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SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) conducted a follow-up health hazard evaluation (HHE) at the Tri-County North (TCN) school, Lewisburg, Ohio. The first NIOSH HHE, conducted in October and November 1992 and February 1993, evaluated indoor environmental quality (IEQ) among employees and determined symptom prevalences. This survey again assessed symptoms among employees and various IEQ parameters following installation of three additional ventilation systems at TCN.

This evaluation, conducted on January 26, 1994, included carbon dioxide (CO_2), temperature, and relative humidity (RH) measurements made at locations in both the north and central wings (also called "pods") of the school. Area air samples were collected for total volatile organic compounds (TVOCs) and formaldehyde. The medical evaluation included a questionnaire survey of all employees.

The CO_2 levels at TCN, which averaged 1289 parts per million (ppm) in the 1992-93 surveys, averaged less than 700 ppm on January 26, 1994, suggesting that the occupied areas of the school were receiving adequate amounts of outside air (OA). In some sections of TCN the CO_2 levels decreased by up to 52% from the levels in October 1992. Increasing the amount of OA supplied to the classrooms and offices was the major recommendation from the initial NIOSH evaluation.

Temperatures during this follow-up survey were within the comfort guidelines recommended by American Society for Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). Relative humidity at TCN, however, averaged below 30% on January 26, 1994, levels which were below the ASHRAE recommended range of 30 → 60% RH.

The formaldehyde levels at TCN, which ranged from 0.02 → 0.04 ppm in the 1992-93 surveys, ranged from less than 0.002 ppm (the minimum detectable concentration) to 0.007 ppm, time-weighted averages (TWAs) over the period sampled. In general, the new ventilation systems at TCN have decreased the formaldehyde levels by approximately 80% since October 1992. It is unlikely that health or comfort effects would result from exposures to formaldehyde at these low concentrations.

In sampling conducted on January 26, 1994, the TVOC levels (originating from the liquid toner used in some of the photocopiers) ranged from less than 0.08 (the minimum detectable concentration) to 11.4 milligrams per cubic meter (mg/m^3) and only the elementary and high school administrative areas had measurable TVOC levels (11.4 and 2.6 mg/m^3, respectively). In comparison, TVOC levels ranged from 1.6 to 18.3 mg/m^3 during the NIOSH survey conducted on October 28, 1992, and TVOC levels were detected in both administrative areas and several classrooms. On February 25, 1993, TVOC levels ranged from less than 0.9 to 26.2 mg/m^3, with only the elementary and high school administrative areas and classroom C104 containing measurable amounts of TVOC. Overall, the TVOC levels have declined at TCN since October 1992 and appear to now be restricted to the elementary and high school administrative areas. A photocopier which used liquid toner was located in each of these areas. There are no exposure criteria for TVOCs in non-industrial environments.

Eighty-nine percent of the responding teachers in the 1994 survey had also participated in the 1992 survey. The rate of symptoms that improved when the employee is away from work *has*

decreased (from 26% in 1992 to 10% in 1994) since the installation of the auxiliary ventilation system. When the 1994 survey results were compared to the 1992 survey, employees were less likely to report that there was too little air in the building or that the school was too humid or too hot, but were more likely to report too much air movement. More employees reported chemical odors in the building more than once a week in the 1994 survey than reported chemical odors more than once a week in the 1992 survey but this increase was not statistically significant. The reason for this increased reporting and the source of the odors is not known.

NIOSH investigators did not identify a health hazard during this follow-up evaluation at TCN. Data gathered during this survey suggests that the amount of outside air supplied to the occupied areas is adequate. As a result of ventilation additions and modifications, the levels of CO_2, TVOCs and formaldehyde have been reduced. Additionally, the rate of work-related symptoms has declined. A recommendation has been made further reduce the TVOC levels by locally exhausting the photocopiers which use liquid toner or by eventually replacing these machines with copiers which use a dry toner system. We also recommended that the new auxiliary ventilation systems be tested and balanced to assure that the intended airflow is reaching the occupied spaces.

Keywords: SIC 8211 (Elementary and Secondary Schools), indoor environmental quality, carbon dioxide, temperature, relative humidity, ventilation, volatile organic compounds, IEQ, IAQ, formaldehyde.

INTRODUCTION

In January 1994, investigators from the National Institute for Occupational Safety and Health (NIOSH) conducted a follow-up health hazard evaluation (HHE) at the Tri-County North (TCN) school, Lewisburg, Ohio. The initial survey (HETA 93-011-2309) was conducted in October and November 1992 and February 1993 and concerned "possible airborne pollutants causing conditions ranging from discomfort to physical reaction for some employees and students."

