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Blue Cross and Blue Shield of Michigan
Grand Rapids, Michigan

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Gregory A. Burr, C.I.H. and Vincent Mortimer, P.E., of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Desktop publishing by Juanita Nelson.

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Health Hazard Evaluation Report 97–0031–2656
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SUMMARY

On May 6 and 7, 1997, investigators from the National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation (HHE) at Blue Cross and Blue Shield, Grand Rapids, Michigan. The HHE request, submitted by the United Auto Workers, concerned employees who were experiencing nasal congestion, headaches, flu–like symptoms, and airway obstruction which they believed were associated with inadequacies in the existing ventilation system.

During this survey, carbon dioxide (CO_2), temperature, and relative humidity (RH) were measured. In addition, air samples for volatile organic compounds (VOCs) were collected at locations within the office and outside the building. A symptoms survey was made available to employees. Finally, the ventilation system was evaluated using tracer–gas (sulfur hexafluoride, SF_6) dispersion/decay methods.

The CO_2 concentrations slightly increased during the work day but never exceeded 800 parts per million (ppm) anywhere in the office building. However, several sections of the building were very sparsely populated (less than seven employees per 1000 ft^2), a situation which reduced the usefulness of CO_2 concentrations in evaluating the adequacy of the ventilation system. Temperatures ranged from 72 → 74°F, near the summer comfort guidelines recommended by the American Society of Heating, Refrigerating, and Air–Conditioning Engineers (ASHRAE) of 73 → 79°F. The RH levels ranged from 33 → 44%, also within the ASHRAE guidelines. The VOC samples revealed the presence of very low levels of ethanol, acetone, isopropanol, toluene, limonene, butyl Cellosolve™, and Freon®, as well as aliphatic hydrocarbons. These low concentrations are not unexpected in a non–industrial workplace. The symptoms most frequently reported by employees responding to the questionnaire were sinus congestion; dry, itching or irritated eyes; strained eyes; and fatigue. The prevalences of "work–related" symptoms (those symptoms which improved when away from work) were generally lower than those seen in NIOSH studies of other problem buildings. The results of the ventilation system evaluation using tracer gas demonstrated that SF_6 was dispersed relatively quickly to some areas, but much more slowly and in lesser amounts to others, indicating an adequate but uneven supply of outside air at the time of the survey. The SF_6 was removed from the building relatively slowly, highlighting the importance of limiting the sources of noxious odors in the building, or using local exhaust ventilation to control potentially troublesome odors.

NIOSH investigators have determined that hazardous conditions did not exist at the time of the survey and an adequate amount of outside air was being supplied to the entire building; however, the air distribution was uneven and may have resulted in sections of the building receiving inadequate amounts of outside air. Recommendations have been made to limit noxious odors inside the building, install (as needed) local exhaust ventilation at work areas to control odors, and to extend the outside air supply ducts to work areas of employees who continue to experience adverse health effects.

Keywords: SIC 6324 (Hospital and Medical Service Plans), carbon dioxide, temperature, relative humidity, ventilation, total volatile organic compounds, IEQ, IAQ, tracer gas, sulfur hexafluoride, VOC

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INTRODUCTION

On November 8, 1996, the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request from the Health and Safety Department of the United Auto Workers (UAW), which represented employees at Blue Cross and Blue Shield, Grand Rapids, Michigan. Workers were concerned with the indoor environmental quality (IEQ) in their building and had been experiencing a variety of health problems (including nasal congestion, headaches, and flu–like symptoms) which they believed were associated with poor ventilation and air circulation problems.

BACKGROUND

Blue Cross and Blue Shield of Michigan is the sole tenant of a three story building constructed in 1989 and located in an industrial park in Grand Rapids, Michigan. Total office space is approximately 42,000 $ft.^2$ and the building has been occupied since about 1991. Work activities included training, sales, field service, customer service, and administrative functions.

About 180 people worked in this building just prior to this NIOSH survey. However, due to a reorganization which occurred just one week before this evaluation, approximately 100 employees were transferred to a nearby office building in the Grand Rapids area. As a result, several areas of the building were either vacant or very sparsely populated.

The NIOSH evaluation conducted on May 6 and 7, 1997, included measurements of carbon dioxide (CO_2), temperature, and relative humidity (RH) throughout the work day. In addition, general area air samples were collected using thermal desorption (TD) tubes and charcoal sorbent tubes to identify and (if possible) quantitate any volatile organic compounds (VOCs) which may be present in the office space. A symptoms survey was made available to the approximately 80 employees at work during this evaluation. The ventilation was evaluated by releasing tracer gas (sulfur hexafluoride, SF_6) into the inlet to the fan supplying outside air to the building and monitoring the concentration of SF_6 at different locations in the building for several hours.

Previous IEQ Evaluations

Previous environmental evaluations by consultants hired by Blue Cross and Blue Shield had failed to identify specific IEQ problems which could be associated with the health problems experienced by the workers. In some of these surveys, however, CO_2 concentrations did exceed 1,000 parts per million (ppm) on occasion, suggesting that some office areas may have been receiving an inadequate amount of outside air. The ventilation system, based on the information provided to NIOSH investigators by the company and union, had not been thoroughly evaluated.

