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SOMERSET COUNTY ASSISTANCE OFFICE BUILDING
SOMERSET, PENNSYLVANIA

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I. SUMMARY

In December 1990, the Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health (NIOSH) received a technical assistance request to evaluate the potential health/comfort problems experienced by employees at the Somerset County Assistance Office (CAO) Building in Somerset, PA. The request was submitted by the superintendent of the office. NIOSH was asked to evaluate the indoor air quality as a result of the following complaints: Irritation of the eyes and skin, afternoon fatigue, lack of fresh air, poor air circulation, temperature extremes, low humidity, and cigarette smoke.

A detailed industrial hygiene evaluation of the building was conducted in April 1991. The evaluation included physical and chemical assessments of building conditions and indoor air quality. No evidence of mold growth was found. Temperature and relative humidity measurements were generally in accordance with recommendations made by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE). Sampling of the air for formaldehyde, organic gases/vapors, carbon monoxide, and carbon dioxide revealed concentrations below exposure limit guidelines of the Occupational Safety and Health Administration (OSHA), the American Conference of Governmental Industrial Hygienists (ACGIH), and NIOSH. Whether or not these industrial standards are protective enough for the comfort and well being of office workers is controversial; however, in this instance, measured airborne concentrations of contaminants were very low and would not be expected to cause symptoms in most people. Carbon dioxide was present at levels that have been found to be typical of indoor air quality complaints. The ventilation system was only partially operative when the investigators arrived at the site. Measurements taken while the system was in full operation indicated that the supply of outdoor air provided to the building was well below ASHRAE recommended rates for office buildings.

On the basis of the data obtained, it was concluded that the complaints made by this group of workers can most likely be attributed to substandard ventilation and exposure to cigarette smoke. Recommendations were made to provide the building with more outdoor air by adjusting the ventilation system and to prohibit smoking in the building or at least in any areas not physically designed to prevent release of tobacco smoke into the office environment.

Keywords: SIC 8399 (Social Services, Not Otherwise Classified), indoor air, ventilation, office building, outdoor air supply

II. INTRODUCTION

In December 1990, the Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health (NIOSH) received a technical assistance request to evaluate the potential health/comfort problems being experienced by employees at the Somerset County Assistance Office (CAO) Building in Somerset, PA. The request, submitted by the superintendent of the office, cited employee complaints of eye and skin irritation and fatigue, especially during afternoon hours. Later conversations with employee representatives revealed that many of the complaints related to air quality. Specifically, there were concerns about lack of fresh air, poor air circulation, temperature extremes, low humidity, and contamination with cigarette smoke.

III. BACKGROUND

The Somerset CAO is a division of the Pennsylvania Department of Public Welfare. Since the completion of construction in June 1987, the Pennsylvania Department of General Services has leased the building from a private individual for the use of Somerset CAO. It is a one-story building with 13,500 square feet of area. Most of it has an open area design with 4-6 foot high partitions arranged to create individual work stations, though some enclosed rooms exist. The floors are carpeted and some of the partitions are covered with fabric. The building is used predominantly for office activities. It also includes client reception and interviewing areas, a small kitchen, storage rooms, and a smoking lounge.

IV. METHODS

On April 17, 1991, NIOSH investigators met with the building's owner, the executive director of the CAO, and employee representatives. The investigators collected information on the health/comfort complaints, reviewed heating, ventilation and air conditioning (HVAC) system specifications, and conducted a general walk-through survey of the building.

A detailed industrial hygiene evaluation of the building was conducted the next day to identify potential air pollution problems related to the complaints. The evaluation included physical and chemical assessments of building conditions and indoor air quality.

The building and HVAC system were visually inspected for indications of water leakage and mold growth. Temperature and relative humidity measurements were taken at different times in several areas of the building using a sling and a battery-operated psychrometer.