INITIAL NIOSH SURVEY (HETA 93-011-2309)

Environmental results from the surveys conducted at TCN in 1992 and 1993 revealed carbon dioxide levels which consistently exceeded 1,000 parts per million (ppm). Formaldehyde levels measured in TCN classrooms ranged from 0.02 to 0.06 ppm, time-weighted averages (TWAs) over the period sampled. The results of air sampling for microorganisms showed no evidence of any significant reservoirs of bacteria or fungi. Very low levels (parts per billion) of hexane, 1,1,1-trichloroethane, toluene, and trichloroethylene were measured in the north and central pods. Higher concentrations of decane (a component of the liquid toner fluid used in several of the photocopiers) were measured in the High School Administrative Office (central pod) and the Elementary School office (north pod). The photocopiers located in both of these areas used a liquid toner solution. The ventilation assessment indicated that the occupied spaces of the TCN facility received an inadequate amount of outside air (OA) per person.

The employee interviews conducted in October 1992 revealed that several teachers had experienced symptoms, including respiratory difficulty, impaired ability to concentrate, nausea, and severe headaches, that had affected their work. A questionnaire was completed by 75 teachers and administrative personnel, 10 cafeteria workers, and 8 custodial employees on October 28, 1992. Overall, the teachers and administrative personnel tended to report more symptoms, with the most commonly reported symptoms being headache, unusual fatigue, nasal congestion, and tired or strained eyes.

FOLLOW-UP NIOSH SURVEY

The January 25, 1994, evaluation was scheduled after additional heating, ventilating, and air conditioning (HVAC) units had been installed and modifications to the existing heat pump system had been made by TCN personnel. In this follow-up survey measurements were again made for temperature, relative humidity (RH), and carbon dioxide (CO_2) at various locations in the central and north sections (pods) at the school. General area air samples were collected to measure levels of total volatile organic compounds (TVOCs) and formaldehyde. The medical evaluation included interviews with TCN employees and a questionnaire survey.

BACKGROUND

The two-story (no basement) TCN elementary/middle/high school was completed in 1990. As shown in Figure 1, the approximately 129,000 ft^2 building is divided into three sections (called "pods"). About 1100 in-house students (grades kindergarten through 12), approximately 70 teachers, and 20 non-teaching staff are located at the school. Elementary classes are located in the north pod, while middle- and high-school classes are located in the central pod. The south pod contains two gymnasiums, locker areas, music and choir rooms, industrial and agricultural vocational classrooms, and other multipurpose areas. Smoking is prohibited in the TCN facility.

VENTILATION

Original Heat Pump System

The original HVAC system at TCN consists of 114 heat pumps, controlled by a central computer system, which conditioned the air in the school. While this system is still operational, additional outside air (OA) is now introduced into the school from three rooftop HVAC units (one per pod) installed during 1993-94.

Virtually every classroom and office suite has its own heat pump, with some of the larger rooms (such as the auditorium) having two or more heat pumps. Each heat pump typically removes air from a room, filters the air, mixes the return air with outside air, conditions (heats or cools) the mixed air, and then supplies the mixed air back to the room. The heat pumps are generally pull-through units with direct drive fans.

A constant volume of air is supplied to the classrooms from the heat pumps through slot diffusers located in the ceiling. Other classroom areas, the offices, and bathrooms use ceiling-mounted four-way louvered diffusers for supply air. In the classrooms, air is returned to the heat pumps through ceiling-mounted registers located on the opposite side of the room from the supply diffusers. In larger areas, such as the gymnasiums, the air returns are located in the wall near the floor. In all situations the return systems are ducted from the room to the heat pump.

New Single-Pass Ventilation System

Prior to 1993, two methods were used to supply OA to the building. For large areas, such as the gymnasiums, the heat pumps pulled air directly from the outside. For heat pumps serving the classrooms, locker rooms, and office suites, dedicated heat pumps pulled outside air into the building, preheated the air (as needed), filtered and conditioned the air, and then delivered this outside air to the return ducts of other heat pumps. All of the main outside air ducts are equipped with dampers which open only when the respective heat pump system is operated. Some of the outside air main ducts and entrances are common to more than one outside air heat pump.

In January 1994, the TCN school system completed installation of three new rooftop HVAC units (one per pod), along with additional gas-fired boilers and a cooling tower. Separate supply ducts (located parallel to the existing ducts supplying the heat pumps) were installed to supply conditioned OA to classrooms, office areas, and other occupied spaces. In addition to the existing supply and return associated with the heat pump system, each classroom had one new supply and exhaust vent installed in the ceiling. The new exhausts vent the room air directly outside the building.

On January 26, 1994, the new single-pass HVAC systems were fully operational in the north and central pods (areas where most of the classrooms and students are located). The new rooftop HVAC system supplying the south pod was not operating because of a problem with the hot water boiler supplying this unit. The original heat pump system supplying the south pod was, however, functioning normally. The south pod contains gymnasiums, locker rooms, and specialty areas (such as music and vocational classrooms). Since the south pod contained fewer classrooms and students, NIOSH investigators determined that the environmental parameters measured in the north and central pods would be minimally affected as a result of the new auxiliary HVAC unit in the south pod not operating.

Other Ventilation Systems

Areas which do not have returns, such as bathrooms and locker rooms, are generally connected to central exhaust systems. Fans for the exhaust systems are located on the roof. Two notable exceptions are the main gymnasium, which has a roof-mounted exhaust fan and two side-wall panel exhaust fans, and the vocational shop area, which has a recirculating ventilation system for the larger shop tools.

