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TRI-COUNTY NORTH SCHOOL
LEWISBURG, OHIO

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SUMMARY

In October 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation from the Tri-County North (TCN) school system, Lewisburg, Ohio. The request concerned "possible airborne pollutants causing conditions ranging from discomfort to physical reaction for some employees and students." An initial visit was made on October 16, 1992, during which a walk-through inspection was conducted of the elementary, middle, and high school classrooms. Measurements were made for temperature, relative humidity (RH), and carbon dioxide (CO_2) at various locations in the central and north sections (also called pods) at the school.

An environmental and medical follow-up evaluation was conducted on October 28, 1992, which included CO_2, temperature, and RH measurements made throughout the school day at locations in both the north and central pods. General area air samples were also collected to measure levels of volatile organic compounds (VOCs) and formaldehyde at various locations in the school. A medical evaluation included individual interviews with selected TCN employees and a questionnaire survey of all employees. A NIOSH mechanical engineer examined the heating, ventilating, and air-conditioning (HVAC) systems servicing the school. A second follow-up survey was conducted on November 9, 1992, to measure levels of acetaldehyde, bacteria, fungi, and thermophilic actinomycetes. A third survey was performed on February 25, 1993, to measure CO_2, temperature, RH, formaldehyde, and VOCs levels after changes had been made in the ventilation system at TCN.

<u>October 28 and November 9, 1992 Environmental Surveys</u>

Carbon dioxide levels consistently exceeded 1,000 parts per million (ppm) throughout the facility. These CO_2 levels suggest that the occupied areas of the school are not receiving adequate amounts of outside air. The temperature and RH levels measured were within the temperature and RH comfort guidelines recommended by American Society for Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). The formaldehyde levels measured in most TCN classrooms ranged from 0.02 to 0.04 ppm, time-weighted averages (TWAs) over the period sampled. One classroom (C113) had formaldehyde levels which ranged from 0.05 to 0.06 ppm. Formaldehyde levels in the range of 0.02 to 0.05 have been observed in other non-industrial work places which have been evaluated by NIOSH. 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. These organic compounds are commonly found in non-industrial indoor environments. No acetaldehyde was detected at the school.

<u>February 25, 1993 Environmental Survey</u>

CO_2 levels, while lower than those measured in October 1992, still exceeded 1,000 ppm throughout the facility. Temperature and RH levels ranged from 71 → 74ºF and 15 → 23% RH, respectively. The cold, dry weather on February 25, 1993 (24ºF and 10% RH) likely contributed to the lower interior RH levels. These RH levels were below the ASHRAE comfort guidelines for winter. The temperatures measured, however, were within the comfort guidelines. The formaldehyde levels in the classrooms were lower than those measured in

October 1992, averaging 0.016 ppm, TWA over the period sampled. Trace amounts of hexane, 1,1,1-trichloroethane, toluene, and trichloroethylene were measured in classrooms. 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 employee interviews 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, ten cafeteria workers, and eight 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.

The ventilation assessement indicated that the occupied spaces of the TCN facility received an inadequate amount of outside air (OA) per person. This conclusion is supported by CO_2 levels in excess of 1000 ppm during the school day.

Data gathered during this evaluation suggests that the amount of outside air supplied to the *occupied areas* remains below the ASHRAE recommended building ventilation design criteria for classrooms. The principal NIOSH recommendation is to increase the amount of OA to the occupied spaces of the school, an improvement which should also further reduce the levels of TVOCs, formaldehyde, and any other air contaminants in the building. Other recommendations include controlling the solvent emission from the photocopiers at the school which use liquid toner solution, increasing the amount of relief ventilation for the school, improving access to ventilation system components, using more efficient filter media, and establishing a formal preventive maintenance schedule.

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

INTRODUCTION

In October 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation from the superintendent of the Tri-County North (TCN) school system, Lewisburg, Ohio. The request concerned "possible airborne pollutants causing conditions ranging from discomfort to physical reaction for some employees and students."

An initial visit to the school by NIOSH investigators was made on October 16, 1992, during which an opening conference was held with the school superintendent and union officials representing the Tri-County North Teachers Association and the Ohio Public School Employees. Following this meeting, a brief walk-through inspection was conducted in all sections of the school (elementary, middle, and high school classrooms). During this walk-though inspection, measurements were made for temperature, relative humidity (RH), and carbon dioxide (CO_2) at various locations in the central and north sections (pods) at the school. The ventilation system was qualitatively examined.

Based on the information gathered from the initial visit, an environmental and medical follow-up evaluation was conducted on October 28, 1992. The environmental survey included the collection of CO_2, temperature, and RH measurements throughout the school day at locations in both the north and central pods. General area air samples were also collected to measure levels of volatile organic compounds (VOCs) and formaldehyde at various locations in the school. The medical evaluation included interviews with TCN employees and a questionnaire survey. A NIOSH mechanical engineer, working with TCN maintenance personnel, examined of the heating, ventilating, and air-conditioning (HVAC) systems servicing the school.

An interim report, which discussed the CO_2, temperature, and relative humidity measurements, the qualitative results from the air samples collected for VOCs, the employee interviews, the questionnaire data, and the ventilation system at the school, was sent to school and union officials in November 1992. A second report, containing quantitative results from air samples collected for selected VOCs such as hexane, 1,1,1-trichloroethane, toluene, and trichloroethylene, was distributed on December 12, 1992.

