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I. SUMMARY

In July 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from the Washington Metropolitan Area Transit Authority (WMATA), Washington, D.C. The request concerned recurring symptoms such as eye irritation and upper respiratory problems among employees in the WMATA communications room. An initial environmental and medical evaluation was made on September 29,1992, during which a walk-through inspection was conducted of the communications room and adjacent battery room. Environmental measurements were collected for temperature, relative humidity (RH), carbon dioxide (CO_2), volatile organic compounds (VOCs), and sulfuric acid (a potential contaminant from the batteries). The design and performance of the air-handling units (AHU) were also evaluated. During the walk-through survey, the halon 1301 fire extinguishing system was examined, since employees were concerned about potential exposures to halon during a recent accidental discharge into the occupied area. Interviews were conducted with employees to obtain information regarding employees' symptoms and perceptions of the building environment. Because various types of telecommunications equipment were located in the communications room, an environmental follow-up evaluation was conducted on November 23, 1992, to measure levels of electric and magnetic fields. Illumination levels were also measured throughout the room.

<u>September 29, 1992 Environmental Survey</u>
Carbon dioxide concentrations ranged from 375 to 510 ppm with a mean of 387 ppm throughout the sampling period. Normally, this would suggest that the occupied area was receiving adequate amounts of outside air (OA), however, due to the very low occupancy of 2 persons/1,000 ft^2, this data may not accurately represent the amount of OA. In fact, of the six supply diffusers for which NIOSH investigators were able to measure flow rates, all were approximately half of the original flow of the system design. Also, a number of deficiencies were identified in the ventilation system. Temperature and RH levels ranged from 68.5 to 73.4 °F and 37 to 46.1% relative humidity (RH), respectively. The temperature and RH measurements were both within the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) comfort guidelines for winter. Low levels (consistent with those commonly found in non-industrial environments) of 1,1,1-trichloroethane, acetone, toluene, xylene, and 2-butanone were measured in the

communications room. Methylene chloride, a human carcinogen, was found to be a trace contaminant of a contact cleaner used throughout the room on a daily basis. No sulfuric acid was detected above the minimum detectable concentration (MDC) of 0.03 mg/m^3. The most commonly reported symptoms during the medical interviews were dry itching or tearing eyes, dry throat, stuffy nose/sinus congestion, headache, fatigue and sleepiness.

November 23, 1992 Environmental Survey

Electric and magnetic field measurements in the battery and communications rooms were found to be below the ACGIH TLVs. One area of concern was located by the transformers and the Data Service Units; the magnetic field measurements ranged from 0.1 to 3,000 mG. Illumination levels in the communications room ranged from 27 to 460 lux; therefore, in some areas, levels were well below the Illuminating Engineering Society (IES) recommended range of 200 - 500 lux. Metal racks located in the room blocked much of the light, in addition, some of the light fixtures contained bulbs which had not been changed recently.

Interviews revealed that many of the employees have experienced symptoms consistent with those commonly referred to as "sick building syndrome". However, on the basis of the environmental data gathered during this investigation, no specific health hazard was identified. Several general recommendations are offered to improve the indoor environment which include balancing the ventilation system, using more efficient filter media, improving lighting conditions, and further assessing possible exposures to methylene chloride.

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eywords: SIC 4111 (local and suburban transit), indoor environmental quality, ELF, E.M. radiation, carbon dioxide, temperature, relative humidity, volatile organic compounds, IEQ, IAQ, ventilation.

II. INTRODUCTION

In July 1992, the National Institute for Occupational Safety and Health (NIOSH) received a management request to conduct a Health Hazard Evaluation (HHE) at the Washington Metropolitan Area Transit Authority (WMATA) in Washington, D.C. The request for an indoor environmental quality (IEQ) investigation was submitted as a result of various health complaints being attributed to the work environment in the communications room, located on the first basement level of the building. The symptoms reported by employees included eye, throat, and upper respiratory tract irritation. These symptoms, reportedly present since the Fall of 1991, were accompanied by reports of a distinctive odor similar to that of "burnt coffee".
An initial site visit was conducted on September 29, 1993, during which environmental samples were collected, the air-handling units (AHUs) were evaluated, and medical interviews were conducted. During the walk-through survey, the halon 1301 fire extinguishing system, serving the communications room, was examined, since there had previously been an accidental discharge of halon into the occupied area.