EVALUATION CRITERIA

INDOOR ENVIRONMENTAL QUALITY

A number of published studies have reported a high prevalence of symptoms among occupants of office buildings.[1,2,3] NIOSH investigators have completed over 700 investigations of the indoor environment in a wide variety of settings. The majority of these investigations have been conducted since 1979.

The symptoms 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.[4,5] 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.[6,7,8,9] Reports are not conclusive as to whether increases of outdoor air above currently recommended amounts ($\geq$15 cubic feet per minute per person [cfm/person]) are beneficial.[9] However, rates lower than these amounts appear to increase the rates of complaints and symptoms in some studies.[10] 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.[11]

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.[12] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[13,14]

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 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.[15,16,17] With few exceptions, pollutant concentrations observed in the office work environment fall well below these published occupational standards or recommended exposure limits. The ASHRAE has published recommended building ventilation design criteria and thermal comfort guidelines.[18,19] 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.[20]

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

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. ASHRAE's most recently published ventilation standard, ASHRAE 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 cfm/person for office spaces, and *15 cfm/person for reception areas, classrooms, libraries, auditoriums, and corridors*.[19] 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 parts per million [ppm]). CO_2 concentration is used as an indicator of the adequacy of outside air supplied to occupied areas. When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased. It is important to note that CO_2 is not an effective indicator of ventilation adequacy if the ventilated area is not occupied at its usual level.

TEMPERATURE AND 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.[21] 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.[18] Assuming slow air movement and 50% RH, the operative temperatures recommended by ASHRAE range from 68-74^{o}F in the winter, and from 73-79^{o}F in the summer. The difference between the two is largely due to seasonal clothing selection. In separate documents, ASHRAE also recommends that RH be maintained between 30 and 60% RH.[18,19] Excessive humidities can support the growth of microorganisms, some of which may be pathogenic or allergenic.

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. 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 (TVOC)* has been used in an attempt to predict certain types of health effects.[22] The use of this TVOC indicator, however, has never been standardized.

Table 1 - Suggested TVOC Levels

Total Concentration (mg/M^3)	Irritation and Discomfort
<0.16	No irritation or discomfort
0.16 - 3	Irritation and discomfort possible *(if other exposures interact)*
3 - 25	Irritation and discomfort probable; headache possible

Source: Molhave, L [1986]. Indoor air quality in relation to sensory irritation due to VOCs. ASHRAE paper 2954.

Some researchers have compared levels of TVOCs with human responses (such as headache and irritative symptoms of the eyes, nose, and throat). *However, neither NIOSH nor the Occupational Safety and Health Administration currently have specific exposure criteria for VOC mixtures in the nonindustrial environment.* Research conducted in Europe suggests that complaints by building occupants may be more likely to occur when TVOC concentrations increase.[23] Table 1 lists TVOC levels which have been associated be some researchers to employee discomfort or irritation. When using these guidelines, however, it should be emphasized that the highly variable nature of these complex VOC mixtures can greatly affect their irritancy potential. For example, the VOC mixtures which were studied by Molhave are not the same as those VOC mixtures which were measured at TCN during this evaluation. Considering the difficulty in interpreting TVOC measurements, caution should be used in attempting to associate health effects (beyond nonspecific sensory irritation) with specific TVOC levels.

FORMALDEHYDE

Sources

Formaldehyde and other aldehydes may be released from foam plastics, carbonless copy paper, particle board, and plywood. Formaldehyde is a constituent of tobacco smoke and of combustion gases from heating stoves and gas appliances. This chemical has also been used in the fabric and clothing industry to impart permanent press characteristics, in the manufacturer of some cosmetics, and in disinfectants and fumigants. Formaldehyde levels in

ambient air can result from diverse sources such as automobile exhaust, combustion processes, and certain industrial activities such as the production of resins.

Health Effects

Effects of exposure to low concentrations of formaldehyde may include irritation of the eyes, throat, and nose; headaches; nausea; nasal congestion; asthma; and skin rashes. It is often difficult to ascribe specific health effects to specific concentrations of formaldehyde because people vary in their subjective responses and complaints. For example, irritation symptoms may occur in people exposed to formaldehyde at concentrations below 0.1 ppm, but more typically they begin at exposures of 1.0 ppm and greater. However, some children or elderly persons, those with pre-existing allergies or respiratory disease, and persons who have become sensitized from prior exposure may have symptoms from exposure to concentrations of formaldehyde between 0.05 and 0.10 ppm. Cases of formaldehyde-induced asthma and bronchial hyperreactivity have been reported.[24]

Non-occupational Exposure Assessments to Formaldehyde

It is not unusual for indoor levels of formaldehyde to typically exceed outdoor levels.[25] Table 2 summarizes data from several studies which measured formaldehyde levels in homes in different parts of the United States, Canada, and the United Kingdom. Mobile homes, due to the large amount of pressed wood products used in their construction, have the highest formaldehyde concentrations. A mean of 0.4 ppm has been found in most of the studies conducted in mobile homes. Most other types of homes generally have average formaldehyde levels less than 0.1 ppm. In one study, older (more than 15 years old) conventional homes were found to have average formaldehyde levels of around 0.03 ppm. In this same study average formaldehyde levels of 0.08 ppm were measured in homes less than five years old.