Ventilation System Description

Ventilation is provided by a constant–volume air distribution heat pump system. Outside air is supplied to each of the top three floors by a central unit on the roof. Although originally configured to mix the outside air with return air from the ceiling space of each of the top three floors, this air handler now supplies 100% outside air to the ceiling plenum near the elevator shaft. From there, this outside air is spread throughout the occupied space by heat pump units above the suspended ceiling. Air from the ceiling space is drawn into the heat pump units, passed over heating or cooling coils, and blown into the occupied space by the heat pump fans.

Outside air is supplied to the basement heat pump by an intake duct, with an opening through the outside wall at the west corner of the basement, and by an intake duct, with an opening through the outside wall at the east corner of the basement, for the boiler air supply. There is no ducted air connection between the basement and the top three floors.

There is one roof–top fan which exhausts air from the rest rooms and janitorial rooms located on the top three floors. Three other roof–top fans exhaust air from the executive toilet and the area in and adjacent to the kitchen located on the third floor.

EVALUATION CRITERIA

Indoor Environmental Quality

The symptoms 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.[1,2] Among these factors are imprecisely defined characteristics of 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.[3,4,5,6] Reports are not conclusive as to whether increases of outdoor air above currently recommended amounts ($\geq$15 cubic feet per minute of outside air per person [CFM OA/person]) are beneficial.[6] However, rates lower than these amounts appear to increase the rates of complaints and symptoms in some studies.[7] 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.[8]

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.[9] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[10,11] 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.

Problems that 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 RH 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.[12,13,14] 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.[15,16] The ACGIH has also developed a manual of guidelines for approaching investigations of building–related symptoms that might be caused by airborne living organisms or their effluents.[17]

Carbon Dioxide

Carbon dioxide is a normal constituent of exhaled breath and, if monitored, can be used as a screening technique to evaluate whether adequate quantities of outside air are being introduced into an occupied space. In ASHRAE's most recently published ventilation standard, 62-1989, Ventilation for Acceptable Indoor Air Quality, a supply rate of CFM OA/person for office spaces is recommended.[16]

Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 300-350 ppm). Carbon dioxide concentration is used as an indicator of the adequacy of outside air supplied to occupied areas.[a] When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected and other indoor contaminants may also be increased. NIOSH has stated that a level of 800 ppm should trigger inspection of ventilation system operation.[18]

Temperature & Relative Humidity

Temperature and RH measurements are often collected as part of an indoor environmental quality investigation because these parameters affect the perception of comfort in an 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 temperature.[15] Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. The American National Standards Institute (ANSI)/ASHRAE Standard 55-1981 specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally acceptable.[15] Assuming slow air movement and 50% RH, the operative temperatures recommended by ASHRAE range from 68–74°F in the winter, and from 73–79°F in the summer. In separate documents, ASHRAE also recommends that RH be maintained between 30 and 60% RH.[15,16]

Volatile Organic Compounds

Volatile organic compounds (VOCs) describe a large class of chemicals which are organic (i.e., containing carbon) and have a sufficiently high vapor pressure to allow some of the compound to exist in the gaseous state at room temperature. These compounds are emitted in varying concentrations from numerous indoor sources including, but not limited to, carpeting, fabrics, adhesives, solvents, paints, cleaners, waxes, cigarettes, and combustion sources. 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 irritant potency of these VOC mixtures can vary.

Neither NIOSH nor OSHA currently have specific exposure criteria for VOC mixtures in the nonindustrial environment. Considering the difficulty in interpreting VOC measurements, caution should be used in attempting to associate health effects (beyond nonspecific sensory irritation) with specific VOC levels.

ENVIRONMENTAL METHODS

Carbon Dioxide

Real–time CO_2 measurements were obtained using a Gastech Model RI-411A, Portable CO_2 Indicator. This portable, battery–operated instrument monitors CO_2 via non-dispersive infrared absorption; it has 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).

[a] The usefulness of CO_2 as an indicator of ventilation effectiveness is reduced in areas with low occupant density (less than seven employees per 1,000 ft^2.) This was the situation in several Blue Cross and Blue Shield departments on May 6 and 7, 1997.

Temperature & Relative Humidity

Real-time temperature and RH measurements were conducted using a TSI battery–operated Model 8360 Velocicalc® Plus Air Velocity meter. The TSI meter is capable of directly measuring dry bulb temperatures from –4 to 140°F and RH from 0 to 95%.

Volatile Organic Compounds

Since concentrations of VOCs in non–industrial settings are typically low, Carbotrap® 300 stainless steel thermal desorption (TD) tubes, configured for the Tekmar® 5010 thermal desorber system, were used to collect air samples at various locations within the Blue Cross and Blue Shield Building (the Field Services area on the second floor and the Administrative Office and Account Services areas on the third floor). One sample was also collected outside the building to evaluate background concentrations. Each TD tube contained three beds of sorbent materials: (1) a front layer of Carbotrap C; (2) a middle layer of Carbotrap; and (3) a back section of Carbosieve S–III. The samples were analyzed using the Tekmar thermal desorber interfaced directly to a gas chromatograph and a mass selective detector. Each sample tube was desorbed at 400NC.