Based on observations made during the initial site visit, a follow-up environmental evaluation was conducted on November 23, 1993. During this survey, extremely low frequency (ELF) electric and magnetic fields, created by equipment associated with the power supply system, were measured in the battery room and in the communications room. In addition, illumination levels were measured throughout the communications room.

This report contains observations made during the walk-through surveys, results from samples collected during both evaluations, a review of the information obtained from employee interviews, and recommendations.

III. BACKGROUND AND DESCRIPTIVE INFORMATION

The Washington Metropolitan Area Transit Authority headquarters is located in the Jackson Graham Building at 600 Fifth Street NW, Washington, D.C. The seven story building is comprised of small office spaces, large work areas, conference rooms, break lounges, restrooms, computer rooms, and subway communication rooms. A subway tunnel enters the building on the third basement level; access to the tunnel from the building has been sealed since the beginning of 1987 to eliminate the infiltration of contaminants into occupied areas of the building. Smoking is prohibited throughout the building.

Approximately 16 employees, five per shift, are assigned to the communications room on the first basement level which is operated on a 24-hour basis. This room occupies an approximate area of 2500 square feet (Figure 1). The nature of the work conducted in the communications room involves electrical repair work; at least two employees remain in this room at all times, while others respond to calls making repairs at various other locations. The room contains telecommunications equipment such as rectifiers, transformers, multiplexors, a telephone switchboard, computers, and carrier transmission systems. The space under the raised floor serves as a plenum for air recirculation and houses cable trays and chilled water lines. Adjacent to the communications room is a battery room containing an uninterrupted power system (UPS) which houses a bank of wet battery cells. The UPS room has since been moved to a different area of the building; however, the wet battery cells still remain in the room to be used as back-up power in case of electrical failure. Sulfuric acid, aerosolized from these batteries, is a potential air contaminant.

Ventilation System

There is one variable air volume (VAV) heating, ventilating, and air conditioning (HVAC) unit which provides ventilation for the communications room (AC-10). Unconditioned outside air enters the mechanical room on the first basement level, housing the AHUs, through a set of dampers located in a 30 foot well. The volume of OA (minimum of 20%) supplied by the air handler to the occupied space is controlled by temperature sensors located in the return air duct. Outside air mixes with return air from the occupied spaces and passes through a fiberglass roll filter followed by either a bank of box filters with a rated efficiency of less than 20% or a bank of pleated glass fiber filters with a rated efficiency of 50%. All filters are reportedly checked three times daily as part of a preventative maintenance program. Filtered, mixed air passes through an electric steam humidifier, a cooling coil, the fan, supply air ductwork, and a VAV box before being delivered to the occupied space. The temperature of the supply air leaving the air handler is kept near 55 degrees Fahrenheit. Air from the occupied areas enters the return plenum below the floor and is returned to the air handler. None of the supply air ductwork is lined internally.

There were three thermostatically controlled ventilation zones (VAV boxes) serving the communications room. The VAV system controls temperature in the occupied space by supplying air at a constant temperature and varying the amount of air flow. This is done by using a dampering mechanism in the VAV box, controlled by the zone thermostat. When cooling is needed, the VAV damper opens more fully to allow more air flow. When the temperature reaches the thermostat setpoint, the damper modulates toward the closed position, decreasing the airflow. Auxiliary cooling is provided to the communications room by three additional air conditioning units responsible for recirculating room air. These units pass air across evaporator cooling coils of an electric-powered mechanical refrigeration system with an air-cooled condenser, however they do not provide ventilation (OA exchange) to the room. Filters used in these units include pre-filters and 3-inch box filters. These units were added in 1985 to accommodate the addition of new equipment, and they cool equipment by forcing cold air into the plenum under the floor where it is then recirculated up into the equipment via diffusers in the floor. The condensation pans, coils, and filters on these units are reportedly visually inspected at the beginning of each shift and preventative maintenance is performed monthly.