Researchers in California have evaluated formaldehyde exposure and irritation symptoms for over 1000 individuals in mobile homes, making this the largest random mobile-home formaldehyde exposure study conducted to date. Formaldehyde levels ranged from less than 0.01 ppm to 0.46 ppm. The researchers found an overall positive correlation between formaldehyde exposure and irritant symptoms. Using information from this study, the California Air Resources Board (CARB) recommended that formaldehyde concentrations be kept below a "target level" of 0.05 ppm inside conventional homes.[26]

In another study, the Dutch Health and Environment Inspectorates compiled measurements which had been made between 1978 and 1981 in homes and schools where there were complaints which may have been caused by formaldehyde.[27] Overall, complaints occurred in approximately 50% of the locations where the formaldehyde level was above 0.1 ppm. In schools, however, this complaint percentage was slightly higher (66%), and in some school locations formaldehyde levels in excess of 2 ppm were measured.

Non-occupational Exposure Guidelines for Formaldehyde

The fact that formaldehyde is found in so many home products, appliances, furnishings, and construction materials has prompted several agencies to set standards or guidelines for residential formaldehyde exposure. ASHRAE has recommended, based on personal comfort, that exposure to formaldehyde be limited to 0.1 ppm. This guideline has also been adopted by the National Aeronautics and Space administration (NASA) and the governments of Canada, Germany, and the United Kingdom.[28] An indoor air formaldehyde concentration of

less than 0.05 ppm is of limited or no concern according to the World Health Organization (WHO).[29] NIOSH considers formaldehyde to be a suspected human carcinogen and, as such, recommends that exposures be reduced to their lowest feasible level. The levels of formaldehyde measured at the TCN facility during this survey are similar to levels measured by NIOSH investigators in other non-industrial work place evaluations.[12,30]

EVALUATION METHODS

ENVIRONMENTAL SURVEYS

Carbon Dioxide

CO_2 measurements were obtained throughout the school day on floors one and two in both the central and north pods (high school and elementary grades, respectively). Real-time CO_2 levels were determined using 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 daily 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 the TSI battery-operated Model 8360 Velocicalc® Plus Air Velocity meter. This meter is capable of directly measuring dry bulb temperature and RH, ranging from -4 to 140ºF, and 0 to 95% RH.

Total Volatile Organic Compounds

Air sampling results from the prior NIOSH evaluations conducted on October 28, 1992, and February 25, 1993, at TCN had indicated that the TVOC chromatogram pattern matched that of a liquid toner fluid used in some photocopiers. In this follow-up survey a total of 10 general area air samples were collected on activated charcoal and analyzed for TVOCs. These samples were collected using a flow rate of 100 cubic centimeters per minute over a sampling period ranging from approximately 9:00 a.m. to 3:30 p.m. One of the air samples collected on January 26, 1994, was qualitatively analyzed by gas chromatograph-mass spectrometry (GC-MS) to identify the VOCs present and confirm that the chromatogram pattern still matched that of the liquid toner fluid. Based on this analysis, the nine remaining charcoal tube samples were then desorbed with carbon disulfide and analyzed by flame ionization gas chromatography using a fused silica capillary column to quantitate the TVOC levels from the photocopier toner fluid.

Formaldehyde

Ten area air samples were collected for formaldehyde at various locations in the central and north pods of the school as well as outside the building. The samples were collected using the NIOSH Sampling and Analytical Method No. 3500 which entails bubbling the sampled air (at a flow rate of 1 liter per minute) through a 1% sodium bisulfite solution. The samples are subsequently analyzed using an ultraviolet spectrophotometer. This is the most sensitive analytical method for formaldehyde to date.

The analytical limit of detection (LOD) for this sample set is estimated at 1.0 micrograms of formaldehyde per sample (µg/sample). The analytical limit of quantitation is estimated at 3.3 µg/sample.

MEDICAL

During the site visit on January 26, 1994, questionnaires were distributed to 88 employees working in the school. The questionnaire asked if the employee had experienced, while at work on the day of the survey, any of the symptoms (irritation, nasal congestion, headaches, etc.) commonly reported by occupants of "problem buildings." The questionnaire also asked about the frequency of occurrence of these symptoms while at work in the building during the four weeks preceding the survey, and whether these symptoms tended to get worse, stay the same, or get better when they were away from work. The final section of the questionnaire asked about environmental comfort (too hot, too cold, unusual odors, etc.) experienced while the employees were working in the building during the four weeks preceding the questionnaire administration. Prevalence rates of employee symptoms and self-reported comfort indices were calculated and compared with the 1992 survey using a chi-square (χ^2) statistical test or a Fisher exact test if an expected cell value was less than 5.