Flow characteristics of the HVAC system were also evaluated to determine the amount of outdoor air being supplied to the building. Measurements of air velocity through supply ducts connected to each of the four air-handling units were obtained from a heated-wire anemometer/thermometer. Airflow from each ceiling air supply grille was also measured as it passed through a flowhood equipped with a velometer. These readings were used to verify data gathered at the air handling units and to determine the distribution of air to individual areas of the facility. The heated-wire anemometer/thermometer was also used to acquire temperature readings of outdoor, mixed, and return air. These readings were applied to the following formula[1] to calculate the percent composition of outdoor air in the ventilation air stream:

$$\text{Outdoor Air (\%)} = \frac{(RA-MA)}{(RA-OA)} \times 100$$

where:

MA = mixed air temperature
RA = return air temperature
OA = outdoor air temperature

Indoor and outdoor air was sampled for several contaminants to assess air quality. One sampling station was placed outside, and five others were placed in the following areas inside the building:

Westside- Cubicle near enclosed office
Westside- Cubicle near smoking lounge
Eastside- Printing/mail area
Eastside- Cubicle
Client interviewing booths

Each station was equipped to measure air concentrations of formaldehyde, organic gases/vapors, carbon monoxide, and carbon dioxide.

Formaldehyde samples were collected according to NIOSH Analytical Method 3500[(2)] with dual midget impingers using a sodium bisulfite solution as a collection media. Two half-shift samples were obtained with air being pulled through the solution at a rate of 400 cubic centimeters per minute (cc/min). The samples were analyzed by visible absorption spectroscopy.

Organic gas/vapor samples were collected on activated charcoal media as specified in NIOSH Analytical Method 1501.[(3)] Three of the sampling stations contained samplers operating at 1 liter per minute (lpm) for the duration of the shift. These samples were submitted for qualitative analysis using flame ionization gas chromatography. All six of the stations were equipped with samplers operating at 100 cc/min for the purpose of quantitative analysis via gas chromatography/mass spectrometry. Components that were identified in the qualitative analyses were targeted in the quantitative analyses.

Carbon monoxide (CO) and carbon dioxide (CO_2) were sampled with long-term direct-reading indicator tubes.[(4)] They were collected over two four-hour periods. A portable infrared CO_2 gas analyzer was also placed in a central location in the building. Readings from this machine were continuously fed to a data logger so that CO_2 concentrations could be monitored throughout the day. Air samples for CO_2 were also taken with short-term direct-reading indicator tubes in various building locations.[(4)]

V. EVALUATION CRITERIA

Evaluation criteria are used as guidelines to assess the potential health effects of occupational exposures to substances and conditions found in the work environment. These criteria consist of concentrations of substances in the air which most workers can be exposed day after day for a working lifetime without experiencing adverse health effects. Because of variation in individual susceptibility, a small percentage of workers may experience health problems or discomfort at exposure levels below these existing criteria. Consequently, it is important to understand that these evaluation criteria do not define the absolute limits between a safe and dangerous level of exposure.

Several sources of evaluation criteria exist and are commonly used by NIOSH investigators to assess occupational exposures. These include:

1. The U.S. Department of Labor (OSHA) Federal Occupational Health Standards; permissible exposure limits (PEL's);[(5)]

2. The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit (Exposure) Values (TLV's);[(6)]

3. NIOSH criteria documents and recommendations; recommended exposure limits (REL's).

Employers are legally required to maintain exposure levels at or below the limits specified by OSHA. The NIOSH and ACGIH limits are recommended. These criteria have been derived from industrial experience, human and animal studies, and when possible, a combination of the three. Differences in the criteria for certain substances exist because the scientific community interprets the available information differently. Additionally, OSHA considers economic feasibility in establishing occupational exposure standards; NIOSH and ACGIH place less emphasis on economic feasibility in development of their criteria.

Exposure limits are generally specified in one or more of the following formats:

1. TWA Limit - Time-weighted average exposure concentration for a normal 8-hour (OSHA,ACGIH) or up to a 10-hour (NIOSH) workday and a 40-hour workweek that should not be exceeded.

2. STEL (Short-Term Exposure Limit) - Time-weighted exposure concentration that should not be exceeded for any 15-minute period during a workday.

3. C (Ceiling) Limit - Concentration that should not be exceeded during any part of the workday.

These exposure criteria are commonly reported as parts of contaminant per million parts of air (ppm), or milligrams of contaminant per cubic meter of air (mg/m^3). The following table contains the environmental criteria for the contaminants evaluated in this study (all values are TWA's unless otherwise specified as STEL or C values):

ENVIRONMENTAL CRITERIA (ppm)

Substance	NIOSH (REL)	ACGIH (TLV)	OSHA (PEL)
Carbon Dioxide	5,000	5,000	10,000
Carbon Monoxide	35	50 ***	35
Formaldehyde*	LFL **	1	1
1,1,1-Trichloroethane	350 C	350	350
Trichloroethylene*	LFL **	50	50
Toluene	100	100	100
C8-C12 Hydrocarbons	No Standard	No Standard	No Standard

*Considered a potential human carcinogen.
**LFL - Lowest feasible limit.
***ACGIH is currently proposing that the TLV for Carbon Monoxide be changed to a level of 25 ppm.

