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TRI-COUNTY NORTH SCHOOL
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SUMMARY

In November 1994, the National Institute for Occupational Safety and Health (NIOSH) conducted a follow-back 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) and determined symptom prevalences. At the request of school administrators, a follow-up survey was conducted in January 1994 after ventilation changes had been made but before these systems had been completely tested and balanced. This survey, which included measurements for carbon dioxide (CO_2), temperature, relative humidity (RH), formaldehyde, and total volatile organic compounds (TVOC), follows the final testing and balancing of the ventilation systems.

Carbon dioxide concentrations averaged 843 parts per million (ppm) in the central pod (range 350 → 1575 ppm) and 684 ppm in the north pod (range 425 → 1250 ppm), although CO_2 levels in some classrooms slightly exceeded 1,000 ppm during periods of higher occupancy. Temperatures and RH ranges measured during this survey (71→ 75ºF and 30 → 38% RH, respectively) were within comfort guidelines recommended by the American Society for Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE).

The formaldehyde concentrations ranged from less than 0.002 (the minimum detectable concentration [MDC]) to 0.019 ppm, time-weighted averages (TWAs). For comparison, formaldehyde concentrations ranged from 0.02 → 0.04 ppm in the 1992-93 surveys and from less than 0.002 ppm (the MDC) to 0.007 ppm in January 1994. It is unlikely that health or comfort effects would result from exposures at these low concentrations.

On November 1, 1994, TVOC concentrations of 3.7 and 4.4 milligrams per cubic meter (mg/m^3) were detected in two of the eight general area air samples (these concentrations were measured near photocopiers located in the elementary and high school administrative areas, respectively). In comparison, on January 26, 1994, the TVOC levels (from the liquid toner used in some photocopiers) ranged from less than 0.08 (the MDC) to 11.4 mg/m^3 (like the November 1994 survey, only the elementary and high school administrative areas had measurable TVOC levels.) Total volatile organic compounds 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. There are no NIOSH exposure criteria for TVOCs in non-industrial environments.

NIOSH did not identify a health hazard during this evaluation. At this point in time, based on the data collected during this evaluation, we see no reason for continued concern about occupancy of this school. Since October 1992, there has been continued improvement in the indoor environmental quality at TCN. The CO_2 concentrations now average less than 1,000 ppm (although short term CO_2 concentrations routinely exceed 1,000 ppm in some fully occupied classrooms). Formaldehyde and TVOCs concentrations have also declined from levels measured in October 1992. Recommendations to further improve employee comfort include further reduction of the TVOC concentrations by locally exhausting the photocopiers which use liquid toner or by eventually replacing these machines with copiers which use a dry toner system. Also, based on a review of ventilation reports, some classrooms did not provide the 15 cubic feet of outside air per person as recommended by ASHRAE standard 62-1989 for maintaining acceptable indoor air quality.

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

INTRODUCTION

A National Institute for Occupational Safety and Health (NIOSH) health hazard evaluation (HHE) was conducted in November 1994 following a request from administrators at the Tri-County North (TCN) Local School System, Lewisburg, Ohio. This HHE, the latest in a series of HHEs at this school, was conducted after the completion of a test-and-balance of newly installed heating, ventilating, and air-conditioning (HVAC) systems.

In the initial survey (HETA 93-011-2309, conducted in October and November 1992 and February 1993) NIOSH was requested to investigate "possible airborne pollutants causing conditions ranging from discomfort to physical reaction for some employees and students." At the request of school administrators, a follow-up evaluation (HETA 94-0129-2397) was conducted in January 1994 following the installation of additional heating and air-conditioning systems in each of the three wings at the school.

INITIAL NIOSH SURVEY (HETA 93-011-2309)

Environmental results from the surveys conducted at TCN in 1992 and 1993 measured carbon dioxide (CO_2) concentrations which consistently exceeded 1,000 parts per million (ppm) throughout the school. 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 (HETA 94-0129-2397)

The January 25, 1994, evaluation was scheduled after additional HVAC units had been installed and modifications to the existing heat pump system had been made by TCN personnel.[1] 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.

SECOND FOLLOW-UP NIOSH SURVEY (HETA 95-0026)

The November 1994 survey included measurements for CO_2, temperature, RH, formaldehyde, and TVOCs. This evaluation followed the completion of final testing and balancing of the newly installed ventilation systems. Although no TCN employees were interviewed and a questionnaire survey was not conducted as part of this follow-up survey, the test and balance report, along with other pertinent ventilation data, was reviewed.