RESULTS

ENVIRONMENTAL

Carbon Dioxide Levels

As shown in Figure 2, CO_2 levels on January 26, 1994, were generally below 1,000 ppm throughout the facility. These CO_2 levels suggest that most of the occupied areas of the school are receiving adequate amounts of outside air throughout the school day. These CO_2 concentrations, as shown in Figure 3, have decreased by up to 52% from the levels measured at TCN in October 1992.

Temperature and Relative Humidity Levels

Temperature and RH levels were measured throughout the school day on January 26, 1994. Temperatures levels, ranging from 70 → 76°F, were within the comfort guidelines recommended by ASHRAE. The RH levels measured, however, ranged from 14 → 21% RH, below the ASHRAE comfort guidelines for winter conditions. Outside conditions on 1/26/94 ranged from 22 → 29°F and 60 → 46% RH, respectively.

Figure 4 compares the average temperature and RH levels measured at TCN during the NIOSH surveys conducted on October 28, 1992, February 25, 1993, and January 26, 1994. While temperatures remain very uniform (ranging from 73 → 74°F), the RH levels decline during the colder winter months. For example, in October 1992 the RH levels ranged from 36 → 44%, while in February 1993 and January 1994 the RH levels consistently averaged less than 20% in the school building. It is not uncommon to occasionally have RH levels less than 30% in buildings located in colder climates (when the buildings are not humidified).

Formaldehyde

As shown in Table 3, the formaldehyde levels measured in TCN classrooms on January 26, 1994, ranged from less than 0.002 (the minimum detectable concentration for this sample set using the NIOSH Sampling and Analytical Method No. 3500) to 0.01 ppm, time-weighted averages (TWAs) over the period sampled. As shown in Figure 3, formaldehyde levels in the north and central pods have declined by approximately 80% since October 1992.

Volatile Organic Compounds (VOCs)

Air samples were collected and analyzed for TVOCs. For the purpose of this NIOSH evaluation, TVOC is defined as a mixture of hydrocarbons whose chromatographic pattern resembled that of a liquid toner solution used in certain brands of photocopiers.

As shown in Table 4, of the nine area air samples collected on January 26, 1994, only two samples measured detectable levels of TVOC. One sample, collected in the supply room adjoining the high school administrative office, measured a TVOC level of 11.4 milligrams per cubic meter of air (mg/m^3). The other location, in the elementary school administrative office, measured 2.6 mg/m^3. It should be noted that a photocopier which used liquid toner was located in both of these administrative office areas. There are no exposure criteria for TVOCs in non-industrial environments.

Comparing these concentrations to those measured in earlier surveys, TVOC levels ranged from 1.6 to 18.3 mg/m^3 during the NIOSH survey conducted on October 28, 1992, and TVOC levels were detected in both administrative areas and several classrooms. On February 25, 1993, TVOC levels ranged from not detectable (ND) to 26.2 mg/m^3, with only the elementary and high school administrative areas and classroom C104 containing measurable amounts of TVOC. Overall, the TVOC levels have declined at TCN since October 1992 and appear to now be restricted to the elementary and high school administrative areas.

MEDICAL

During the visit, questionnaires were distributed to 88 employees at work on the days of the evaluation. Respondents included 58 teachers, one teaching assistant, six administrators, three custodial staff, nine cafeteria workers, two librarians, five who listed themselves as "other", and four who did not answer the question concerning occupation. The median age of respondents lay in the range 40 to 49 years of age. Six currently smoked cigarettes, 10 were former smokers, and 71 had never smoked. Seventy-six percent of the respondents had worked in the building since it had opened (four years ago), 18% had worked in the building for three years and 6% had worked in the building less than three years.

The questionnaire results are shown in Table 5. The first column of Table 5 shows the percentage of the 88 respondents who reported the occurrence of symptoms while at work on the day of the survey. Headache, unusual fatigue, dry throat, and nasal congestion are the most commonly reported symptoms.

The second column shows the percentage of employees who reported experiencing the respective symptom once a week or more often while at work during the four weeks preceding the survey. With a few exceptions, these symptom prevalences are similar to those for symptoms experienced on the day of the survey.

The third column shows the percentage of employees who reported experiencing the respective symptom once a week or more often while at work during the four weeks preceding the survey and also reported that the symptom tended to get better when they were away from work. This latter criterion has, in some studies of indoor air quality, been used to define a "building related" symptom, but it is possible that a symptom which does not usually improve when away from the building could also be due to conditions at work.

The reported "building-related" frequent symptom prevalence shown in column three, are lower than the corresponding symptom prevalence over the last four weeks shown in the second column, and are highest for fatigue and headache. Overall, nine (10% of the 88) respondents reported having one or more symptoms that had occurred at work one or more days a week during the preceding four weeks and tended to get better when away from work. All of the employees reporting symptoms that improved away from the building were teachers -- nine out of the 58 teachers taking the questionnaire reported symptoms while none of the 30 other respondents (cafeteria workers, librarians, administrators, or secretaries) reported symptoms ($\chi^2=5.2$, $p=0.02$).

