	0.35	" "
	1:49	0.23	" "
BZ Ht.** of PC*** #3	1:55	0.02	PC #3 and #4 running
	2:07	0.01	PC #2, #3, & #4 running
BZ Ht. of PC #4	2:15	0.01	PC #2 and #4 running
	2:18	0.02	" "
3' from exhaust of PC #5 and #6	2:30	0.09	PC #1 and #5 running
	2:33	0.06	PC #1 and #6 running
	2:45	0.17	PC #5 and #6 running
BZ Ht. of PC #5	2:46	0.01	PC #1 and #5 running
	2:51	0.02	" "
	2:55	0.01	" "
BZ Ht. of PC #6	3:00	0.02	PC #1 and #6 running
	3:02	0.01	PC #2 and #6 running
3' from exhaust of PC #1	3:15	0.22	PC #1 and #5 running
	3:22	0.41	PC #1 and 3 running
	3:28	0.18	PC #1 running
	3:50	0.31	" "

* ppm = parts per million parts of air
** PC = photocopier
*** BZ Ht. = breathing zone

Table 2

Results of Real-time Ozone Measurements

Pitney Bowes Photocopy Center
Boston, Massachusetts
September 12, 1991

HETA 91-254

Location	Time	Ozone (ppm)*	Comments
3' from exhaust of PC** #1	8:55	0.08	PC #1 running
	9:31	0.13	" "
	9:35	0.06	PC #1 and #4 running
BZ Ht.*** of PC #1	9:05	0.03	PC #1 and #4 running
	9:18	0.02	PC #1 running
	2:50	0.04	PC #1, #3, & #5
3' from exhaust of PC #2	9:50	0.09	PC #2 running
	10:03	0.11	" "
BZ Ht. of PC #2	9:30	0.06	PC #2 running
	9:37	0.03	PC #2 running
	9:40	0.08	PC #2 and #5 running
3' from exhaust of PC #3 and #4	11:05	0.17	PC #3 and #4 running
	11:15	0.08	PC #4 running
BZ Ht. of PC #3	11:20	0.02	PC #4 running
BZ Ht. of PC #4	11:25	0.02	PC #4 and #2 running
3' from exhaust of PC #5 and #6	10:23	0.06	PC #5 running
BZ Ht. of PC #5	10:20	0.01	PC #5 running
	10:25	0.02	" "

* ppm = parts per million parts of air
** PC = photocopier
*** BZ Ht. = breathing zone height

Table 3

Indoor Air Quality Data

Pitney Bowes Photocopy Center
Boston, Massachusetts
September 11, 1991

HETA 91-254

Location	Time	CO_2 (ppm)*	Temp (F)	RH (%)	RSP (µg/m^3) **	# of Occupants
	9:15	500	77	41	20	2
Binding	11:10	425	76	40	N/D***	1
Area	1:23	575	78	38	20	2
	4:30	675	78	35	50	1
	9:16	500	77	41	20	3
At PC****	11:12	575	76	40	20	4
#3 and #4	1:26	575	79	38	20	2
	4:34	650	78	35	20	5
	9:20	500	76	41	20	5
Customer	11:15	575	76	43	20	3
Serv. Desk	1:31	550	77	40	20	1
	4:36	625	78	35	20	3
	9:17	450	77	41	20	2
Management	11:14	525	75	40	20	0
Office	1:29	550	77	39	20	1
	4:39	575	78	34	20	0
Outdoors	9:22	350	52	59	10	--
	4:45	325	72	28	10	--

* ppm = parts per million parts of air
** (µg/m^3) = milligrams per cubic meter of air
*** N/D = none detected
**** PC = photocopier

Table 4

Indoor Air Quality Data

Pitney Bowes Photocopy Center
Boston, Massachusetts
September 12, 1991

HETA 91-254

Location	Time (ppm)*	CO_2 (F)	Temp (%)	RH ($\mu g/m^3$)**	RSP	# of Occupants
	7:40	325	78	34	N/D***	0
Binding	11:15	725	78	37	40	0
Area	12:55	725	79	38	20	0
	4:35	825	79	37	30	1
	7:42	300	77	34	N/D	0
At PC****	11:20	675	78	38	40	0
#3 and #4	12:57	700	79	38	20	2
	4:37	775	79	37	30	3
	7:45	300	76	34	20	0
Customer	11:23	700	77	38	40	3
Serv. Desk	1:00	675	79	39	20	2
	4:39	775	79	37	30	3
Outdoors	8:00	375	55	49	20	--
	4:47	400	72	27	20	--
	7:47	300	76	35	20	0
Management	11:25	675	78	37	20	1
Office	1:02	675	79	38	20	0
	4:40	725	78	37	30	0

* ppm = parts per million parts of air
** ($\mu g/m^3$) = milligrams per cubic meter of air
*** N/D = none detected
**** PC = photocopier

Figure 1

Thermal Comfort Chart