BACKGROUND

The two-story (no basement) TCN elementary/middle/high school was completed in 1990. 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 occupy 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 consisted of 114 heat pumps, controlled by a central computer system, which conditioned the air in the school. While this system is still operational, additional 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

[1] The final testing and balancing of the ventilation systems was still underway when the January 1994 NIOSH follow-up survey, requested by TCN administrators, was conducted.

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 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 constant volume 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. The gymnasium and vocational shops were not evaluated as part of this NIOSH investigation.

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 American Society for Heating, Refrigerating, and Air-Conditioning Engineers (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. The American Society for Heating, Refrigerating, and Air-Conditioning Engineers' 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 ppm). Carbon dioxide 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.

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°F in the winter, and from 73-79°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 *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. *Neither NIOSH nor OSHA currently have specific exposure criteria for VOC*

mixtures in the nonindustrial environment. 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.[23]

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. The American Society for Heating, Refrigerating, and Air-Conditioning Engineers 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.[24] An indoor air formaldehyde concentration of less than 0.05 ppm is of limited or no concern according to the World Health Organization (WHO).[25] The National Institute for Occupational Safety and Health 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 latest survey are very low and should be considered background concentrations.[12,26]

EVALUATION METHODS

ENVIRONMENTAL SURVEY

Carbon Dioxide

Carbon dioxide 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 a Gastech Model RI-411A, Portable CO_2 Indicator. This portable, battery-operated instrument monitors CO_2 via non-dispersive infrared absorption with a range of 0-4975 ppm, and a sensitivity of 25 ppm. Instrument calibration was performed 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 140°F, and 0 to 95% RH.

Total Volatile Organic Compounds

Air sampling results from the prior NIOSH evaluations conducted on October 28, 1992, February 25, 1993, and January 26, 1994, at TCN had indicated that the TVOC chromatogram pattern matched that of a liquid toner fluid used in some photocopiers. In this survey, a total of eight 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 8:00 a.m. to 3:30 p.m. The charcoal tube samples were 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

Twelve 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 0.8 micrograms of formaldehyde per sample (µg/sample). The analytical limit of quantitation is estimated at 2.3 µg/sample.

VENTILATION SYSTEM ASSESSMENT

The 1994 test and balance report prepared by the Preferred Balancing Company was reviewed, along with ventilation drawings.

RESULTS

ENVIRONMENTAL

Carbon Dioxide Levels

As shown in Figure 1, CO_2 levels averaged 843 ppm in the central pod (range 350 ➔ 1575 ppm) and 684 ppm in the north pod (range 425 ➔ 1250 ppm). These CO_2 levels suggest that, on average, most of the occupied areas of the school are receiving adequate amounts of outside air when averaged for the entire school day. While the CO_2 concentrations have declined from the high levels first measured by NIOSH at the school in October 1992, it was noted that on November 1, 1994, classrooms with a full complement of students [19 to 26 students + teacher(s)] routinely exceeded 1000 ppm (see Figure 2).

Temperature and Relative Humidity Levels

Indoor temperature and RH levels measured throughout the school day ranged from 71 ➔ 75°F and 30 ➔ 38%, respectively. These levels are within the comfort guidelines recommended by ASHRAE.

Formaldehyde

As shown in Table 1, the formaldehyde levels measured in TCN classrooms on November 1, 1994, ranged from less than 0.002 ppm (the minimum detectable concentration [MDC] for this sample set using the NIOSH Sampling and Analytical Method No. 3500) to 0.019 ppm, expressed as TWAs over the period sampled. These formaldehyde concentrations are very close to ambient levels measured outside of the school building.

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 2, of the eight area air samples collected on November 1, 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 concentration of 4.4 milligrams per cubic meter of air (mg/m^3). The concentration measured at the other location, in the elementary school administrative office, was 3.7 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.

As a review, in October 28, 1992, TVOC concentrations at TCN ranged from 1.6 to 18.3 mg/m^3 and TVOCs were detected in both administrative offices as well as 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 offices and classroom C104 containing measurable amounts of TVOC. The TVOC concentrations have declined at TCN since October 1992 and are now restricted to the elementary and high school administrative offices.