The rate of symptoms among TCN employees *has decreased* since the installation of the auxiliary ventilation system. In the October 1992 study, 26 employees (28%) reported one or more symptoms that improved when they were away from work, and in the present study 9 employees (10%) reported one or more symptoms that improved when they were away from

work. The difference between prevalence rates in the two studies is statistically significant ($p=0.003$). There was a statistically significant decrease in the reporting of strained eyes ($p=0.02$) and headache ($p=0.01$), and non-significant decreases ($p<0.1$) in the reporting of irritated eyes and fatigue (Table 6).

Table 7 shows results of employee reports regarding environmental conditions at their work areas on the day of the survey and during the four weeks preceding the survey. Column one shows the results for the day of the survey. It shows that 17% of the respondents perceived that the ventilation system was providing too much air movement, 13% thought it was too hot, and 18% felt that it was too cold during at least part of their work day.

The second column shows the responses to the questions about environmental comfort conditions experienced in the facility during the four weeks preceding the survey. Adverse environmental conditions (too hot, too cold, odors, etc.) were considered "frequent" if they were reported to occur at work once a week or more often. The results are similar to those shown in the first column for workstation environmental conditions experienced during the day of the survey. Sixteen percent of respondents perceived too much air movement, only 1% reported insufficient air movement, 6% frequently were too hot, 17% were frequently too cold, 5% perceived frequent chemical odors in the workplace, and 9% frequently sensed other unpleasant odors.

Since the last NIOSH medical survey and improvements in the ventilation system, employees noted changes in environmental conditions in the building. When the 1994 survey results were compared to the 1992 survey, employees were less likely to report that there was too little air in the building ($p=0.004$) or that the school was too humid or too hot but were more likely to report too much air movement (see Table 8). More employees reported chemical odors in the building than in the 1992 survey. One teacher reported chemical odors in the 1992 survey and three teachers and one other employee reported chemical odors in the 1994 survey. This increase was not statistically significant (Fisher exact 2-tailed p value=0.20). The reason for this increased reporting and the source of the odors is not known.

DISCUSSION AND CONCLUSIONS

ENVIRONMENTAL

- Carbon dioxide concentrations throughout the north and central pods averaged less than 1000 ppm. Indoor CO_2 levels in excess of 1000 ppm suggest that the occupied areas of the school are not receiving adequate amounts of outside air. Carbon dioxide concentrations have decreased by up to 52% from the levels measured at TCN in October 1992.

- Temperatures measured during the NIOSH surveys conducted in October 1992, February 1993, and January 1994 have remained very uniform (ranging from 73 → 74ºF) and within the comfort guidelines recommended by ASHRAE.

- Relative humidity levels measured in January 1994 were below the comfort guidelines recommended by ASHRAE. Based on the RH levels measured during the three NIOSH surveys at TCN, RH levels appear to decline during the colder winter months. For example, in October 1992 the RH levels ranged from 36 → 44%, while in February 1993

and January 1994 the RH levels consistently averaged less than 20% in the school building. It is not uncommon to occasionally have RH levels less than 30% in buildings located in colder climates (when the buildings are not humidified).

- The formaldehyde levels at TCN on January 26, 1994, averaged 0.007 ppm. These levels, which are very close to ambient levels outside the school building, have been measured by NIOSH investigators in other non-industrial workplaces. It is unlikely that health or comfort effects would result from exposures to formaldehyde at these low concentrations. The formaldehyde concentrations have declined by approximately 80% from the levels first measured by NIOSH at TCN during the October 1992 survey.

- Ventilation changes in the school designed to increase the amount of OA per person (for the occupied spaces) has been successful in reducing the CO_2, formaldehyde, and TVOC levels.

- In this evaluation quantifiable TVOC levels were detected only in locations which were near photocopiers which used liquid toner. In contrast, TVOC levels measured in the NIOSH survey on 10/28/92 detected quantifiable levels in several classrooms in the north and central pods as well as in the vicinity of the photocopiers. *While NIOSH investigators cannot at this time establish a TVOC level under which no health effects would be expected, reducing exposures is always appropriate. This could be accomplished by locally exhausting the photocopiers which use liquid toner or by eventually replacing these machines with copiers which use a dry toner system.*

MEDICAL

- Eighty-nine percent of the responding teachers in the 1994 survey reported that they also participated in the 1992 survey.

- Nine teachers (10%) reported one or more symptoms that improved when they were away from work in the 1994 survey and 26 employees (28%) reported one or more symptoms that improved when they were away from work in the 1992 survey. This difference in prevalence rates was statistically significant (p=0.003). No symptoms were reported by employees who were not teachers in the 1994 survey.

- The number of employees reporting "too little air movement" in the building decreased from 11 in 1992 to one in 1994 (p=0.04). The number of employees reporting "too much air movement" increased from seven in 1992 to 14 in 1994 (p=0.08). This difference likely reflects environmental changes from the operation of the new ventilation system.

RECOMMENDATIONS

1. The CO_2 concentrations in some north and south pod classrooms slightly exceeded 1000 ppm during part of the school day on January 26, 1994. To reduce these CO_2 levels below 1000 ppm, the auxiliary HVAC units should be tested and balanced to determine if the intended airflow is reaching these classrooms.