While the extremely sensitive TD method can identify VOCs present in the parts per billion range, it does not indicate the *quantity* of these chemicals. To quantitate the VOCs, if the TD analysis suggested that sufficient amounts were present, air samples were collected at four office locations using activated charcoal as the sorbent material.

Questionnaires

An indoor air quality and work environment symptoms survey was made available to the approximately 80 employees at work during this evaluation. A copy of this questionnaire is attached as an Appendix.

Ventilation Assessment

The ventilation was evaluated by releasing a small quantity of a tracer gas (sulfur hexafluoride, SF_6) into the inlet to the roof–top air handler (fan) supplying outside air to the building. Sulfur hexafluoride is useful as a tracer compound since it is a colorless, odorless gas that is chemically and toxicologically inert, and there would be no other sources of SF_6 in the building.[19,20] Target concentrations of SF_6 are typically in the range of 1 to 10 ppm, well below its TWA exposure limit of 1,000 ppm.[12,13,14] The concentration of this tracer gas in the air at 13 locations covering all four floors of the building was then monitored for several hours using ten MIRAN–203 and three B&K–1302 infrared analyzers. The electrical output signal from each MIRAN–203 was processed and stored by a Metrosonics dl–2300 datalogger; the B&K instrument included a built–in datalogger. Later, this digitized, stored and time–stamped data was transferred to a computer for analysis.

The analysis involved computing an average concentration at the sampled point for each minute that the air concentration was monitored. A graph of these data shows the build–up and decay of tracer gas concentrations at each location. Since the SF_6 was an unique temporary component of the outside air supplied to the building by the ventilation system, the build–up of tracer gas concentration is indicative of how quickly outside air gets gets to the sampled locations. The subsequent decay of the SF_6 concentration is a quantifiable representation of the rate at which outside air is supplied to the building.

Air velocity at selected points was measured with a TSI VelociCalc hot–wire anemometer, and air flow rate was measured at the supply and exhaust grilles in the ceiling with a TSI AccuBalance flow hood.

RESULTS

Carbon Dioxide

As shown in Figure 1, the CO_2 concentrations, which slightly increased during the work day, never exceeded 800 ppm throughout the office building. However, several sections of the building were very sparsely populated (less than seven employees per 1000 ft^2), reducing the usefulness of CO_2 concentrations in evaluating the adequacy of the ventilation system.

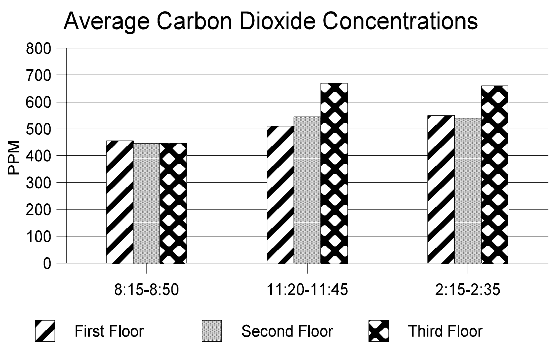

Figure 1

Temperature & Relative Humidity

Temperatures were consistent on all floors, ranging from 72 → 74°F. This range of temperatures is near the summer comfort guidelines recommended by the American Society of Heating, Refrigerating, and Air–Conditioning Engineers (ASHRAE) of 73 → 79°F. The RH levels ranged from 33 → 44%, within the ASHRAE guidelines.

Volatile Organic Compounds

The TD air samples revealed the presence of very low levels of ethanol, acetone, isopropanol, toluene, limonene, butyl Cellosolve™, and Freon®, as well as a wide variety of aliphatic hydrocarbons. The air sample collected outside the building contained ethyl acetate, ethanol, and Freon®. None of the substances identified on the TD tubes appeared to be present in amounts which would be quantifiable from the charcoal tube samples which had been collected side–by–side with the qualitative TD samples. For this reason the charcoal tubes were not analyzed for specific volatile organic compounds.

Questionnaires

Thirty–seven (46%)of approximately 80 Blue Cross and Blue Shield employees returned completed questionnaires. The ages of the entire group of 37 employees ranged from 17 to 59, and more than half had worked in this building for more than five years. Most (69%) spent four or more hours of their workday using a computer. Almost one–half (46%) to the respondents had never smoked cigarettes, while 35% were current smokers.

The questionnaire results are summarized in Tables 1 and 2. The first data column of Table 1 shows the percentage of the 37 employees who frequently reported the occurrence of symptoms within the past month. The symptoms most frequently reported were sinus congestion; dry, itching or irritated eyes; strained eyes; and fatigue. The second column of Table 1 shows the percentage of employees who reported symptoms that got better when they were away from work. This criterion has, in some industrial hygiene studies, been used to define a work–related symptom, but it is possible that a symptom which does not improve away from the workplace could also be due to conditions at work. Table 2 shows results of frequently experienced environmental conditions at employee workstations within the past month.