DISCUSSION

ENVIRONMENTAL

- Carbon dioxide concentrations at TCN *averaged* less than 1000 ppm on the day of this survey. However, a limited survey of classrooms with a full complement of students and teachers [approximately 20 to 25 students + teacher(s)] showed that CO_2 concentrations frequently exceeded 1000 ppm. Some of these classrooms were also below the 15 cubic feet per minute of outside air per person (15 CFM OA/person) recommended by ASHRAE standard 62-1989 to maintain acceptable indoor air quality (see Ventilation System Assessment for more information). Additional CO_2 monitoring of classrooms and an examination of the test and balance reports and other ventilation data by TCN staff may be useful in identifying areas of the school which may still not meet the ASHRAE 62-1989 ventilation criteria.

- Temperatures and RHs measured during this (and all of the NIOSH surveys) have remained very uniform and generally within the comfort guidelines recommended by ASHRAE.

- The formaldehyde concentrations at TCN on November 1, 1994, averaged 0.01 ppm, a concentration which is very close to the ambient levels outside the school building. These formaldehyde levels are unlikely to cause the health or comfort effects that some of the TCN employees have experienced. There is no need to further reduce the formaldehyde levels at the school.

- In this evaluation, quantifiable TVOC levels were only detected at locations which were near photocopiers using liquid toner. In contrast, TVOC levels measured in the NIOSH survey in October 1992 detected quantifiable TVOC 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.*

VENTILATION SYSTEM ASSESSMENT

The intent of this assessment was to estimate the amount of OA currently being supplied to TCN by reviewing pertinent ventilation data, including the 1994 test and balance report prepared by the Preferred Balancing Company. Table 3 contains both the design and actual airflow to the north and central pods. Table 4 compares CO_2 concentrations measured in selected classrooms (those with a full complement of students and teacher[s]) with the estimated amount of OA being supplied to the area. In these tables the *design airflow* refers to the amount of air the ventilation system was originally designed to provide. The *actual airflow* refers to the amount of airflow measured by the test and balance company in 1994. Typically these two values should not differ by more than 10 percent.

From this review the following conclusions were reached.

- For the north and central pods at TCN, the *design* and *actual* OA amounts were within 10% of one another.

- The estimated amount of OA per person (OA/person) for selected classrooms averaged 12 CFM of OA/person (range 5 to 25 CFM of OA/person), a level slightly below the ASHRAE indoor air quality recommendation for classrooms of 15 CFM of OA/person. The 12 CFM of OA/person, however, does exceed the ventilation level required by the Ohio Basic Building Code.

COMPARISON OF THE PREVALENCE OF SYMPTOMS AT TRI-COUNTY NORTH SCHOOL WITH OTHER NIOSH STUDIES

Table 5 compares the prevalence of symptoms at Tri-County North school (based on information gathered from the January 1994 survey) with data obtained from other NIOSH IEQ evaluations. In 1993, for example, NIOSH conducted 160 IEQ studies at a variety of non-industrial work sites, including offices, schools, libraries, and museums. Based on this comparison, the prevalence of symptoms among Tri-County North employees was extremely low.

CONCLUSIONS

At this point in time, based on the data collected during this evaluation, we see no reason for continued concern about occupancy of this school. Since the initial NIOSH evaluation conducted in October 1992, there has been continued improvement in the overall indoor environmental quality at TCN. For example, concentrations of CO_2, formaldehyde, and TVOCs have been lowered as a result of improvements in the ventilation systems at the school. The prevalence of symptoms among the TCN staff have declined from rates in 1992 that, when compared to other non-industrial work environments, were already extremely low.

Based on the results from this latest survey, however, several areas remain which could be further investigated by school personnel. The slightly elevated CO_2 concentrations measured in some classrooms may be the result of ventilation rates which are below those recommended in ASHRAE's most recently published ventilation standard (ASHRAE 62-1989, Ventilation for Acceptable Indoor Air Quality, see Table 5 for more details.) For schools, this ASHRAE standard recommends 15 CFM OA/person. Another area of interest are the TVOC concentrations which, although markedly reduced from levels first measured at the schoon 1992 and 1993, could be further lowered by utilizing local exhaust ventilation at the photocopiers using liquid toner or by replacing these copiers with machines which use a dry toner. It is the opinion of NIOSH investigators that by meeting ASHRAE ventilation guidelines and further reducing TVOC levels, employee comfort could be improved.