2. Three teachers reported chemical odors in the building, an increase from the 1992 NIOSH survey of TCN workers. While the source of these odors is not known, the

liquid toner used in photocopiers located in the elementary and high school administrative office areas contributes VOCs into these locations, perhaps accounting for reports of "chemical odors." To reduce the TVOCs emitted from these photocopiers, the machines could be locally exhausted or eventually replaced with photocopiers which use a dry toner system.

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Copies of this report have been sent to:

1. Tri-County North Local Schools
2. Tri-County North Teachers Association
3. Ohio Public School Employees Union
4. Ohio Department of Health, Division of Epidemiology and Toxicology
5. Ohio Department of Health, State Environmental Health Services

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

March 15, 1994
HETA 94-0129

Mr. Timothy Hopkins, Superintendent
Tri-County North Local Schools
436 North Commerce Street
Lewisburg, Ohio 45338

Dear Mr. Hopkins:

Enclosed is the National Institute for Occupational Safety and Health (NIOSH) final report containing information gathered during the environmental and medical evaluation conducted at the Tri-County North school on January 26, 1994. To summarize the content of this report, carbon dioxide, temperature, and relative humidity measurements were again collected throughout the north and central pods. In addition, air samples were collected for total volatile organic compounds and formaldehyde and 88 questionnaires returned by TCN employees were analyzed.

At this time, no additional site visits by NIOSH investigators are anticipated. If you have any questions regarding this interim report or any aspects of this survey please do not hesitate to contact us at (513) 841-4374 (Mr. Burr) or (513) 841-4386 (Dr. Malkin).

Sincerely yours,

Gregory A. Burr, C.I.H.
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Ms. Bonnie Price, President, Ohio Public School Employees Union

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Table 2

Reported Levels of Formaldehyde in Private Residences

Type of Residence	No. of Residences	Formaldehyde (ppm)	
		Range	Mean
U.S. homes without area-formaldehyde foam insulation (UFFI)	41	0 - 0.1	-
U.S. homes with UFFI (complaint and noncomplaint)	636	0 - 3.4	0.1
U.S. mobile homes	431	0 - 3.5	0.4
Canadian houses without UFFI	383	(3% >0.1 ppm)	-
Canadian houses with UFFI	1850	(10% >0.1 ppm)	0.1
U.S. houses without UFFI and without particle board	17	-	-
U.S. houses with UFFI but without particle board subfloors	600	-	0.1
U.S. mobile homes	several hundred		-
U.K. buildings without UFFI	50	0 - >0.3 (3% >0.01 ppm)	0.1
U.K. buildings with UFFI	128	0 - >1 (7% >0.1 ppm)	0.1
U.S. houses without UFFI	42	0 - 0.2	0.1
U.S. houses without UFFI	32	-	0.1
U.S. houses with UFFI	-	-	0.1
Mobile homes (Minnesota complaint)	100	0.3	-
Mobile homes (Wisconsin complaint)	-	0 - 4.2	0.9
Mobile homes (Wisconsin complaint)	65	<0.1 - 3.7	0.5
Mobile homes (Washington complaint)	-	0 - 1.8	0.1 - 0.4
U.S. mobile homes Never occupied Older, occupied	260	-	 0.9 0.3
East Tennessee homes	40	0 - 0.4	0.1
Age 0-5 years	18	0	0.1
Age 5-15 years	11	-	-
Age >15 years	11	-	-
Conventional California, Colorado, and S. Dakota homes	64	0 - 0.1	0.1
Specialized U.S. housing	52	0 - 0.3	0.1

Source for table: Gammage RB, Hawthorne AR. "Current Status of Measurement Techniques and Concentrations of Formaldehyde in Residences." Turoski V. Formaldehyde: analytical chemistry and toxicology. Page 125. "Developed from a symposium sponsored by the Division of Environmental Chemistry at the 187th Meeting of the American Chemical Society, St. Louis, Missouri, April 8-13, 1984."

Table 3

Formaldehyde Levels

January 26, 1994
Tri-County North School, Lewisburg, Ohio
HETA 94-0129

Sample No.	Location	Sample Period	Sample Volume (liters)		Concentration, ppm (parts per million)
					Formaldehyde
1	TCN District Office	9:50 am to 4:08 pm	378		Trace
2	Administrative Office (High School, Reception Area)	8:51 am to 3:35 pm	404		0.0097
3	Room C104 (Art Room)	8:53 am to 3:37 pm	404		Trace
4	Administrative Office (Elementary)	9:00 am to 3:43 pm	403		0.0087
5	Room N211 (Mega Room)	9:21 am to 3:56 pm	395		Trace
6	Room N202	9:25 am to 3:57 pm	392		Trace
7	Room C217	9:30 am to 3:54 pm	384		0.0083
8	Room N119	8:57 am to 3:39 pm	403		Trace
9	Room C116	9:13 am to 4:16 pm	423		Trace
10	Outside the building	9:16 am to 3:46 pm	410		ND
Minimum *Detectable* Concentration (assuming a 400 liter air sample)					0.0020
Minimum *Quantifiable* Concentration (assuming a 400 liter air sample)					0.0067