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 1125 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 SYSTEM

Description

The TCN school uses 114 heat pumps, controlled by a central computer system, to condition the air in the school. Virtually every classroom and office suite has its own heat pump. Some of the larger rooms, such as the auditorium, are served by two 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 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.

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.

Provision for Outside Air

Two methods are used to supply outside air to the building. For large areas, such as the gymnasiums, the heat pumps pull air directly from the outside. For heat pumps serving the classrooms, locker rooms, and office suites, dedicated heat pumps pull outside air into the building, preheat the air (if needed), filter and condition the air, and then deliver 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.

Rooms without exhausts are designed to be under positive pressure (air flows out of the rooms). Air which is not recirculated flows from the rooms through leaks in the outside walls or into the interior hallways. Air entering the hallways flows to locations with exhaust systems or exits the building through leaks in the outside walls. No relief vents were installed on the school's roof .

Filters

The filter media used for the classroom, office suite, and outside air heat pumps was made from vinyl-coated hog or horse hair. It has an American Society for Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) dust spot test efficiency of less than 20%, similar to oil-coated, metal mesh filters. Classroom and office suite filters were usually located in the return duct near the return grilles. Filters are wedged in the duct without a supporting frame. Each hog's hair filter is replaced about every three weeks with filters which were previously removed and cleaned. New filter media is stiff and self supporting. Filters are replaced when they lose their stiffness and will not stay in place in the duct.

The filters for the heat pumps which serve large areas, such as the gymnasiums, use 1" thick fiberglass panel filters similar to those used in home furnaces. This type of filter also has an ASHRAE dust spot test efficiency of less than 20%. Filters for these heat pumps are located at the entrance to the units. Used panel filters are discarded and replaced with new filters.

Heating and Cooling Operation

All of the heat pumps are supplied with temperature-controlled water from two mechanical rooms. The heat pumps use the water for a heat sink or heat source depending on whether the heat pump is in the cooling or heating mode, respectively. A temperature sensor in each room relays temperature information to a central computer. The computer places each heat pump into the heating or cooling mode depending on the set-point limits in the central computer.

The water returning from the heat pumps, depending on its temperature, is either tempered in a shell and tube heat exchanger or is heated in a series of boilers in one of the mechanical rooms. The number of boilers in operation varies with the heating demands. In the shell and tube heat exchangers, the heat pump return water transfers heat to or from water from the cooling tower systems. Cooling tower water, after transferring heat with the heat pump return water, is pumped from the heat exchanger to cooling towers on the school roof and back to reservoirs in the mechanical rooms. After tempering, the water is supplied to the heat pumps.

Cooling tower water is treated in the reservoirs with descaling, antimicrobial and algicide agents before being pumped back into the heat exchanger systems. In the heat exchanger, heat pump water is not mixed with the treated cooling tower water.

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) 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 relative humidity 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 carbon dioxide (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.

<u>CARBON DIOXIDE</u>

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 cubic feet per minute per person (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]). 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. 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°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 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.

Indoor environmental quality studies have measured wide ranges of VOC concentrations in indoor air as well as differences in the mixtures of chemicals which are present. Research also suggests that the 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.

Some researchers have compared levels of TVOCs with human responses (such as headache and

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.	

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.

MICROBIOLOGICAL CONTAMINANTS

Microorganisms (including fungi and bacteria) are normal inhabitants of the environment. The saprophytic varieties (those utilizing non-living organic matter as a food source) inhabit soil, vegetation, water, or any reservoir that can provide an ample supply of a nutrient substrate. Under the appropriate conditions (optimum temperature, pH, and with sufficient moisture and available nutrients) saprophytic microorganism populations can be amplified. Through various mechanisms, these organisms can then be disseminated as individual cells or in association with soil/dust or water particles. In the outdoor environment, the levels of microbial aerosols will vary according to the geographic location, climatic conditions, and surrounding activity. In a "normal" indoor environment, the level of microorganisms may vary somewhat as a function of the cleanliness of the HVAC system and the numbers and activity level of the occupants. Generally, the indoor levels are expected to be below the outdoor levels (depending on HVAC system filter efficiency) with consistently similar ranking among the microbial species.[24,25]

Some individuals manifest increased immunologic responses to antigenic agents encountered in the environment. These responses and the subsequent expression of allergic disease is based, partly, on a genetic predisposition.[26] Allergic diseases typically associated with exposures in indoor environments include allergic rhinitis (nasal allergy), allergic asthma, allergic bronchopulmonary aspergillosis (ABPA), and extrinsic allergic alveolitis (hypersensitivity pneumonitis).[24] Allergic respiratory diseases resulting from exposures to microbial agents have been documented in agricultural, biotechnology, office, and home environments.[27,28,29,30,31,32,33,34]

Individual symptomatology varies with the disease. Allergic rhinitis is characterized by paroxysms of sneezing; itching of the nose, eyes, palate, or pharynx; nasal stuffiness with partial or total airflow obstruction; and rhinorrhea (runny nose) with postnasal drainage. Allergic asthma is characterized by episodic or prolonged wheezing and shortness of breath in response to bronchial (airways) narrowing. Allergic bronchopulmonary aspergillosis is characterized by cough, lassitude, low-grade fever, and wheezing.[24,35] Heavy exposures to airborne microorganisms can cause an acute form of extrinsic allergic alveolitis which is characterized by chills, fever, malaise, cough, and dyspnea (shortness of breath) appearing four to eight hours after exposure. In the chronic form, thought to be induced by continuous low-level exposure, onset occurs without chills, fever, or malaise and is characterized by progressive shortness of breath with weight loss.[36]