Ventilation Assessment

Following a release of SF_6 into the roof–top air handler fan intake supplying outside air to the building, the tracer gas was detected almost instantaneously at the sampling location on the 3rd floor (on the office side of the partition in the south corner of the building across from the elevator lobby). Within the next minute, SF_6 was detected at each of the sampling locations on the 1st and 2nd floors on the west side of the building. At the other two sampling locations on each of the 1st, 2nd, and 3rd floors, SF_6 was detected within three to 15 minutes after a release. At the sampling location in the basement elevator lobby, SF_6 was detected between 10 and 30 minutes after the release, and at the sampling location in the mail room in the basement, SF_6 was detected within one to two minutes. These appearance times are summarized in Table 3.

Following a release of SF_6 into the roof–top air handler and the subsequent appearance at each of the sampling locations, additional time passed until the SF_6 concentration reached a peak. Similar to the pattern of the time delay until SF_6 appeared at the sampling locations after a release, the SF_6 concentration reached a peak value within 11 minutes at the sampling locations in the south corner of the 3rd floor, in the west portions of the 1st and 2nd floors, and in the mail room in the basement. At the other sampling locations, the peak SF_6 concentration occurred between ½ and 2½ hours after the release. The times (in minutes) at which the peak concentration was reached following a release of SF_6 are summarized in Table 4.

The peak values of the SF_6 concentrations at the sampling locations varied considerably. Generally, the peak values were highest at the locations where SF_6 appeared and subsequently peaked most quickly. The values of the peak SF_6 concentrations (in ppm) are presented in Table 5.

After the SF_6 had been completely dispersed and was being replaced throughout the building by outside air, the air change rate of outside air could be determined relative to the volume of air space for each floor. This "decay" of concentration has a particular mathematical form called a logarithm. When the concentration values are transformed to logarithms, a linear relationship with time results. This linear relationship forms a straight line on a graph of the logarithm of concentration versus time, and the slope of this line is directly proportional to the air change rate. This air change rate (or air exchange rate) is typically presented in units of air changes per hour (ACH), although all the air in a space does not actually "change" in any calculable period of time. These values, shown in Table 6, ranged from less than 0.1 ACH for the basement elevator lobby to more than 2 ACH for the west corner of the 1st floor.

A value of 1 ACH would mean that a quantity of outside air equal to the volume of the space was being supplied to the space in a 1–hour period of time. If the air in the space was "perfectly mixed," and equal quantities of outside air reached all parts of the space in the same period of time, the calculated air change rate would be valid for the entire space. Typically, mixing is not only "imperfect" but also variable, due to the random movement of people and changing sources of heat and air movement. Therefore, it is expected that different value of air change rates will be measured depending on the location in a building or room and the time period of the measurement. Even with a uniform air change rate, more time than the time calculated from the number of ACHs will be required to replace most of the air in the space with "fresh" outside air. For example, at a rate of 1 air change per hour, 3 hours might be required to replace 95% of the air.

Although the number of ACHs may not be, by itself, a meaningful indicator of ventilation effectiveness, the value is a useful quantity in the calculation of other numbers which may be used to evaluate ventilation effectiveness. In this particular case, values of air changes per hour are the first intermediate values in a physically understandable form to be gleaned from the SF_6 decay data after the peaks of the measured concentrations have occurred. From these values, knowing the volume of the air space on each floor, a value of the flow rate (cubic feet of air per minute, CFM) of outside air supplied by the ventilation can be calculated. These values can then be divided by the number of employees assigned to each floor to give a value of CFM per person, which can be compared to the recommendations in ASHRAE's standard 62–89.[16] Using the average air change rate for both tests for each floor, an estimated floor space of 14,000 $ft.^2$ and an approximate ceiling height (including the space above the suspended ceiling) of 12 ft, and the number of persons thought to have been working in the building at the time of the initial symptoms, the estimated rate at which outside air is supplied per person has been calculated and summarized in Table 7. Table 8 summarizes estimated values for the CFM/person for the areas with the *lowest* estimated air change rate on each of the main three floors.

Other Results

Two bulk samples were obtained from a ceiling panel situated near a humidifer located in the ceiling plenum space on the second floor. These samples were collected since a dark black discoloration (which NIOSH investigators suspected was mold growth) was visible on the back of several ceiling panels which were removed during the tracer gas ventilation testing. Upon microscopic examination and culturing, these samples were found to have fungal growth, specifically *Alternaria*, *Phoma*, and. All three are common indoor fungi.[21]

DISCUSSION AND CONCLUSIONS

In the evaluation of the healthfulness/hazardousness of the workplace, one approach is to question "if" workers are (or are likely to have been) adversely affected in this workplace. Another approach is to search for significant deficiencies in indoor environmental quality and ventilation configuration and flow rates, which could be associated with worker illness.