Some research suggests that industrial exposure criteria cited above may be inappropriate for evaluating indoor air quality (IAQ) problems in office buildings.[7] Due to the variation in age and health status, the general population is more susceptible to injury than the industrial population, and the industrial population is often under continual health supervision and the general population may not be. The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) is an organization that recommends minimum standards for air quality, particularly IAQ and minimum ventilation rates acceptable to human occupants. They define acceptable IAQ as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction." They state that for a contaminant it is customary to assume that a concentration at 1/10 the TLV would not produce complaints in a nonindustrial population in residential, office, school, or other similar environments.[7]

ASHRAE also recommends criteria for indoor air temperatures and ventilation rates for office buildings as detailed below:[7,8]

ASHRAE INDOOR AIR QUALITY RECOMMENDATIONS

Temperature and Relative Humidity (RD)		Air Changes Per Hour	Minimum Rate of Supplied Outdoor Air
Winter	Summer		
70-74°F 20-30% RH	74-78°F 40-50% RH	4 to 10	20 cfm*/person (office areas) 60 cfm/person (smoking lounges)**

*cfm - cubic feet per minute
**May include air transferred from adjoining spaces of the building

Carbon dioxide (CO_2) concentrations in indoor air are often used as an indirect measure of a building's capacity to dilute indoor-generated odors and irritants. The following table shows that employee complaints about indoor air quality arise when the concentration of CO_2 exceeds 600 ppm:[9,10]

RELATION OF CARBON DIOXIDE LEVELS TO EMPLOYEE COMPLAINTS

Carbon Dioxide (ppm)	Comments
< 600	Adequate outdoor air intake; complaints rare
600 - 800	There may be occasional complaints, particularly if the air temperature rises
800 - 1000	Complaints more prevalent
> 1000	Insufficient make-up air; complaints are general

VI. RESULTS AND DISCUSSION

Building Evaluation:

Some ceiling tiles in the building showed signs of previous water leaks. Employees informed the investigators that none were recent and that the sources of the leaks had been repaired. There were no signs of visible mold growth in the building.

Temperature and Relative Humidity:

Fourteen temperature and relative humidity measurements were taken in the building throughout the day. Temperatures ranged from a low of 69°F to a high of 74°F, and the relative humidity readings were between 28% and 45%. Temperature and relative humidity readings at any given sampling station differed from each other throughout the day by only 1°F and a few percentage points, respectively. One of the union representatives presented a record of relative humidity readings she obtained during January, February, and the first half of March. Almost all the readings were either 30% or 35%, but there were five days on which they were 20%, 25%, or 40%. These temperatures and humidities were generally in accordance with the ASHRAE recommended criteria.

Ventilation System Evaluation:

The Somerset CAO is a modern, relatively air-tight building. The windows do not open, and the HVAC system is the primary source of outdoor air to building occupants. Four rooftop-mounted HVAC units serve the building; each unit supplies air to one-quarter of the building. The units have heating and air-conditioning capabilities but do not provide humidification. Every unit has its own thermostat/control system to regulate temperatures over specific time frames. The control panels, which are located in two small mechanical rooms, are not accessible to the employees.

Air travels from the units through rigid and flexible duct work before entering the occupied spaces through adjustable ceiling supply terminals (diffusers). Air is exhausted from the office areas through ceiling grilles into an open return air plenum above the false ceiling. This air then flows to the HVAC units where it mixes with outdoor air and is sent back to the office areas. An attic area exists above the air plenum. The attic and air plenum are separated by a layer of fiberglass insulation over a layer of plastic sheeting. The attic has ventilators extending through the roof.

Visual inspection of the ventilation system revealed no signs of biological growth around any of the roof units or ceiling grilles. The inspectors also saw no standing water under the units.