Comment:
ND = Not detected (level is below the MDC)
Trace = Concentration between the MDC and the MQC
TCN = Tri-County North School, Lewisburg, Ohio

Table 4

Quantitation of Photocopier Toner Fluid

January 26, 1994
Tri-County North School, Lewisburg, Ohio
HETA 94-0129

Sample No.	Location	Sample Period	Sample Volume (liters)		Concentration, mg/m^3 (milligrams per cubic meter)
					Photocopier Toner Fluid/Xylene
11	Outside building	9:16 am to 3:46 pm	41.0		ND
12	Room C104 (Art Room)	8:53 am to 3:37 pm	40.4		ND
14	Administrative Office (Elementary)	9:00 am to 3:43 pm	40.3		2.6
15	Administrative Office (High School)	8:50 am to 3:38 pm	40.3		11.4
16	Room N119	8:57 am to 3:39 pm	40.3		ND
17	Room N202	9:25 am to 3:57 pm	39.2		ND
18	Room C214	9:33 am to 3:52 pm	37.9		ND
19	Room N211 (Mega Room)	9:21 am to 3:55 pm	39.4		ND
20	Room C116	9:13 am to 4:16 pm	42.3		ND
Minimum *Detectable* Concentration (assuming a 40 liter air sample)					0.08
Minimum *Quantifiable* Concentration (assuming a 40 liter air sample)					0.28

Comment:

The chromatogram of the VOC found on the samples matched the pattern from a liquid toner used by a Savin® photocopier. Liquid toner was used as a standard for the sample analysis. Values below the MDC are listed at ND (not detected).

Table 5

Symptoms Experienced at Work

January 26, 1994
Tri-County North School, Lewisburg, Ohio
HETA 94-0129

Symptoms of 88 Workers	Experienced on Days of Survey While at Work	Frequently Experienced Last Four Weeks While at Work	Have Frequent Symptoms that Improve When Away from Work
Dry, itching, or irritated eyes	5%	9%	0%
Tired or strained eyes	8%	5%	1%
Stuffy nose, or sinus congestion	15%	14%	0%
Sore or dry throat	5%	5%	0%
Unusual fatigue or drowsiness	14%	15%	5%
Headache	13%	10%	3%
Difficulty with memory or concentration	9%	6%	1%
Dry throat	13%	9%	2%
Dizziness or lightheadedness	6%	2%	0%
Cough	8%	7%	0%
Chest tightness	2%	6%	1%
Wheezing	3%	3%	0%
Shortness of breath	5%	5%	1%

Table 6

Number of Employees with Frequent Symptoms that Improve When Away from Work

October 28, 1992 and January 26, 1994
Tri-County North School, Lewisburg, Ohio
HETA 94-0129

	October 28, 1992 n = 93	January 26, 1994 n = 88	p value
Dry, itching, or irritated eyes	5	0	0.06*
Tired or strained eyes	9	1	0.02*
Stuffy nose, or sinus congestion	4	0	0.12*
Dry throat	5	2	0.44*
Unusual fatigue or drowsiness	11	4	0.08
Headache	13	3	0.01
Difficulty with memory or concentration	0	1	0.49
Sore throat	1	0	1.00*
Dizziness or lightheadedness	2	0	0.50*
Cough	2	0	0.50*
Chest tightness	0	1	0.49
Wheezing	0	0	1.00*
Shortness of breath	1	1	1.00*

* = Fisher exact 2-tailed P-value
n = number of employees

Table 7

Description Of Workplace Conditions

January 26, 1994
Tri-County North School, Lewisburg, Ohio
HETA 94-0129

Conditions	Experienced at Work During Days of the Survey n = 88	Frequently Experienced While at Work During Previous Four Weeks n = 88
Too much air movement	17%	16%
Too little air movement	2%	1%
Temperature too hot	13%	6%
Temperature too cold	18%	17%
Air too humid	0%	2%
Air too dry	8%	7%
Tobacco smoke odors	2%	2%
Chemical odors (e.g., paint, cleaning fluids, etc.)	5%	5%
Other unpleasant odors (e.g., body odor, food odor, perfume)	9%	9%

n = number of employees

Table 8

Number of Employees Reporting Comfort Deficiencies 1992-1994

January 26, 1994
Tri-County North School, Lewisburg, Ohio
HETA 94-0129

Comfort Parameter	Number Reporting Environmental Parameter in 1992 n = 93	Number Reporting Environmental Parameter in 1994 n = 88	p value
Too much air movement	7	14	0.08
Too little air movement	11	1	0.004
Temperature too hot	10	5	0.22
Temperature too cold	14	15	0.72
Air too humid	6	2	0.28*
Air too dry	7	6	0.85
Chemical odors (paint, cleaning fluid, etc.)	1	4	0.20*
Other unpleasant odors (body odor, food odor, perfume)	9	8	0.89

* = Fisher exact 2-tailed P-value
N = number of employees

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer and authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HEALTH HAZARD EVALUATION REPORT

HETA 94-0129-2397
TRI-COUNTY NORTH SCHOOL
LEWISBURG, OHIO