Several incidents took place in the communications room which preceded the symptoms experienced by the employees beginning in September 1991, however, no specific incident was identified by management as being the causative factor of the employee complaints. As part of the installation of a Halon 1301 fire extinguishing system, the communications room was sealed at the beginning of 1991, however, the ventilation system was not re-balanced after the renovations were completed. An accidental release of halon occurred on June 21, 1991, while the room was occupied. In addition, a leak in the chilled water line, located in the recirculating air plenum, was discovered at the beginning of March 1992. It was unknown how long the leak was present.

Halon 1301 Fire Extinguishing System

A Halon 1301 total flooding fire protection system was installed in five areas on the first basement level over a four-year period, from 1987 to 1991, by a fire protection contractor. This type of system utilizes Halon 1301 to extinguish fires in enclosed areas where water-based or dry chemical systems would severely damage the electrical equipment, and where the use of CO_2 would create a danger to personnel within the room. The halon mixture, consisting of 6% Halon 1301 and 94% nitrogen, is stored in 442-gallon tanks with six tanks located in the communications room.

Fifteen pairs of under-floor and ceiling-mounted fire detection devices which respond to smoke, flame and/or heat were located throughout the communications room. When the system has been activated, an alarm sounds and there is an automatic shutdown of the ventilation system. During shutdown, supply air dampers are closed to prevent oxygen from reaching the room, additional emergency dampers are opened to relieve pressure in the ductwork, and all fans in the system are shut down. Thirty seconds after the alarm sounds (allowing workers time to leave), halon is discharged from two ceiling mounted discharge nozzles. At this point, the doors to the room automatically lock.

A purge system, which can be activated by the fire department or the fire protection contractor, was also added to the present ventilation system. This dedicated exhaust system is used to clear the room of halon after a fire is extinguished. After halon is removed from the room, all dampers in the system are automatically re-opened by activating a switch on the control panel. Reportedly, before employees are permitted to re-enter the room, measurements are taken with a halon/freon detector to test for residual airborne levels of halon. Employees are allowed to enter the room once no detectable levels are found. Employee training concerning the extinguishing system was reportedly conducted at the time of installation.

On June 21, 1991, an accidental discharge of two 442 gallon halon tanks occurred in the communications room following several alarms and manual shut-downs by employees in the room. The HVAC system was shut-down and the room was evacuated. At the time, a chilled water renovation contractor was conducting soldering operations in the room. The smoke caused by the soldering is believed to have activated the halon system in the room; however, the exact cause of the discharge is unknown, since reports from employees and management differ concerning the incident. Employees re-entered the room after the fire protection contractor purged the area and reportedly found no residual levels of halon in the room.

Chilled Water Line
There was a high level of concern among the occupants of the communications room regarding the presence of ethylene glycol in the chilled water. Employees became concerned after a building maintenance manager stated that ethylene glycol was an additive in the water and was the probable cause of the odor the employees had reported.

A representative from the building's current ventilation contractor (since 1987) stated that the previous contractor had added ethylene glycol to the water in the early 80's in order to prevent freezing of the pipes. Presently, the only substance being added to the chilled water is a corrosion inhibitor which contains sodium nitrite and polyacrylic acid.

IV. EVALUATION METHODS

September 29, 1992 Survey

Employee Interviews
Individual medical interviews were conducted with eleven of the sixteen employees who were assigned to the communications room. Employees working on both the day and evening shifts were interviewed. The purpose of these interviews was to gain further insight into employee complaints regarding working in the communications room. Workers were asked to comment on their concerns about indoor environmental quality and on other aspects of work at WMATA, including employee-management relations and communications regarding perceived environmental problems in the communications room.

Carbon Dioxide
Carbon dioxide (CO_2) measurements were obtained throughout the work shift at various locations in the communications room. Real-time CO_2 levels were determined using a Gastech Model RI-411A, Portable CO_2 Indicator. This portable, battery-operated instrument monitors CO_2 via non-dispersive infrared absorption with a range of 0-4975 ppm, and a sensitivity of 25 ppm. Instrument calibration was performed prior to use with a known concentration of CO_2 span gas (800 ppm).