The system is programmed to operate continuously from 6:00 a.m. to 5:30 p.m. on weekdays and is not operated on the weekends. On the afternoon that the inspectors arrived, two of the units were not operating. It was discovered that the timers had been programmed to activate the two units in the evening rather than the morning. It was not known how long this condition existed. Adjustments were made to the timers immediately following the discovery. The next day after all four units had been in operation for a few hours, many workers stated that the air conditions in the building had improved dramatically.

Even with all the units in operation, some workers stated that the ceiling air terminals over their desks were not supplying air. Closer examination revealed that air was entering the room through these terminals. One of the investigators suggested that a simple solution to eliminate the confusion would be to place small streamers on a few terminals to allow a quick visual check for air flow. When airflow tests using the flowhood were conducted, all ceiling diffusers were found to be fully open; however, two of the diffusers (one in the smoking room) had no air flowing through them. It was found that the duct to these diffusers was disconnected, and the building owner immediately corrected the problem. Following these modifications, the total airflow into the occupied areas of the building, as measured with the flowhood, was approximately 7000 cfm. Using the heated-wire anemometer in the supply ducts from each air-handling unit, a total air supply of 7500 cfm was determined. The discrepancy between these two figures is most likely due to air leakage around the flowhood and in the duct system. Total outdoor air being pulled into the building was determined to be approximately 500 cfm. This outdoor air represented 7% (by volume) of the total air entering the office areas through ceiling terminals. This ventilation rate is well below the ASHRAE recommended rate of 1800 cfm of outdoor air for an office building with an occupancy of 90 persons.

There is a small smoking lounge connected to the main HVAC system via a supply duct. Rather than exhausting the smoke-contaminated air into the common return air plenum and exposing all employees to the smoke, an exhaust fan pulls the air from the room into the attic, where it passes through the attic ventilators to the outdoors. Visual inspection of this system revealed that the duct above this exhaust fan did not extend fully into the attic area. Instead, it reached only halfway through the layer of insulation on the attic floor, but the hole for the duct was cut all the way through the layer and was clear. Approximately 240 cfm of air was being pulled from the smoking room. Air flowing in from the ceiling air supply terminal was approximately 120 cfm, and air was being pulled into the room through the grille in the door. The supply of outdoor/transfer air was well below the ASHRAE recommended rate of 840 cfm for a smoking lounge with approximately 14 persons.

The investigators did not feel that the smoking room was the source of cigarette smoke that generated complaints in the office areas because it was under negative pressure with respect to adjoining areas of the building. Other sources of cigarette smoke existed. Employees have been required to use the smoking room or to go outdoors if they chose to smoke, but some employees revealed that, until just a week before the evaluation, this policy did not apply to one of the supervisors. She was allowed to smoke in her office, and at times co-workers also smoked in her office. This office is enclosed, but it shares the common air plenum that carries return air from the rest of the building before it is redistributed. As a result, this practice did not result in a smoke-free working environment for any employee. The front entrance to the building provided another source of smoke. Visitors are allowed to smoke in the area between two sets of glass doors. This area has no provisions for ventilation. It was noted that air from this area would flow into the building when the doors were used. Distribution of this air throughout the building is inevitable. A follow-up telephone conversation with one of the employee representatives revealed that smoking was no longer taking place in the supervisor's office and that most visitors who smoke go outside instead of to the entryway to smoke. Complaints about smoke had subsided. It should be noted that during the winter months, the warmth and protection provided by the entryway will probably draw smokers indoors.

Airborne Contaminants:

The levels of formaldehyde measured during the survey were extremely low. It was not possible to quantify any levels over the 8-hour sampling period. The limit of quantitation (LOQ) for this method was 0.018 ppm. Formaldehyde was not detected on the outside sample.

The major peaks noted on the chromatogram from the qualitative gas/vapor analysis were 1,1,1-trichloroethane, trichloroethylene, toluene, and a number of branched and straight chained hydrocarbons (C8-C12). This series of hydrocarbons is typical of what has previously been found in other office building charcoal tube samples. Based on these qualitative findings, quantitative analysis was performed on these substances. Only trace amounts of these compounds (all below the evaluation criteria) were found during this analysis.

The 8-hour TWA's for CO ranged from 0.63 ppm to 0.82 ppm inside the building. All of these values were less than 3% of the NIOSH recommended limit of 35 ppm. CO was not detected in the outdoor air sample.