In this building, during this survey, no evidence of unhealthful conditions was found. No sampled air contaminant concentrations exceeded current health and safety limits. The temperature and relative humidity were within the recommended ranges. Carbon dioxide levels were less than 1000 ppm, indicating not only that there was there no health hazard from excessive levels of CO_2, but also that the ventilation was adequate for the number of occupants. Carbon monoxide levels, measured with one of the instruments used to monitor tracer gas concentrations, were always substantially less than one ppm, indicating no problems with automobile exhaust or gas–fired burner flu gases being drawn into and/or retained in the building. As shown in Table 9, the prevalences of "work–related" symptoms (those symptoms which improved when away from work) were generally lower than those seen in NIOSH IEQ studies of other problem buildings.[b] Using the average rate at which the tracer gas concentration decreased to estimate the rate at which outside air was supplied to the building relative to the number of workers, it appears that the ASHRAE standard of 20 CFM/Person was satisfied. Finally, some darkening visible on the upper surface of ceiling panels near an outlet of a humidification unit in the space above the suspended ceiling suggested possible mold or mildew growth. However, an analysis of a ceiling panel did not reveal any fungi which could ordinarily cause illness.

There is no way to "know" if workers were exposed to unhealthful conditions in the past. One way to evaluate indoor environmental quality, however, is to assess the ventilation configuration and flow rates at the time of the survey and estimate how the ventilation may have been different in the past, and the effects that may have had on IEQ.

In this building, in the past, there may have been an inadequate amount of outside air supplied to the occupied spaces. The ventilation system was designed originally to recirculate some of the air returned from the occupied space, mixed with "fresh" outside air. If the percentage of outside air supplied to the building was 50%, the 20 CFM/person criterion would not be met on the three main floors. Since most building ventilation systems operate with less (in some cases, much less) than 50% outside air, it seems likely that there was not enough outside air supplied to all areas so that ASHRAE standards would have been met always and everywhere at the time of the first complaints. Fortunately, the building ventilation system was changed to supply 100% outside air, and the also occupancy has been reduced. Both of these changes

[b] It should be noted that factors other than symptom prevalence may influence whether a building is a "problem building."

have increased the amount of outside air available for each worker.

Another consideration is that, even with ventilation which is more than adequate to supply sufficient outside air, any contaminant that does get into the building may take quite a while to be completely removed. For example, if 100 ppm of a contaminant became dispersed in the building, at an air exchange rate of 1 ACH, over 40 minutes would be required to reduce the concentration in half, and about 4½ hours to reduce the concentration to 1 ppm. In some areas of the building, local air exchange rates were less than 0.5 ACH, which would more than double the times given for 1 ACH. *(Note: this example is for instructional purposes only; there is no evidence or reason to suspect any air contaminants were present in the Blue Cross and Blue Shield building at the level near 100 ppm.)*

A relatively large difference existed in all measures of ventilation performance (SF_6 appearance time, time for the SF_6 concentration to peak, and the peak value of SF_6) for the different areas of each floor. Although tracer gas appeared relatively quickly on all floors, it took substantially longer to reach some areas than to reach others, and the SF_6 concentration peaks occurred much (up to two hours) later. The peak concentration values were also smaller in these less–quickly–reached areas, and the air change rates were lower, indicating that less outside air overall reached these areas. Some variation is expected, but the differences observed during this survey were relatively large. Table 8 summarizes estimated CFM/person values for the areas with the lowest estimated air change rate on each of the main three floors.

In conclusion, it seems that enough outside air is being supplied to this building, even at the previous (higher) levels of occupancy. However, even at these air exchange rates, contaminants would still be removed slowly from the building, requiring one hour or more to reduce a contaminant concentration to half of its original value. No significant concentrations or sources of contaminants were found during the survey; but with a 100% outside air system, the indoor environment is greatly affected by the outdoor environment, so the occasional appearance of noxious odors in the building may be expected from outside sources. From the uneven dispersion of tracer gas, it appears that there is, or was, an air distribution problem. If workers continue to complain about the quality of the indoor work environment with the newly reduced level of occupancy, extending the outside air supply ducts, with supply registers placed along the length of duct, to the far corners of each floor would help to better distribute the fresh air being supplied to the building.

RECOMMENDATIONS

If workers continue to experience adverse health effects with the newly reduced level of occupancy, extend the outside air supply ducts, with supply registers along the length, to the far corners of each floor.

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Table 1 – Symptoms Experienced by Employees While at Work†
Blue Cross and Blue Shield, Grand Rapids, Michigan (HETA 97–0031)

Symptoms of 37 Workers	Frequently Experienced in the Last Month While at Work‡	Have Frequent Symptoms That Improve When Away From Work
Dry, itching, or irritated eyes	35%	24%
Wheezing	5%	5%
Headache	19%	11%
Sore Throat	19%	3%
Unusual tiredness, fatigue	22%	14%
Chest tightness	8%	8%
Sinus congestion	35%	24%
Cough	19%	8%
Strained eyes	27%	19%
Difficulty concentrating	16%	8%
Dry throat	19%	0%
Dizziness	14%	5%
Shortness of breath	11%	8%

† Symptoms of employees who completed and returned questionnaires.
‡ "Frequently experienced" symptoms were defined as those symptoms experienced at least once per week.