Acceptable levels of airborne microorganisms have not been established, primarily because allergic reactions can occur even with relatively low air concentrations of allergens, and individuals differ with respect to immunogenic susceptibilities. The current strategy for on-site evaluation of environmental microbial contamination involves an inspection to identify sources (reservoirs) of microbial growth and potential routes of dissemination. In those locations where contamination is visibly evident or suspected, bulk samples may be collected to identify the predominant species (fungi, bacteria, and thermoactinomycetes). In limited situations, air samples may be collected to document the presence of a suspected microbial contaminant. Air sample results can be evaluated epidemiologically by comparing those from the "complaint areas" to those from non-complaint areas, or by relating exposure to immunologic findings.

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.

Symptoms

Symptoms 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 preexisting 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 developed specially to formaldehyde are uncommon.[37]

Non-occupational Exposure Assessments to Formaldehyde

It is not unusual for indoor levels of formaldehyde to typically exceed outdoor levels.[38] 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 irritation 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.[39]

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.[40] 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.[41] An indoor air formaldehyde concentration of less than 0.05 ppm is of limited or no concern according to the World Health Organization (WHO).[42] 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.

EVALUATION METHODS

ENVIRONMENTAL SURVEYS (10/28/92 AND 11/9/92)

Carbon Dioxide

Carbon dioxide (CO_2) measurements were obtained throughout the school day on floors 1 and 2 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 a Vaisala, Model HM 34, battery-operated meter. This meter is capable of providing direct readings for dry bulb temperature and RH ranging from -4 to 140^{o}F, and 0 to 100%, respectively.

Volatile Organic Compounds

A total of 18 general area air samples were collected on October 28 for VOCs. Since concentrations of VOCs were expected to be low, Carbotrap® 300 stainless steel thermal desorption (TD) tubes, configured for the Tekmar® 5010 thermal desorber system, were used to sample at eight locations in the north and central pods of the school. Each TD tube contained three beds of sorbent materials: (1) a front layer of Carbotrap C; (2) a middle layer of Carbotrap; and (3) a back section of Carbosieve S-III. The samples were analyzed using the Tekmar thermal desorber interfaced directly to a gas chromatograph and a mass selective detector. Each sample tube was desorbed at 400NC for ten minutes. Known concentrations of several common solvents were prepared and analyzed among with this sample set to *estimate* concentrations.

The extremely sensitive TD method can identify VOCs present in the parts per billion range but does not indicate the *quantity* of these chemicals. To quantitate the airborne levels of the VOCs present on October 28, 1992, ten air samples were collected at locations throughout the north and central pods using activated charcoal as the sorbent material. Based on the qualitative TD results, these charcoal tube air samples were prepared and analyzed for carbon tetrachloride, benzene, hexane, 1,1,1-trichloroethane, toluene, trichloroethylene, total hydrocarbons (photocopier toner fluid + xylene), and siloxanes using a combination of NIOSH Sampling and Analytical Methods Nos. 1550 and 1501. Each sample was desorbed with carbon disulfide and analyzed by flame ionization gas chromatography using a fused silica capillary column.

Formaldehyde

Sixteen 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 through a 1% sodium bisulfite solution, and subsequent analysis using an ultraviolet spectrophotometer. This is the most sensitive analytical method for formaldehyde to date.

The limit of detection (LOD) for this sample set is estimated at 0.5 micrograms of formaldehyde per sample (µg/sample). The limit of quantitation is estimated at 1.4 µg/sample.

Microbiological Contaminants

Visible evidence of microbial contamination, standing, or leaking water was not apparent at TCN on October 28, 1992. Since the school was first occupied, however, problems have periodically arisen in inadequate drainage of the condensate pans from the HVAC systems. Additionally, during this time period two roof leaks have occurred. Any damage resulting from these water leaks has been corrected.

On November 9, 1992, microbial samples were collected at four locations inside the school (classrooms C-216, C-108, S-106B, and N-115). Samples were also collected from one location outside the building near the central pod air intake. Three sample runs were conducted in each classroom, and four sample runs were completed at the outside location. A sample run consists of a collection period of ten minutes and is defined as the simultaneous collection of samples for airborne fungi, bacteria, and thermoactinomyces (TA).

To determine the concentrations of airborne fungi and bacteria, the Andersen 2-stage viable cascade impactor was used at a calibrated flow rate of 28.3 liters per minute (lpm). The 50% effective cutoff diameter for the Andersen two-stage sampler is 8 µm, therefore, larger, non-respirable particles are collected on the top stage and smaller, respirable particles are collected on the bottom stage. The Andersen single-stage viable cascade impactor was used for the collection of TA's at a calibrated flow rate of 28.3 lpm. The Andersen single-stage is designed to collect particles 0.65 µm and larger. Standard Plate Count and Malt Extract agars were used for enumeration of bacteria (including TA's) and fungi, respectively. The sample plates for fungi and bacteria were incubated at 30°C. The sample plates for TA's were incubated at 55°C. The taxa of the microorganisms collected was identified by three different methods: Microlog's Biolog® system was used for bacteria, morphological identification for fungi, and incubation and visual inspection for TA's.