Temperature and Relative Humidity
Real-time temperature and RH measurements were conducted using a Vaisala, Model HM 34, battery-operated meter. This meter is capable of providing direct readings for dry bulb temperature and RH ranging from -4 to 140°F, and 0 to 100%, respectively.

Volatile Organic Compounds (VOCs)
Six locations were selected in the communications room to measure area levels of VOCs. Some areas, such as the fan coil units (FCUs), were selected based on previous odor reports by WMATA employees. All samples were analyzed quantitatively. A background sample of the outdoor air was also collected at the air intake of AC-10. Figure 1 shows the locations where the samples were collected in the communications room.

Supelco™ Carbotrap™ 300 tubes were used to collect the samples at a flow rate of 50 cc/min over a sampling period of approximately five hours, for an average total sample volume of 13.7 liters. Samples were subsequently analyzed for trace levels of VOCs using a Supelco Dynatherm thermal desorption unit and GC-MS.

Bulk Samples
A sample of the chilled water serving the fan coil units (FCUs) in the area was collected for qualitative analysis of volatile organic compounds (VOCs) by gas chromatography/mass spectrometry (GC-MS).

A sample of a contact cleaner used in the communications room on a daily basis was submitted for qualitative analysis of VOCs by GC-MS. The material safety data sheet (MSDS) for this substance states that the components of the cleaner include 94-99% Freon 113 and 0-5% carbon dioxide.

Sulfuric Acid
Three area samples were collected for sulfuric acid by drawing air through silica gel tubes at a flow rate of 0.2 LPM using battery-operated sampling pumps. Samples were collected in the battery room and surrounding areas. Figure 1 shows the locations where these samples were collected.

Samples were collected and analyzed according to NIOSH Method 7903.[1] The analytical limit of detection (LOD) was 2 µg/sample, which equates to a minimum detectable concentration (MDC) of 0.03 mg/m^3 based on a sampling volume of 58 liters.

Ventilation Assessment
A visual examination was made of the air handling unit (AC-10). The unit was inspected for the presence, condition, and correct installation of filter media; position of outside air dampers; signs of microbiological growth; and condition of duct linings, coils, and drain pans. A brief survey of the ventilation system supplying conditioned air to the communication room included airflow measurements at several supply air diffusers with a flow hood. A complete set of measurements was not collected, since several of the supply diffusers were blocked with equipment.

<u>November 23, 1992 Survey</u>

Electromagnetic Fields
Exposure to 60-Hz electric and magnetic fields was measured using a Holaday Industries, Inc. (HI) Extremely Low Frequency (ELF) Sensor (Model HI-3602) connected to a HI-3600 meter. The electric field strength is measured as volts per meter (V/m) and the magnetic field strength is expressed in units of milligauss (mG). Measurements were made in both the communication and battery rooms at waist height. All systems were calibrated either by NIOSH or the manufacturer within six months of the date of this evaluation.

Optical Radiation
Luminance (brightness levels) was measured with a Spectra Mini-Spot photometer having a one degree field of view. The minimum luminance that can be read is 0.5 footlamberts

(fL) and the overall accuracy is ± 10%. The values are measured as fL and converted to candela per square centimeter (cd/cm^2). The luminance of a source is a measure of its brightness when observed by an individual without eye protection, regardless of the distance from the source.

Illumination measurements were performed with a calibrated model 500 Litemate photometer system manufactured by Photo Research, Inc. that reports measurements in units of lux over the wavelength region from 380 to 760 nanometer (nm).

V. EVALUATION CRITERIA

Indoor Environmental Quality

NIOSH investigators have completed over 1,100 investigations of the occupational indoor environment in a wide variety of non-industrial settings. The majority of these investigations have been conducted since 1979.

The symptoms and health complaints reported to NIOSH 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. A number of published studies have reported high prevalences of symptoms among occupants of office buildings.[2,3,4,5,6] Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[7,8] 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.[9,10,11,12,13,14,15] Reports are not conclusive as to whether increases of outdoor air above currently recommended amounts (≥15 cubic feet per minute per person) are beneficial.[11] However, rates lower than these amounts appear to increase the rates of complaints and symptoms in some studies.[16] 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 or indoor sources.[17]

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.[18,19,20] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[17,21,22,23]
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 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, these problems could not be directly linked to the reported health effects.