Table 2 – Description of Workplace Conditions by Employees†
Blue Cross and Blue Shield, Grand Rapids, Michigan (HETA 97–0031)

Conditions	Frequently Experienced in the Last Month While at Work‡
Too much air movement	8%
Too little air movement	24%
Temperature too hot	30%
Temperature too cold	14%
Air too humid	5%
Air too dry	24%
Tobacco smoke odors	11%
Chemical odors	22%
Other unpleasant odors (e.g. exhaust gases, sewer odors)	11%

† Description of conditions from employees who completed and returned questionnaires.
‡ "Frequently experienced" defined as those workplace conditions experienced at least once per week.

Table 3 – Approximate Delay in Minutes until the Tracer Gas Sulfur Hexafluoride Appeared at the Sampling Locations Following a Release
Blue Cross and Blue Shield, Grand Rapids, Michigan (HETA 97–0031)

Floor	Area	1st Test	2nd Test	Average of Both Tests
3rd	North	3	3	3
	South	1	1	1
	East	9	7	8
2nd	Southwest	N/A	3	3
	Southeast	4	10	7
	East	10	11	10
	West	1	3	2
1st	Southeast	2	15	9
	East	9	13	11
	West	1	2	2
Basement	Elevator Lobby	29	9	19
	Mail Room	1	1	1

Table 4 – Approximate Time in Minutes until the Concentration of the Tracer Gas Sulfur Hexafluoride Reached a Peak Following a Release
Blue Cross and Blue Shield, Grand Rapids, Michigan (HETA 97–0031)

Floor	Area	1st Test	2nd Test	Average of Both Tests
3rd	North	46	37	41
	South	7	3	5
	East	86	59	72
2nd	Southwest	N/A	11	11
	Southeast	92	68	80
	East	66	67	67
	West	11	10	11
1st	Southeast	92	83	88
	East	64	57	61
	West	8	7	7
Basement	Elevator Lobby	149	80	114
	Mail Room	4	2	3

Table 5 – Approximate Peak Concentrations Following a Release of Tracer Gas
Blue Cross and Blue Shield, Grand Rapids, Michigan (HETA 97–0031)

Floor	Area	1st Test	2nd Test	Average of Both Tests
3rd	North	0.6	0.4	.05
	South	1.3	0.9	1.1
	East	0.5	0.3	0.4
2nd	Southwest	N/A	0.9	0.9
	Southeast	0.7	0.5	0.6
	East	0.9	0.6	0.7
	West	3.4	3.9	3.7
1st	Southeast	0.8	0.6	0.7
	East	1.0	0.8	0.9
	West	1.8	2.0	1.9
Basement	Elevator Lobby	0.2	0.6	0.4
	Mail Room	14.1	11.5	12.8

Table 6 – Estimated Air Change Rate Estimated from Two Releases of Tracer Gas
Blue Cross and Blue Shield, Grand Rapids, Michigan (HETA 97–0031)

Floor	Area	1st Test	2nd Test	Average of Both Tests
3rd	North	0.24	0.56	0.40
	South	0.37	0.89	0.63
	East	0.23	0.36	0.30
	Average of 3 Locations	0.28	0.60	0.44
2nd	Southwest	0.58	0.71	0.65
	Southeast	0.43	0.43	0.43
	East	0.36	0.46	0.41
	West	0.86	1.23	1.04
	Average of 4 Locations	0.56	0.71	0.64
1st	Southeast	0.53	0.57	0.55
	East	0.66	1.10	0.88
	West	0.99	2.14	1.56
	Average of 3 Locations	0.73	1.27	1.0
Basement	Elevator Lobby	0.07	0.37	0.22
	Mail Room	0.66	0.90	0.78
	Average of 2 Locations	0.36	0.64	0.50

**Table 7 – Ventilation Rate (Cubic Feet per Minute per Person) Calculated from Estimated Air Change Rate and Occupancy
Blue Cross and Blue Shield, Grand Rapids, Michigan (HETA 97–0031)**

Floor	Occupants	ACH	CFM	CFM/Person
3rd	50	0.44	1230	25
2nd	50	0.64	1760	35
1st	85	1.0	2800	33
Basement	2	0.50	233	117

ACH = Air Changes per Hour
CFM = Cubic Feet per Minute

**Table 8 – Ventilation Rate (Cubic Feet per Minute per Person) Calculated from Minimum Air Change Rate in Selected Areas
Blue Cross and Blue Shield, Grand Rapids, Michigan (HETA 97–0031)**

Floor	Area	ACH	CFM/Person
3rd	East	0.23	13
2nd	East	0.36	20
1st	Southeast	0.53	17

ACH = Air Changes per Hour
CFM = Cubic Feet per Minute

Table 9 – Comparison of the Prevalence of Symptoms Occurring Frequently and Which Improve When Away From Work Blue Cross and Blue Shield, Grand Rapids, Michigan (HETA 97–0031)