Carbon Dioxide is present in the normal atmosphere in concentrations varying from 250 ppm to 350 ppm.[11] The long-term direct reading indicator tubes revealed that during the 8-hour sampling period, the TWA's for CO_2 in the various locations inside the building ranged from 611 ppm to 888 ppm. The lowest of these measurements was found in the client interviewing area, but the remainder of the areas had TWA's which exceeded 820 ppm carbon monoxide. These values were typical of those found in other buildings which produced complaints about indoor air quality. The infrared gas analyzer, located in the center of the westside office area, recorded average CO_2 concentrations over 10-minute periods throughout the day. A graph of these measurements is included as Figure 1. A maximum level of 1033 ppm and a minimum level of 502 ppm were reported over the course of the day. It can be seen that the level dramatically decreased throughout the day. Because the main source of CO_2 in an occupied office building is human respiration, CO_2 levels are expected to increase during the day (or stay relatively constant if ventilation is adequate). The investigators suspect that, contrary to their requests, the outdoor air dampers on the rooftop HVAC units were adjusted to increase the fresh air intake just after noon that day. If this suspicion is correct, the graph clearly illustrates the improvement in indoor air quality that can be made by increasing the supply of outdoor air. Even though afternoon CO_2 levels decreased, they were still in a range at which occasional complaints from workers might be expected, particularly if the temperature rises.[9,10]

Some of the workers mentioned that on occasion, especially if maintenance workers are in the attic above them, particles that they referred to as "sparkles" would fall from a ceiling grille. The investigators examined these particles, which had a metallic appearance, and assumed that they were remnants of the initial installation of the duct work. Although not measured, the amount of material being introduced into the work area did not appear to be significant enough to warrant further investigation.

Some other workers were worried about a collection of dust on their computer monitors. The thin layer of dust appeared to be only common dust that had accumulated over a period of time. The small amount of dust on the monitors and the period of time since the last cleaning indicated to the investigators that there was not a significant dust exposure.

VII. CONCLUSIONS

Air measurements for formaldehyde, CO, and organic gases/vapors at the Somerset CAO revealed no levels that exceeded industrial exposure criteria. Most of the organic gases/vapors were not present at detectable levels, and quantifiable levels of formaldehyde were not found.

Carbon dioxide is not expected to exceed occupational health standards in an office setting as, indeed, it did not at the CAO. Carbon dioxide measurements are used as an indication of the dilution capabilities of a building's ventilation system. Measurements for CO_2 at the CAO were indicative of a ventilation system that did not properly dilute the building's air. Air flow tests conducted on the ventilation system supported these findings. The system did not introduce an adequate amount of outdoor air into the building.

Although no quantitative measurements were made for the presence of cigarette smoke in the office areas, the search for sources of smoke and routes of entry revealed how easily smoke could contaminate these areas.

From the information gathered, it appears that inadequate ventilation and contamination of the air with cigarette smoke were the major contributing factors to employee complaints at the Somerset CAO.

VIII. RECOMMENDATIONS

Following are steps that should be taken to improve air quality in the building:

1. Rebalance (adjust) the HVAC system to ensure that it is operating according to ASHRAE recommended standards for outdoor air supply, indoor temperature, and relative humidity. To ensure proper rebalancing, the services of a skilled, reputable HVAC engineering firm with experience in rebalancing HVAC systems should be sought.

2. Establish a mechanism (protocol) for routine maintenance and surveillance of the ventilation system to ensure that ASHRAE recommendations are met. This protocol should restrict access to the system's control panels to only those people trained to operate them.

3. Do not allow smoking in any area of the building which is not a designated smoking area. Because tobacco smoke is harmful not only to the smoker but also to nonsmokers who are exposed to the side stream smoke,[12] any room designated as a smoking area should have

a separate exhaust system to prevent recirculation of the smoke throughout the building. The exhaust system should be sized to keep the room under negative pressure with respect to adjacent areas of the building while providing a ventilation rate of at least 60 cfm of outdoor/transfer air per person based on the maximum number of people likely to use the room. A more healthy and less expensive solution is to offer smoking cessation programs to the employees and to totally prohibit smoking in the building.

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X. AUTHORSHIP AND ACKNOWLEDGEMENTS

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