RECOMMENDATIONS

1. It is recommended that the school continue to measure for CO_2 since concentrations in several north and south pod classrooms exceeded 1,000 ppm during part of the school day on November 1, 1994. This monitoring should be conducted in sufficient detail to determine if CO_2 concentrations routinely exceed 1,000 ppm in rooms with a typical class size of 25 to 25 occupants. This information should then be compared with the test and balance reports and other pertinent ventilation data to determine if the ventilation rates for these areas are meeting ASHRAE criteria (See Recommendation 2).

2. It is recommended that the 1994 test and balance report prepared by the Preferred Balancing Company be reviewed to calculate the total amount of OA provided to each classroom. This recommendation is based on the fact that in this NIOSH evaluation the OA supplied to 12 classrooms was calculated and shown to vary considerably (from approximately 5 to 25 CFM of OA/person, average of 12 CFM OA/person).

   While a further reduction in CO_2 concentrations may be realized if classroom ventilation rates are slightly increased to the ASHRAE indoor air quality recommendation of 15 CFM of OA/person, it should be emphasized that increasing the amount of OA/person supplied to these classrooms will not guarantee that CO_2 concentrations will remain below 1,000 ppm at

all times during the school day. For example, several classes exceeded the 15 CFM of OA/person criterion and still had CO_2 concentrations above 1,000 ppm. In addition, increasing the ventilation rates in these classrooms to meet the current ASHRAE indoor air quality criteria would not necessarily insure employee health. Still, NIOSH considers it prudent to follow ASHRAE ventilation recommendations whenever possible.

3. The liquid toner used in photocopiers located in the elementary and high school administrative office areas is a source for VOCs. 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.

4. Since it focusses on school, the U.S. Environmental Protection Agency (EPA) publication entitled "IAQ Tools for Schools" may provide helpful guidance in maintaining acceptable indoor air quality at TCN. This document should be available from the EPA IAQ Clearinghouse beginning in 1995. The IAQ Clearinghouse telephone number is 1-800-438-4318 (FAX 301-588-3408).

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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.

Table 1
Formaldehyde Concentrations at
Tri-County North School, Lewisburg, Ohio

Sampling Conducted on November 1, 1994
HETA 95-0026

Sample No.	Location	Sample Period	Sample Volume (liters)		Concentration, ppm (parts per million)
					Formaldehyde
1	Outside the building	8:16 am to 2:04 pm	350		ND
2	Room C104 (Art Room)	8:20 am to 2:11 pm	350		0.01
3	Study Hall (Central Pod)	8:14 am to 2:14 pm	360		0.011
4	Supply Room, High School Administrative Office Side (near a photocopier)	8:02 am to 2:18 pm	377		0.019
5	Reception Area (Middle School Administrative Area)	8:29 am to 2:20 pm	350		0.017
6	Room C116 (Biology)	8:56 am to 2:32 pm	337		0.012
7	Room C114 (Lecture Hall)	8:54 am to 2:32 pm	340		0.007
8	Elementary School Office (near a photocopier)	8:37 am to 2:37 pm	360		0.014
9	Room N119	8:32 am to 2:43 pm	371		0.012
10	Room N211	8:45 am to 2:45 pm	361		0.009
11	Room N202	8:42 am to 2:49 pm	368		0.009
12	Room C204	8:50 am to 9:17 am	27		ND
Minimum *Detectable* Concentration (assuming a 360 liter air sample)					0.002
Minimum *Quantifiable* Concentration (assuming a 360 liter air sample)					0.006

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 2
Concentration of Photocopier Toner Vapor at
Tri-County North School, Lewisburg, Ohio

Sampling Conducted on November 1, 1994
HETA 95-0026

Sample No.	Location	Sample Period	Sample Volume (liters)	Concentration, mg/m^3 (milligrams per cubic meter)
				Photocopier Toner Vapor/Xylene
15	Outside building	8:16 am to 2:04 pm	35	ND
16	RoomC104(ArtRoom)	8:20 am to 2:11 pm	35	ND
17	StudyHall(CentralPod)	8:14 am to 2:14 pm	36	ND
18	Supply Room, High School Administrative Office Side (near a photocopier)	8:02 am to 2:18 pm	38	4.4
19	Reception Area (Middle School Administrative Area)	8:29 am to 2:20 pm	35	ND
20	Elementary School Office (near a photocopier)	8:37 am to 2:37 pm	36	3.7
21	Room N211	8:45 am to 2:45 pm	36	ND
22	Room N119	8:32 am to 2:43 pm	37	ND
Minimum *Detectable* Concentration (assuming a 36 liter air sample)				0.25
Minimum *Quantifiable* Concentration (assuming a 36 liter air sample)				0.83