Symptom	Survey Locations				
	Office Building, Detroit, MI[a] (n=184)	Office Building, Harrisburg, PA[b] (n=416)	Office Building, Cleveland, OH[c] (n=127)	NIOSH IEQ Study of 80 Office Buildings[d] (n=2435)	Blue Cross & Blue Shield Building (n= 37)
Dry, itching or irritated eyes	27%	36%	30%	30%	**24%**
Stuffy or runny nose, or sinus congestion	24%	31%	26%	21%	**24%**
Tired or strained eyes	30%	40%	43%	32%	**19%**
Unusual tiredness, fatigue, or drowsiness	30%	33%	43%	25%	**14%**
Headache	23%	28%	25%	25%	**11%**
Cough	12%	5%	11%	9%	**8%**
Chest Tightness	6%	3%	5%	6%	**8%**
Difficulty Concentrating	7%	8%	11%	9%	**8%**
Shortness of Breath	8%	4%	7%	5%	**8%**
Wheezing	4%	3%	6%	4%	**5%**
Sore or dry throat	28%	21%	28%	16%	**3%**

Abbreviations and Comments:

1. IEQ = Indoor Environmental Quality n = Number of people completing the questionnaire
2. The entire NIOSH IEQ study included 160 sites comprising office buildings, schools, and other non–industrial work settings.

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Appendix

Indoor Air Quality and Work Environmental Symptoms Survey
Blue Cross and Blue Shield
Grand Rapids, Michigan
May 1997
HETA 97–0031

U.S. Department of Health and Human Services
U.S. Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

February 1997

Form Approved
OMB No. 0920-0260
Expires August 31, 1997

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
U.S. PUBLIC HEALTH SERVICE
CENTERS FOR DISEASE CONTROL AND PREVENTION
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

INDOOR AIR QUALITY AND WORK ENVIRONMENT SYMPTOMS SURVEY

Blue Cross and Blue Shield of Michigan
May 1997
HETA 97-0031

The National Institute for Occupational Safety and Health (NIOSH) is part of the United States Public Health Service and the division of the Centers for Disease Control (CDC) that is concerned with workplace health and safety. We are here at the request of the employees to evaluate the environment of your workplace and any possible health concerns. Measurements of a variety of environmental conditions are being taken in your work area throughout the day.

To help determine how these measurements relate to your comfort and health, please complete the attached questionnaire. Your participation in this part of the evaluation of this building is voluntary, but very important. Your completed questionnaire will be collected and analyzed by NIOSH investigators and your responses WILL NOT BE SEEN BY MANAGEMENT OR UNION REPRESENTATIVES.

Although optional, we would prefer you place your name on the questionnaire in the event further questions or follow-up may be necessary.

After completing the questionnaire, please return it to a NIOSH study investigator (no later than 4:30 pm on May 6, 1997).

YOUR PARTICIPATION IN THIS SURVEY IS APPRECIATED.
THANK YOU FOR BEING AN IMPORTANT PART OF THIS EVALUATION

YOUR FULL NAME (Optional-Please Print):______________________________

This form is provided to assist in completing a health hazard evaluation conducted by the U.S. Department of Health and Human Services. Public reporting burden for this collection of information is estimated to average 15 minutes per response. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to PHS Reports Clearance Officer; ATTN.: PRA (0920-0260); Hubert H. Humphrey Bldg., Rm 737-F; 200 Independence Ave., SW; Washington, DC 20201. (See Statement of Authority below.)

STATEMENT OF AUTHORITY:
Sections 20(a)(3-6) of the Occupational Safety and Health Act (29 USC 669(a)(6-9), and Section 501(a)(11) of the Federal Mine Safety and Health Act (30 USC 951(a)(11). The identity of the participant will be protected under provisions of the Privacy Act (5 USC). The voluntary cooperation of the participant is required.

NIOSH INDOOR ENVIRONMENTAL QUALITY SURVEY
(HETA 97-0031)

I.D. Number _ _ _ _ (1-4)
Location Code _ _ _ _ (5-8)
(leave blank)

Today's Date: ____/____/____ (9-14)

This survey is being conducted to determine the environmental quality of your office building. This questionnaire asks about how you think your office environment affects you. Please answer the questions as accurately and completely as you can, regardless of how satisfied or dissatisfied you are with conditions in the office.

ALL OF YOUR ANSWERS WILL BE TREATED IN THE STRICTEST CONFIDENCE.

I. WORKPLACE INFORMATION

1. How long have you worked *in this building*, to the nearest year? _ _ years (15-16) **How long have you worked *at this location in the building*?** _ _ years _ _ months (17-20)	**4. How comfortable is the chair at your workstation?** 1 _ Very comfortable (25) 2 _ Reasonably comfortable 3 _ Somewhat uncomfortable 4 _ Very uncomfortable 5 _ Don't have one specific chair
2. On average, how many hours a week do you work *in this building*? _ _ hours per week (21-22)	**5. In general, how clean is your workspace area?** 1 _ Very clean (26) 2 _ Reasonably clean 3 _ Somewhat dusty or dirty 4 _ Very dusty or dirty
3. What floor do you work on? _ _ floor (23-24)	**6. About how many hours a day do you work with a computer or word processor, to the nearest hour?** _ _ hours per day (27-28)