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.[24,25,26] With few exceptions, pollutant concentrations observed in non-industrial indoor environments fall well below these published occupational standards or recommended exposure limits. ASHRAE has published recommended building ventilation design criteria and thermal comfort guidelines.[27,28] 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.[29]

Measurement of indoor environmental contaminants has rarely proved to be helpful in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proven relationship between contaminants and specific building-related illnesses. However, measuring ventilation and comfort indicators such as carbon dioxide (CO_2), temperature and relative humidity, has proven useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems.

NIOSH and the Environmental Protection Agency (EPA) jointly published a manual on building air quality, written to help prevent environmental problems in buildings and solve problems when they occur.[30] This manual suggests that indoor environmental quality (IEQ) is a constantly changing interaction of a complex set of factors. Four of the most important elements involved in the development of IEQ problems are: 1) a source of odors or contaminants; 2) a problem with the design or operation of the HVAC system; 3) a pathway between the contaminant source and the location of the complaint; 4) and the building occupants. A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems.

Specific Substances and Physical Agents

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 ANSI/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 telecommunication centers,* 15 cfm/person for reception areas, and 60 cfm/person for smoking lounges, and provides estimated maximum occupancy figures for each area.[27] Maintaining the recommended ASHRAE outdoor air supply rates when the outdoor air is of good quality, and there are no significant indoor emission sources, should provide for acceptable indoor air quality.

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. Carbon dioxide is not thought to be a cause of indoor environmental quality symptoms. Rather, it is used as an indicator of the adequacy of OA supplied to the occupied areas. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased. It is important to note that CO_2 is not an effective indicator if the ventilated area is vacated or sparsely populated (< 7 people/1,000 ft^2).

Temperature and Relative Humidity
Temperature and RH parameters affect the perception of comfort in the indoor environment. 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 55-1992 specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally acceptable. Assuming slow air movement and 50% RH, the operative temperatures recommended by ASHRAE range from 68-74°F in the winter, and 73-79°F in the summer.[26] The difference between the two is largely due to seasonal clothing selection. In a separate document (ASHRAE Standard 62-1989), ASHRAE recommends that the RH be maintained between 30 and 60%.[27] Excessive humidities can support the growth of microorganisms, some of which may be pathogenic or allergenic.

Volatile Organic Chemicals
VOCs, including formaldehyde and other aldehydes, are emitted in varying concentrations from numerous indoor sources (e.g., carpeting, fabrics, adhesives, solvents, paints, cleaners, waxes, cigarettes, kerosene heaters, and other combustion heating products). New building materials, products,and furnishings are known to emit a large number of organic chemicals into indoor air.[16]

Indoor environmental quality studies have measured wide ranges of VOC concentrations in indoor air as well as differences in the mixtures of chemicals which are present. Research also suggests that the irritating potency of these VOC mixtures can vary. While in some instances it may be useful to identify some of the individual chemicals which may be present, the concept of "total volatile organic compounds (TVOCs)" has been used to measure the potential of a VOC mixture to cause discomfort.[31]

Some researchers have developed tentative dose-response relationships comparing VOCs with human responses such as headache and irritative symptoms of the eyes, nose, and throat. However, neither NIOSH nor OSHA have specific exposure criteria for VOC mixtures in the nonindustrial environment. Research conducted in Europe suggests that complaints of irritation and discomfort by building occupants are probable when TVOC concentrations are higher than 3 mg/m.[32]

Sulfuric Acid
Sulfuric acid is a colorless to dark-brown, oily, odorless liquid.
Sulfuric acid is a strong tissue irritant; contact with it can result in severe chemical burns. Inhalation of its vapor can cause nose and throat irritation, cough, bronchitis, pulmonary edema (accumulation of fluid in the lungs), and bleeding from the nose, lungs, and stomach.[33,34] The NIOSH recommended exposure level (REL) and the OSHA permissible exposure limit (PEL) 8-hour time-weighted average (TWA) for sulfuric acid is 1 mg/m^3.[23,24]