ENVIRONMENTAL SURVEY (2/25/93)

Real-time measurements for CO_2, temperature, and RH were made in selected classrooms in the north and central pods. These measurements were made between 11:15 a.m. and 2:50 p.m. using the same monitoring equipment that was used in the previous evaluations at the school.

General area air samples for formaldehyde (average sampling period of 188 minutes; average sample volume 188 liters) were collected in 14 classrooms following NIOSH Sampling and Analytical Method No. 3500. Classrooms in which formaldehyde samples were not collected during the first follow-up visit were included in this series of sampling.

General area air samples were collected to quantitatively measure levels of VOCs using both charcoal tubes and thermal desorption (TD) tubes. The charcoal tube air samples were prepared and analyzed for the same group of chemicals as during the initial follow-up survey, using a combination of NIOSH Sampling and Analytical Methods Nos. 1550 and 1501. In conjunction with the charcoal tube samples, Carbotrap 300® thermal desorption tubes (consisting of a three bed sorbent containing Carbotrap C/Carbotrap/Carbosieve S-III materials for trapping VOCs over a wide range of volatility) were also used. Each Carbotrap tube was thermally desorbed using a Supelco Dynatherm thermal desorption unit and subsequently analyzed using gas chromatography/ mass spectrophotometery (GC/MS). In contrast to the qualitative-only TD analytical method used in the October 28, 1992, survey, the TD analytical technique selected for the February 2, 1993, follow-up survey was also quantitative (VOCs present in the parts per billion range could be *both identified and measured*).

MEDICAL

During the initial visit on October 16, 1992, private interviews were held with five teachers, four of whom had been identified as possibly having experienced building related health problems.

During the second site visit on October 28, 1992, a self-administered questionnaire was distributed and collected from all teachers, administrative personnel, cafeteria workers, and custodial employees who were at work on that date. The questionnaire asked if the employee had experienced, while at work on the day of the survey, any of the 13 symptoms commonly reported by occupants of "problem buildings." The questionnaire also asked about the frequency of occurrence of these symptoms while at work during the four weeks preceding the survey, and whether these symptoms tended to get worse, stay the same, or get better when the respondent was away from work. A separate section of the questionnaire asked about environmental comfort (too hot, too cold, unusual odors, etc.) experienced while the employees were working in the school building during the four weeks preceding the questionnaire administration.

VENTILATION

The main ventilation issue was the elevated CO_2 concentrations in the school. Investigation of the ventilation systems, therefore, centered around trying to determine the reason for the elevated levels. The investigation included the following areas.

1. The outside air dampers were checked to assure that they were open. Outside air inlets were also checked to determine if recirculation of exhaust air was influencing the CO_2 concentrations.

2. A Roscoe® Fog Machine (model number 1500) was used in one classroom (C107) to determine if supply air was short-circuiting to the return system. The fog machine permits visualization of the air flow patterns by generating a low-toxicity aerosol (commonly referred to as smoke.) Smoke was released into the return grille of the classroom and observed as it flowed into the room with the supply air. In addition, smoke was generated at the door of the classroom to verify that the room was under positive pressure (air flows from the room) and in the hallway outside of the classroom to determine the direction of the air flow outside of the classroom.

3. Several first floor classrooms (see Figure 1 for the location of these rooms) in the central pod had CO_2 levels which eventually exceeded 2500 ppm on October 28, 1992. After verifying that the outside air damper for the branch was open and that no other dampers in the branch existed, the outside air heat pump for the branch was examined to determine if the unit had operational problems.

4. Measured air flows (obtained from a Test and Balance report prepared by the Kahoe Air Balance Co., dated October 19, 1992), design air flows, and CO_2 concentrations measured during the survey were analyzed.

5. Operation and maintenance procedures for the HVAC system were discussed with mechanical personnel.

RESULTS

ENVIRONMENTAL

Carbon Dioxide Levels

As shown in Table 3, CO_2 levels on October 28, 1992, increased quickly during the school day and consistently exceeded 1,000 ppm throughout the facility. These CO_2 levels suggest that the occupied areas of the school are not receiving adequate amounts of outside air. The data also indicate that the CO_2 concentrations in the building leveled off after reaching a maximum concentration ranging between 1500 and 2000 ppm. However, during the afternoon of October 28, 1992, CO_2 levels ranging up to 4000 ppm were measured in classrooms C-111, C-107, C-113, and C-110. These elevated CO_2 levels were due, in all likelihood, to a backward running supply fan in the heat pump which supplied outside air to this corridor of first floor classrooms. By operating in reverse, the fan was not providing the designed amount of outside air to this part of the school building. Once discovered, the operation of this fan was immediately corrected by the school's maintenance staff.

Measurements for CO_2 were made twice during the school day (late morning and early afternoon) during the follow-up survey on February 25, 1993. As shown in Table 4, CO_2 concentrations, while still exceeding 1000 ppm in the classrooms, were slightly lower than levels measured in October 1992.

Temperature and Relative Humidity Levels

Table 5 contains the temperature and RH levels measured on October 28, 1992. These measurements were within the temperature and RH comfort guidelines recommended by ASHRAE. The temperatures and RH levels measured at TCN on February 25, 1993, ranged from 71 → 74°F and 15 → 23% RH, respectively. In contrast to the milder ambient temperature and RH on October 28, 1992, the colder and drier weather conditions on February 25, 1993 (24°F and 10% RH) contributed to the lower RH levels in the school (below the ASHRAE comfort guidelines for winter conditions).