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 3
Estimated Amount of Outside Air (in CFM) per Occupant Following the Addition of Additional Air Handling Units
Tri-County North School, Lewisburg, Ohio
HETA 950026

		Design Airflow (CFM)				Actual Airflow (CFM)			
		North Building		Central Building		North Building		Central Building	
		1st Floor	2nd Floor	1st Floor	2nd Floor	1st Floor	2nd Floor	1st Floor	2nd Floor
A	New AHU System (Supplies 100% OA)	8280	3360	10695	3565	7833	3558	10292	3828
B	Existing Heat Pump System (Supplies Recirculated + OA)	13915	15110	25605	17895	9298	11025	18351	11716
C	Estimated OA, Existing Heat Pump System	139	151	256	179	93	110	184	117
D	Total OA (Row A + Row B)	8419	3511	10951	3744	7926	3668	10476	3945
E	Estimated Occupancy (Staff + Students)	280	200	300	400	280	200	300	400
F	OA (in CFM) per occupant (Row D ÷ Row E)	30	18	37	9	28	18	35	10

Abbreviations: AHU = Air Handling UnitOA= Outside AirCFM=Cubic Feet (of Air) per Minute

Comments:

1. The percentage of OA in the total air provided by the existing heat pump systems was estimated at 10%. This was arrived at by considering the following factors: (1) the original system was designed to meet the Ohio Basic Building Code (Section M-1602.0) which requires that mechanical ventilations supplying school classrooms be able to provide at least 25 CFM of ventilation air per person, with a maximum of 67% of this ventilation air being recirculated; and (2) outside air measurements made by the Kahoe Air Balance Company at TCN in 1992 averaged approximately 10 CFM of outside air per occupant.
2. An average class size of 20 (teachers + students) was assumed. This number was then multiplied by the number of classrooms in that particular floor of the building.

Table 4
Estimated Amounts of Outside Air Per Occupant
Tri-County North School System, Lewisburg, Ohio
HETA 95-0026

Classroom	Time (p.m.)	Occupancy	CO_2 Concentration (ppm)	Outside Air		Estimated CFM of OA/Person
				New AHU System (Actual)	Existing Heat Pump System (Estimated)	
C 111	12:50	19	1025	255	51	16
C 108	12:52	21	1200	150	53	10
C 113	12:54	14	1125	195	50	18
C 110	12:56	22	1400	171	52	10
C 116	12:58	25	1025	550	64	25
C 213	1:00	26	1500	160	42	8
C 212	1:02	21	1100	180	46	11
C 211	1:04	26	1350	195	44	9
C 204	1:06	23	1425	200	42	11
C 206	1:08	21	975	205	63	13
N 203	1:10	21	1150	190	49	11
N 201	1:12	26	975	180	51	9
N 116	1:14	22	1225	195	58	12
N 120	1:16	23	825	70	56	5

Abbreviations:
AHU = Air Handling Unit
CFM = Cubic feet of air per minute
CO_2 = Carbon Dioxide
ppm = Parts per million
OA = Outside air

Comments:

1. The amount of outside air provided by each existing heat pump system was estimated at 10% of the actual total amount of air supplied to the classroom by the heat pump. The total air supplied by each heat pump system was measured by the Preferred Balancing Company in January 1994.
2. The actual amount of OA supplied by the new AHUs was measured by the Preferred Balancing Company in January 1994.

Table 5
Comparison of the Prevalence of Symptoms Occurring At Least Once a Week and Improving Away From Work
Tri-County North School System, Lewisburg, OH
HETA 95-0026

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 85 Office Buildings[d] (n=2652)	Tri-County North Sch., Lewisburg, OH[e] (n= 88)
Dry, itching or irritated eyes	27%	36%	30%	30%	**0%**
Tired or strained eyes	30%	40%	43%	33%	**1%**
Unusual tiredness, fatigue, or drowsiness	30%	33%	43%	26%	**5%**
Headache	23%	28%	25%	25%	**3%**
Sore or dry throat	28%	21%	28%	16%	**2%**
Stuffy or runny nose, or sinus congestion	24%	31%	26%	22%	**0%**
Cough	12%	5%%	11%	10%	**0%**

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. The results from these surveys, conducted in 1993, are still being analyzed and will be published by NIOSH in 1995.

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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 95-0026-
TRI-COUNTY NORTH SCHOOL
LEWISBURG, OHIO