Electric and Magnetic Field Exposure
The American Conference of Governmental Industrial Hygienists (ACGIH) has published Threshold Limit Values (TLVs) for sub-radiofrequency electric and magnetic fields. At 60 Hertz (Hz), which is classified as extremely low frequency (ELF), the electric intensity TLV is 25,000 volts per meter (V/m) for an 8-hour time-weighted average and the magnetic flux density TLV is 10,000 milligauss (mG) or 10 Gauss for an 8-hour time-weighted average.[25]

The basis of the ELF electric field TLV is to minimize occupational hazards arising from sparks and contact current situations. The magnetic field TLV addresses induction of magnetophosphenes (a visual sensation of white light) in the visual system and production of induced currents in the body.
Neither OSHA nor NIOSH have issued any criteria related to ELF exposure.

Optical Radiation
The ACGIH exposure limits used by the NIOSH investigators to interpret optical radiation (ultraviolet, visible, and infrared) exposures are based on an 8-hour TWA exposure level.[25] The Illuminating Engineering Society (IES) lighting guideline levels were also used to evaluate lighting conditions.[35] While these guidelines do not list a specific illumination level for electrical repair work, the level suggested by IES for performance of visual tasks of high contrast is 200 - 500 lux.

VI. RESULTS AND DISCUSSION

Employee Interviews
The predominant type of symptoms reported by interviewed employees included headache, runny nose, stuffy nose/sinus congestion, dry throat, fatigue, sleepiness, and dry, itching, or irritated eyes. One employee reported being evaluated by his physician for a chronic cough; no cause was determined. Many employees reported experiencing eye irritation during and shortly after the discharge of halon in June 1991. Likewise, a number of the interviewed employees reported experiencing eye and throat irritation (as well as odors) before and for several months after the March 1992, repair of the chilled water line leak. However many employees stated that their symptoms had significantly improved since that time.

CO_2, Temperature, and RH
As shown in Figure 3, CO_2 levels in the communications room ranged from 375 to 510

ppm throughout the work shift. These concentrations were very similar to the average ambient level of 425 ppm. The concentrations suggest that the amount of outside air delivered to the communications room on this day was sufficient for the level of occupancy. However, due to the low level of occupancy in the communications room, CO_2 concentrations may not have been a good indicator of the amount of outside air being supplied to the room. Temperature and RH levels ranged from 68.5 to 73.4 $^{\circ}$F and 37 to 46.1% RH, respectively. The temperature and RH measurements were all within the ASHRAE comfort guidelines for winter as described previously in the Evaluation Criteria section (Figure 3).

Volatile Organic Compounds
Levels of total VOCs found in the communications room are shown in Figure 4. The table on the following page shows the individual compounds which attributed to the calculated total VOC levels, as well as the detection limits and minimum detectable concentrations for each compound. The highest level was found in the wire closet (0.54 mg/m^3), with lower levels in the office and near the fan coil units, ranging from 0.16 to 0.23 mg/m^3. Ambient air levels of total VOCs were the lowest (approximately 0.02 mg/m^3), with the main components being aliphatic hydrocarbons in the C_6-C_{11} range.

Compound	Detection Limit (ng/sample)	MDC (mg/m^3)
acetone	75.0	0.006
2-butanone	75.0	0.006
1,1,1-trichloroethane	50.0	0.004
carbon tetrachloride	50.0	0.004
trichloroethene	50.0	0.004
benzene	50.0	0.004
4-methyl-2-pentanone	75.0	0.006
tetrachloroethene	50.0	0.004
toluene	50.0	0.004
total xylene	50.0	0.004
methyl cellosolve	500.00	0.041
cellosolve	500.00	0.041
butyl cellosolve	500.00	0.041
freon 22	50.0	0.004
pentane	N/A	N/A

The samples collected in the communications room were found to have trace levels of acetone, 2-butanone, toluene, total xylenes, and various hydrocarbons.