Formaldehyde

As shown in Table 6, the formaldehyde levels measured in TCN classrooms on October 28, 1992, ranged from 0.017 to 0.058 ppm, expressed as time-weighted averages. The highest formaldehyde concentrations were measured in C113, one of the group of first floor/central pod classrooms which had CO_2 levels ranging up to 4,000 ppm. For comparison, formaldehyde levels measured outside the school ranged from 0.004 and 0.006 ppm (levels between the minimum detectable and minimum quantifiable concentrations for this sampling and analytical method).

Table 6 also contains the formaldehyde levels measured in 14 classrooms during the follow-up survey conducted on February 25, 1993. Formaldehyde concentrations ranged from 0.011

→ 0.023 ppm (no formaldehyde sample was collected outside the school because of the extreme cold). On average, formaldehyde levels measured in February 1993 were approximately 50% lower than those measured at TCN in October 1992.

Volatile Organic Compounds (VOCs)

- Qualitative Screening

  Copies of the reconstructed total ion chromatograms from the eight TD samples collected in the TCN facility (with peaks labelled) obtained from the gas chromatograph-mass selective detector are presented in Figure 2. Since the compounds identified were similar for all samples, only the major components are numbered on all chromatograms. Table 7 lists each peak number from the chromatograms with its corresponding identification. A hydrocarbon pattern was detected on several of the TD tubes which was attributed by NIOSH chemists to a liquid dispersant used in some photocopier machines. The detection limits for the various solvents under these conditions appeared to be approximately 50 nanograms per sample.

- Quantitative Analysis

  The quantitative results obtained from VOC sampling performed on October 28, 1992, and February 25, 1993, are shown in Tables 8 and 9. Very low levels (parts per billion, ppb) of hexane, 1,1,1-trichloroethane, toluene, and trichloroethylene were measured in the north and central pods during both surveys. These organic compounds are commonly found in trace amounts in indoor environments. Substantially higher levels of decane were measured during the February 1993 survey in two locations: 1) a photocopier/storage room near the high school administrative office in the central pod; and 2) in the elementary school administrative office located in the north pod. A photocopier which used liquid toner was present in both of these locations.

  In addition to the identification and quantification of individual chemicals at TCN, additional air samples were also analyzed for total VOCs (TVOC). 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. Since xylene eluted in the same area as the toner fluid, the results of the xylene peaks were added with those of the toner fluid and reported together.

  Using the above TVOC definition, the levels measured in the north and central pods of the school on October 28, 1992, averaged 8.0 milligrams per cubic meter of air (mg/M^3) and ranged from 1.6 mg/M^3 (room C205) to 18.3 mg/M^3 (room C104). As Table 10 shows, TVOC levels were measured at all sample locations in the school on October 28, suggesting a somewhat uniform distribution. In contrast, TVOC sampling conducted on February 25, 1993, measured levels in only 3 of 8 interior sampling locations. As shown in Table 11, these locations included the high school administrative office area in the central pod, the elementary school administrative office in the north pod, and the art classroom (C104). As previously mentioned, a photocopier which used liquid toner was located in both administrative office areas. The third location, classroom C104, was situated near the high school administrative area.

Microbiological Contaminants

Indoor bioaerosol concentrations may reflect the incursion of outdoor bioaerosols in the absence of indoor sources or reservoirs. Therefore, in most buildings, the indoor bioaerosol concentrations should be substantially lower than the concentrations found outside.[43]

The results of the bioaerosol sampling for fungi are summarized in Figure 3 and detailed in Table 12. The outdoor sample showed a mean total fungal count of 975 colony forming units per cubic meter (CFU/M^3). The most numerous genus in the outdoor samples was *Cladosporium*. Also identified in the outdoor samples at lesser concentrations were the genera *Alternaria*, *Penicillium,* and *Aspergillus*. Unspeciated colonies of yeast were detected, as well. The levels of fungi detected indoors were considerably lower, with the indoor levels less than one third of the outdoor levels in all of the samples.[44] Qualitatively, the molds that were detected in the indoor air were similar to outdoors, which included *Cladosporium, Penicillium, Aspergillus,* and *Alternaria*, along with a few other common saprophytic molds.

The results of the bioaerosol sampling for bacteria are summarized in Figure 4 and detailed in Table 12. The outdoor sample showed a mean total airborne bacteria count of 16 CFU/M^3. Among the taxa identified in the outdoor samples were *Staphylococcus hominis* and *kloosii*, *Bacillus pasteurii,* and *Coryne*. Although the indoor samples were higher than the outdoor samples for bacteria, the levels found were still much lower than levels usually associated with hypersensitivity pneumonitis. Gram-positive bacteria, such as *Staphylococcus* and *Corynebacterium* species, can be found as normal flora on human skin, and during the normal activities of a work-day most people would shed thousands of these bacteria into the air.[45] Therefore, the presence of these bacteria in the air generally reflects human activity, rather than some building-related source. *Staphylococcus* species was common in room C-216, as well as in room C-108, and *Corynebacterium* species was detected in room N-115.

MEDICAL

The interviews revealed that several teachers had experienced severe symptoms (e.g., respiratory difficulty, impaired ability to concentrate, nausea, severe headaches) that had affected their work. One employee had missed a considerable number of work days because of the severity of her symptoms.