II. INFORMATION ABOUT HEALTH AND WELL-BEING

1. Have you ever been told by a doctor that you have or had any of the following?

	YES (1)	NO (2)
Migraine		(29)
Asthma		(30)
Eczema		(31)
Hay fever		(32)
Allergy to dust		(33)
Allergy to molds		(34)

2. **Does the presence of tobacco smoke in your work environment bother you?**

   1_ Yes (35)
   2_ No

3. **Do you consider yourself especially sensitive to the presence of chemicals in your work environment (e.g., fumes from office machines, carpets)?**

   1_ Yes (36)
   2_ No

4. **What is your tobacco smoking status?**

   1_ never smoked (37)
   2_ former smoker
   3_ current smoker

5. **What type of corrective lenses do you usually wear at work?**

   1_ none (38)
   2_ glasses
   3_ contact lenses
   4_ both (glasses and contacts)

6. **How old were you on your last birthday?**

   _ _ years (39-40)

7. **Are you:**

   1_ male (41)
   2_ female

III. DESCRIPTION OF WORKPLACE CONDITIONS

During the **LAST MONTH YOU WERE AT WORK**, how often have you experienced each of the following environmental conditions while working in this building? • If you answer "Not in Last Month" for a condition, please move down the page to the next condition.					**TODAY**, while working at your usual workstation, did you experience this environmental condition?		
CONDITIONS	**Not in last month (1)**	**1-3 days in last month (2)**	**1-3 days *per wk* in last month (3)**	**Every or Almost Every Workday (4)**	**IN THE MORNING (1)**	**IN THE AFTER-NOON (2)**	**NOT TODAY (3)**
too much air movement							(82-83)
too little air movement							(84-85)
temperature too hot							(86-87)
temperature too cold							(88-89)
air too humid							(90-91)
air too dry							(92-93)
tobacco smoke odors							(94-95)
chemical odors (e.g., paint, cleaning fluids, etc.)							(96-97)
other unpleasant odors (e.g.. body odor, food odor, perfume)							(98-99)

IV. INFORMATION ABOUT YOU AND YOUR JOB

1. What is your job category?

1__ Managerial (100)
2__ Professional
3__ Technical
4__ Secretarial or Clerical
5__ Other (specify) ________

2. All in all, how satisfied are you with your job?

1__ Very satisfied (101)
2__ Somewhat satisfied
3__ Not too satisfied
4__ Not at all satisfied

3. What is the highest grade you completed in school?

1__ 8th grade or less (102)
2__ Some high school
3__ High school graduate
4__ Some college
5__ College degree
6__ Graduate degree

4. Please rate the lighting at your workstation.

__ Much too dim
__ A little too dim
__ Just right
__ A little too bright
__ Much too bright

(103)

5. How satisfied are you with the conversational privacy at your workstation?

__ Very satisfied
__ Somewhat satisfied
__ Not too satisfied
__ Not at all satisfied

(104)

6. To the nearest hour, how much sleep do you normally get on a worknight (Sunday through Thursday)?

__ __ hours (105)

7. In the last month, has your sleep been restless or disturbed?

__ not at all
__ a little bit
__ moderately
__ quite a bit
__ extremely

(106)

8. How many caffeinated beverages do you normally drink during a day (include at work and away from work; one beverage equals 6 ounces of coffee or tea or 12 ounces of caffeinated soft drink)?

__ __ beverages (107)

9. Which best describes the space in which your current workstation is located?

__ Private office
__ Open space with partitions
__ Open space without partitions
__ Other (specify) ________

(108)

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During the **LAST MONTH YOU WERE AT WORK**, how often have you experienced each of the following symptoms while working **in this building**? • If you answer "Not in Last Month" for a symptom, please move down the page to the next symptom.					During the **LAST MONTH YOU WERE AT WORK**, what happened to this symptom at times when you were away from work? (eg, holidays, weekends)			<u>While at work **TODAY**</u>, did you experience this symptom?	
SYMPTOMS	Not in last month (1)	1-3 days in last month (2)	1-3 days *per wk* in last month (3)	Every or Almost Every Workday (4)	Got Worse (1)	Stayed Same (2)	Got Better (3)	YES (1)	NO (2)
dry, itching, or irritated eyes									(42-44)
wheezing									(45-47)
headache									(48-50)
sore throat									(51-53)
unusual tiredness, fatigue, or drowsiness									(54-56)
chest tightness									(57-59)
stuffy or runny nose, or sinus congestion									(60-62)
cough									(63-65)
tired or strained eyes									(66-68)
difficulty remembering things or concentrating									(69-71)
dry throat									(72-74)
dizziness or lightheadedness									(75-77)
shortness of breath									(78-80)
In the LAST Month, how often have any of these symptoms either reduced your ability to work or caused you to stay home or leave work early? Please check ONLY ONE of the four boxes to the right.				(81)					

National Institute for
Occupational Safety and Health

NIOSH

Delivering on the Nation's promise:
Safety and health at work
For all people
Through research and prevention