1,1,1-trichloroethane, present in each indoor sample in a significantly greater proportion than any other compound, was found above the minimum detectable concentration (MDC) of 0.004 mg/m^3, based on an averagesample volume of 13.7 liters. The laboratory reported limit of detection was 50 nanograms per sample. One possible source of 1,1,1-trichloroethane, as indicated from bulk sample analysis, is the contact cleaner which is used throughout the communications room on a daily basis.

Higher levels of VOCs were found in the wire closet , of which 1,1,1-trichloroethane was the major component. Although 1,1,1-trichloroethane was the predominant compound found in the air samples throughout the communications room, exposure to this individual chemical at the low concentrations found in the communications room would not be expected to cause any of the described acute health effects in the request or during the employee interviews.

Bulk Samples
Ethanol was the major organic compound detected in the chilled water sample. Trace amounts of ethylene glycol and acetic acid were also detected, both of which have been associated with causing eye, nose, and throat irritation when present in sufficient concentrations. It is likely that these compounds were constituents of antifreeze products previously added to the chilled water system (product names and material safety data sheets were not available at the time of the site visit).

Worker exposures to substances found in the chilled water should have been eliminated when the line was sealed in March 1992. The only way to determine whether employees were exposed to any of the components of the chilled water would have been to collect personal breathing zone air samples at the time of the leak . According to employees, symptoms subsided three months following the repair of the line. It is unknown how long the leak was present.

Freon 113 was the major constituent of the contact cleaner (as stated on the MSDS). Trace quantities of 1,1,1-trichloroethane, carbon dioxide, methylene chloride (Freon 30), dichlorofluoromethane (Freon 12), and other contaminants of the contact cleaner were also detected. Exposures to low levels of halogenated chlorofluorohydrocarbons, such as the freons which were detected, can result in mild eye, skin, and respiratory tract irritation.[32] In addition, NIOSH considers methylene chloride a human carcinogen for which exposures should be held to the lowest feasible concentration.[36]

Sulfuric Acid
Of the three air samples collected, all were below the minimum detectable concentration of 0.03 mg/m^3 based on an average sampling volume of 57 liters.

Electromagnetic Fields
The electric field measurements in the battery room ranged from 3.1 to 63.6 V/m (average = 42.7), while magnetic field measurements ranged from 3.0 to 4000 mG. Both the electric and magnetic field measurements were below the respective ACGIH TLVs (25,000 V/m for electric fields and 10,000 mG for magnetic fields).

Electric and magnetic field measurements were also taken in the communications room; all measurements were found to be below the ACGIH TLVs. Magnetic field measurements ranged from 0.1 - 3000 mG.

During the walk-through survey on November 23, 1992, NIOSH investigators observed that many of the face shields stored in the battery room were damaged and not suitable for use. Recommendations were made to repair or replace the shields and to repair the straps on the shields.

Many of the employees reported receiving shocks when working on electrical wiring. One possible contributing factor, as discussed below, was the low illumination levels found in the work area which impaired the vision of the workers.

Optical Radiation
Results of illumination measurements are shown in Figure 5. Illumination levels in the communications room ranged from 27 to 460 lux; therefore, in some of the areas, illumination levels were below the IES recommended levels of 200 - 500 lux. Metal racks located in the room contributed to some of the low illumination levels. In addition, some of the lighting fixtures contained bulbs which had not been changed recently. WMATA management reported that these bulbs had not been changed because the fixtures were blocked by the equipment.

Ventilation Assessment
The outside air damper serving unit AC-10 was situated in a well which brings in air from street level. Due to the location of this intake, vehicle exhaust fumes could potentially be entrained into the building.
Of the six supply diffusers for which NIOSH investigators were able to measure flow rates, all were approximately half of the flow specified in the original system design. WMATA ventilation engineers reported that the flow rate measurements they have made in the past averaged 30% below the original design flow rates. These measurements indicate further that the CO_2 concentrations may not have accurately represented the amount of outside air based on the low occupancy of the area. The system reportedly has not been recently balanced due to the extensive renovations occurring on this floor.