On October 28, 1992, a self-administered questionnaire was distributed and collected from all teachers and administrative personnel (75), cafeteria workers (10), and eight custodial employees (8), who were at work on that day. Table 13 shows the percentage of middle and high school workers (teachers and administrative personnel), elementary school workers (teachers & administrative personnel), cafeteria workers, and custodial employees who reported the occurrence of symptoms while at work on the day of the survey. Overall, the teachers and administrative personnel tended to report more symptoms, with the most commonly reported symptoms being headache, unusual fatigue, nasal congestion, dry and sore throat, and tired or strained eyes.

Table 14 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. In general, the results are similar to the responses shown in Table 13 for the day of the survey; the teachers and administrative personal reported more symptoms than the cafeteria and maintenance personnel.

Table 15 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 away from work. This latter criterion has, in some studies, 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 addition of the criterion regarding symptom improvement when away from work markedly decreases the percentage of positive responses for individual symptoms; however, as Table 16 shows, even when using this restrictive criterion, many employees still reported experiencing one or more "building related" symptoms. Table 16 shows the number of employees who had one or more symptoms that occur at work at least once a week and that tended to get better when away from work. Twelve (29%) of the 42 middle and high school employees reported experiencing one or more such symptoms, and 13 (39%) of the 33 elementary school respondents did likewise.

Table 17 shows the responses to the questions about environmental comfort in the school buildings. Complaints about environmental conditions (too hot, too cold, odors, etc.) were considered present (for the purposes of tabulation) if they occurred at work once a week or more. In general, few employees had frequent complaints about the temperature, humidity, or presence of unusual odors. However, some cafeteria personnel did report problems with being too hot or too cold.

VENTILATION

Outside Air Dampers

The outside air dampers, readily accessible in one of the HVAC systems at the school, were visually checked and found to be open on October 28, 1992. For the remaining systems, direct visual inspection of the position of the outside air dampers was not performed as part of this evaluation. Instead, damper position indicators were checked. While these indicators suggested that the outside air dampers for the remaining systems were fully open, not all of the indicators clearly showed the damper position. For example, damper position is normally indicated by a line on the damper shaft which is parallel to the damper blade. While a few of the dampers were marked in such a manner, most had a collar on the shaft with an indicator pointing to a scale which ranged from 0 to 90. School administrators and maintenance personnel were unsure what this scale represented, making it difficult to easily determine the outside air damper position.

Outside Air Intakes

Several of the outside air intakes were located on the roof. One rooftop outside air intake, which served the south pod, had numerous exhaust vents located near it. Some of these were suspected to be sanitary vents because of their proximity to the restroom in the south pod.

The height of these vents (approximately 12 inches) and their close proximity to the outside air intake make recirculation from the vents to the outside air intake possible.

Outside Air Heat Pump (Central Pod)

A fan situated inside a heat pump which provided outside air to the group of classrooms with the inordinate CO_2 concentrations on October 28, 1992, (>2500 ppm CO_2) was running backwards. The operation of this outside air heat pump unit was immediately corrected by the TCN maintenance staff. While the cause for this apparent malfunction should be further investigated, it was theorized by TCN maintenance personnel and NIOSH investigators that the classroom heat pump fans were being turned on before the outside air heat pump's fan, a situation which could cause the outside air heat pump's fan to turn backward.

Relief Vents

The school was not equipped with relief vents normally found on one and two story buildings. Relief vents provide a route for surplus air to exit the building. Without these vents, doors may be hard to open, whistling of air exfiltrating through cracks may be a nuisance, and the distribution of outside air through the building may be hindered. Building personnel reported that when a relief route is provided for air through a roof access door located in a mechanical room in the south pod, air rushed out of the access door.

Air Flow/Ventilation Smoke Testing

The smoke testing conducted in C107 demonstrated that short-circuiting between the supply and return was not a problem. However, this testing showed that the smoke was very slow to disperse, indicating that poor ventilation of the room may be contributing to the elevated CO_2 concentrations. Other smoke testing results showed that the room was under positive pressure, and air entering the hallway dispersed evenly to both sides of the door. No distinct pattern of air flow to the nearest exhaust (in bathrooms) was obvious.

Filters

The filters used in all of the units are adequate to stop large particles. Smaller particles, however, could pass through the filter until it became dirty enough to filter out the smaller particles. Dust which gets past the filter can settle out on the interior surfaces of the heat pumps, affecting efficiency and increasing energy and maintenance costs. Dust loading inside the ventilation system can also serve as a substrate for bioaerosol growth or can become a nuisance when it dislodges and is blown into the building.

The units serving larger areas did not have end caps over the filter plenums. Without the caps, unfiltered air can possibly enter the unit, leading to buildup of debris on the coil and in the unit.

Condensate Drains

Condensate drains on the units had traps and were connected to central drain lines. Installation instructions for the drains in the heat pump literature was not very specific about the depth of the trap or the correct installation of a central drain. School personnel reported that some of the central drain lines ran uphill from some units, reportedly causing condensate water to run down into those units. The central drains also did not have vents. Without vents, water in the central lines could be prevented from draining. The depth of the trap is a problem when the depth is not greater than the suction pressure of the fan because condensate could be prevented from draining. If the unit does not drain, water can overflow the condensate pan, saturate the interior insulation of the unit, and eventually drip out of the unit onto ceiling tiles and floors.

Maintenance

One mechanic is responsible for maintaining and repairing all 114 heat pumps. This manpower level is inadequate to properly care for the HVAC system at the school.

DISCUSSION AND CONCLUSIONS

VENTILATION ASSESSMENT

NIOSH investigators determined that the Ohio Basic Building Code (OBBC) ventilation design criteria in existence when the TCN school was initially designed and constructed required 5 cfm of OA per person for classrooms. This contrasts with the current ASHRAE building ventilation design criteria (62-1989) recommends 15 cfm of OA/person for spaces such as classrooms to maintain acceptable indoor environmental quality.

Section M-1602.0 of the current OBBC requires that mechanical ventilation systems 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 (OBBC Section M-1603.0). This equates to 8.3 cfm of OA per person for school classrooms, a level which is still below the ASHRAE recommended design guideline of 15 cfm/OA/person.

Analysis of the Amount of Outside Air Supplied To The School

To further examine the ventilation effectiveness at TCN, a comparison was made between the

Table 18

COMPARISON BETWEEN DESIGNED AND MEASURED SPACES

Design OA = 9,125 cfm
Measured OA = 11,701 cfm (for areas measured)
This equates to 28% more measured OA than designed.

ESTIMATION OF ACTUAL OA FOR ENTIRE BUILDING

Building design OA: 21,175 cfm
Estimated actual OA: 21,175 × 1.28 = 27,153 cfm

ESTIMATED CFM/OA/PERSON

Estimated actual OA: 27,153 cfm
Staff & Students: ≈ 1225
This equates to ≈ 22 cfm/OA/person (27,153 cfm ÷ 1225)

design and measured OA for the school. Measured OA data were available for approximately 75% of the classrooms and other spaces of TCN. These data were then compared to the design OA for these same areas of the building. Assuming that the difference between the design and actual OA for these spaces was representative for the entire building, an estimate for the actual OA being supplied to TCN was calculated.

As shown in Table 18, the actual OA measurements exceeded the design values by approximately 28% (meaning that 28% more OA was being supplied to the school than what was originally designed). Dividing the estimated actual building OA by the number of occupants (≈ 1225) equates to approximately 22 cfm of OA per person. For comparison, using the lower building *design* OA value equates to approximately 17 cfm of OA per person. Both of these OA ventilation rates exceed the ASHRAE guideline of 15 cfm of OA per person.

Analysis of the Amount of Outside Air Supplied to Occupied Spaces

In addition to evaluating the total amount of OA supplied to the entire school, an analysis of the quantity of OA supplied per person by classroom was made using measured air flows obtained from a Test and Balance report prepared by the Kahoe Air Balance Co. (report dated October 19, 1992). Population counts and class schedules by day of the week for grades 1 through 8 were provided by school personnel. To account for the influence of different class sizes, lunch, recess, and teacher preparation time, a time-weighted average (TWA) population for each classroom was calculated. Intervals when no one was in the classroom were factored into the TWA populations (as zeroes) since CO_2 levels decrease in unoccupied spaces supplied with outside air. In some classrooms the OA per person was calculated in two ways. The first was for days when the children went outside the school for recess every day of the week. The second way was when they stayed inside every day. Actual conditions should be somewhere between these two values.

As shown in Table 19, the amount of OA per person ranged from 7 to 10 cfm when calculated by classroom, a significant decrease from the 20 cfm of OA per person when the OA supplied to the *entire* school was divided among all of the occupants. One possible explanation for this discrepancy is that the heat pumps for the classrooms are directly supplied with OA from dedicated air systems, and return air for the each classroom's heat pump is taken from the classroom. Since the classrooms were originally designed to be under positive pressure, OA cannot infiltrate through walls, and any excess OA in the building (but outside of the classroom) cannot enter into the classroom heat pump systems. Therefore, the only sources of OA for the classrooms is from the heat pump system which serves those classrooms. Any excess OA is removed from the building by exhaust systems and exfiltration through leaks in the building envelope.

ENVIRONMENTAL RESULTS

- Carbon dioxide (CO_2) concentrations throughout the north and central pods increased quickly during the school day, leveling off between 1500 and 2000 ppm. NIOSH investigators consider indoor CO_2 levels in excess of 1000 ppm as suggestive that the occupied areas of the school are not receiving adequate amounts of outside air. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased.

- The temperature and RH levels measured on October 28, 1992, were within the comfort guidelines recommended by ASHRAE.

- The formaldehyde levels at TCN on October 28, 1992, averaged 0.036 ppm. Formaldehyde levels on February 25, 1993, averaged 0.016 ppm, a decrease of approximately 50% from the previous survey. These levels have been measured by NIOSH investigators in other non-industrial work places. It is unclear what health or comfort effects may result from exposures to formaldehyde at these low concentrations. Comparing the formaldehyde results from the October and February surveys, the levels have declined and are approaching ambient levels. As noted earlier in this report, it is not unusual for indoor levels of formaldehyde to exceed outdoor levels.

  Ventilation changes in the school designed to increase the amount of OA per person (for the occupied spaces) should further reduce these formaldehyde levels. It is the opinion of NIOSH investigators that any ventilation modifications/changes should be made with the intention of satisfying the ASHRAE recommended building ventilation design criteria (62-1989) for classrooms and not exclusively for reducing the formaldehyde levels at TCN.