Filter media in the HVAC systems were found to be clean and intact. Incorrect installation of a box filter in AC-10 resulted in a portion of the supply air by-passing the filter. Presently, air is pre-filtered, then filtered by either a pleated glass fiber filter (efficiency 50%) or a box-type filter (efficiency 20%). The original design of the system was for the more efficient box-type filters. Since the system was originally designed for box filters, alterations to obtain proper fit may be needed if using the pleated filters. All condensation pans and drains appeared to be free of visible signs of microbial growth.

VII. CONCLUSIONS

No specific health hazards were identified at the time of the NIOSH evaluation.

Several factors, or contaminant sources, could have contributed to the symptoms experienced by the employees located in the communications room during and shortly after the June 1991, Halon incident and the chilled water leaks which were repaired in March of 1992. The NIOSH investigation took place long after these events so actual exposures could not be assessed.

None of the environmental samples collected as part of this evaluation revealed inadequate ventilation, temperatures or relative humidities outside the ASHRAE comfort guidelines, or the presence of unusually high levels of volatile organic compounds in the air. CO_2 levels indicated that a sufficient amount of outside air was being delivered to the room. However, due to the low occupancy (2 people per 1,000 ft^2), the CO_2 data can be misleading. Flow hood measurements on several air supply diffusers revealed that supply air flow rates were half the original system design. Therefore, the efficiency of the HVAC system needs to be further evaluated.

The material safety data sheet for Malter International XL-100 lists its components as Freon 113, carbon dioxide, and a propellant. Bulk sample analysis revealed that methylene chloride was a trace contaminant of the contact cleaner. NIOSH has designated this compound as a human carcinogen for which exposures should be held to the lowest feasible concentration. Although no detectable airborne levels of methylene chloride were found during the NIOSH evaluation, since it is a volatile component of the cleaner and considering the way the cleaner is used (aerosolized), the potential exist for exposures to this compound.

Reports of building-related health complaints have become increasingly common in recent years; unfortunately the causes of these symptoms have not been clearly identified. As discussed in the criteria section of this report, many factors are being considered (e.g., volatile organic compounds, formaldehyde, microbial proliferation within buildings, inadequate amounts of outside air etc.). While it has been difficult to identify concentrations of specific contaminants that are associated with the occurrence of symptoms, it is felt by many researchers in the field that the occurrence of symptoms among building occupants can be lessened by providing a properly maintained interior environment.

VIII. RECOMMENDATIONS

The following recommendations are offered to provide and maintain acceptable indoor environmental quality in the area of concern.

1. The entire HVAC system serving the communications room should be evaluated, tested, and balanced. A properly balanced system should result in an even

distribution of supply air in the occupied space. The system should be adjusted to deliver a minimum of 20 cfm per person of outside air during periods of normal occupancy as specified in the 1989 ASHRAE standard.

2. Since trace levels of methylene chloride were found in a bulk sample of the contact cleaner, further exposure assessment should be conducted to determine whether employees are being exposed to airborne levels of this compound.

3. Annual training should be required for personnel located in the areas where the halon system has been installed, and should include proper evacuation routes of the area, and potential health effects from over-exposure to Halon 1301. Employees should also receive training concerning the proper manual operation of the system, and be specifically informed of when they should resort to using manual operation.

4. To improve employee comfort, better lighting should be provided in areas of the communications room which were found to be under 200 lux. It may also help to eliminate electrical shocks received by personnel working in dimly lit areas where their vision is compromised.

5. The box-type filters (20% efficiency) do not provide adequate filtration for preventing dust accumulations in the ventilation system. Dust accumulations could be a health problem for hypersensitive (allergic) individuals. Filters with an ASHRAE dust spot efficiency rating of 35 to 60% should be used as recommended by ASHRAE, instead of the filters which are less than 20% efficient currently being used. The most efficient filters whose pressure drop the system can handle should be used. A mechanical firm should be consulted to determine the maximum filter efficiency.

6. Environmental complaints should be addressed by facility managers promptly and effectively. Failure to respond promptly can result in such outcomes as increasing health complaints, reducing worker productivity and creating distrust among employees and management. Actions that are taken to remediate the problem should be communicated to employees immediately. These actions could prevent the dissemination of inaccurate information and prevent further escalation of the problem.

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