- The low levels of hexane, 1,1,1-trichloroethane, toluene, and trichloroethylene found in air sampling conducted at TCN have been routinely measured in other non-industrial indoor environments. Exposure to these individual chemicals at such low concentrations would not be expected to cause health effects in the majority of the population. The levels of decane measured in several locations at TCN, however, were higher than what may typically be measured in non-industrial work places. The decane likely originated from the liquid toner fluid used in the photocopiers located in the administrative offices for the elementary and high schools.

- Levels of total volatile organic compounds (TVOCs) were measured during this evaluation in a range where some irritation or discomfort may occur in some individuals. Some of the TVOCs measured at TCN were attributed to a liquid dispersant used in some brands of photocopiers. It is not known by NIOSH investigators why TVOC levels were relatively pervasive through the school on October 28, 1992, averaging approximately 8 mg/m^3 in the classrooms and offices tested in the north and central pods. In the follow-up survey conducted in February 1993, TVOC levels were measured only in locations which were near photocopiers which used liquid toner. *While NIOSH investigators do not at this time recommend a target TVOC level under which no health effects are expected, it is nonetheless recommended that TVOC levels at TCN be reduced.* Control alternatives have been suggested in the Recommendations section of this report.

- The results of air sampling for microorganisms showed no evidence of any significant indoor building reservoirs of bacteria or fungi which would constitute a significant health risk. The presence of *Enterobacter* species in Room C-216 indicates that possible water damage occurred in this area at one time, either to the carpeting ceiling tile, or the HVAC system which could potentially support bacterial growth. An additional source could be resulting from the dissemination of bacteria from standing water in the HVAC system. Although the levels which were found were low, a potential problem could arise if the situation above existed and growth were to continue.

MEDICAL RESULTS

During the present school year, there has been much concern about symptoms being experienced by TCN students and school employees while they are in the building. The questionnaire survey showed that many workers had frequently experienced symptoms (e.g., headache, nasal congestion, eye irritation) while in the building and that, in many cases, symptoms tended to get better when they were away from the building. One third of the teachers reported having frequently experienced one or more such "building related" symptoms.

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

RECOMMENDATIONS

1. Increase the amount of outside air supplied to the *occupied areas* of the TCN school. This will require careful evaluation by a mechanical engineering firm to determine the amount of outside air currently being provided as well as assessing the capabilities and limitations of the existing system to provide additional outside air. At TCN, the environmental data collected by NIOSH investigators suggest that an inadequate amount of OA is currently being supplied to the *occupied* areas of the school. The amount of OA air to the classrooms, administrative offices, and other occupied areas of the school should be increased to levels recommended by ASHRAE 62-1989 (15 cubic feet of OA per person).

2. Increase the amount of relief ventilation for the TCN facility. The utility of installing relief vents should be investigated by a qualified mechanical firm with consultation from manufacturers of relief vents. The relief vents should be equipped with backdraft dampers which are set to maintain a slight positive pressure in the building.

3. The levels of TVOCs should be reduced. This may be accomplished by such means as ventilation (either general, local, or both), air cleaning, source removal, and source modification. Among these control alternatives, ventilation is perhaps the most frequently employed solution. At TCN, the environmental data suggest that the photocopiers which use liquid toner are a sigificant contributor to the TVOC levels. Local exhaust ventilation is recommended to control the solvent emission from the photocopiers which use liquid toner. It is also reasonable to expect that by increasing the amount of OA air to the classrooms, administrative offices, and other occupied areas of the school to levels recommended by ASHRAE 62-1989 (15 cubic feet of OA per person), TVOC levels should decrease. The ventilation changes made at TCN between October 1992 and February (increasing the amount of outside air introduced into the school, increasing the exhaust ventilation in the restrooms, and opening exterior windows in the evenings (after normal school hours) may have contributed to the decline in TVOC levels in classrooms.

4. Accesses to all outside air dampers should be installed so they can be inspected and maintained. In addition, damper shafts should be uniformly marked so damper position can be easily seen.

5. The height of exhaust vents on the roof should be raised to reduce the chance of recirculation into nearby outside air intakes.

6. The cause of the backward running fan on the outside air heat pump located in the central pod should be determined.

7. A more efficient filter media should be used in all of the heat pump units. The efficiency of the filtration systems should be the maximum possible without seriously affecting the airflow rate of the fans. A mechanical firm or the manufacturer of the heat pump units should be able to determine the maximum filter efficiency.

   In addition, all of the filter systems should be checked for air by-passing around the filters. Units without covers over the filter access slots should have covers installed. These covers should provide support for the filters, and have gaskets to prevent air from by-passing the filters.

8. The condensate drainage systems for all of the units should be inspected for proper drainage. Criteria that need to be met should include the following:

   a) The units should be tilted toward the drain side of the unit far enough so that no water stands in the units' condensate pans.

   b) The drain connections to the units should be flush or recessed below the bottoms of the condensate pans.

   c) The top of the horizontal drainpipe on the outlet side of the trap should be 1" below the bottom of the condensate pan.

   d) The distance from the bottom of the horizontal drain pipe on the outlet side of the trap to the top of the pipe at the bottom of the U section of the trap should be equal to the suction pressure of the fan plus a 1" safety margin.

   e) Drain lines from the units to the central drain should not be smaller than the drain outlet on the unit.

   f) Minimum recommended drain pipe size is 1" for units up to 2000 cfm.

   g) Central drain lines should be large enough to freely drain all of the condensate water from all of the units connected to the line (no water should back up in the central drain line because the line is too narrow to accommodate the flow.

   h) The central condensate drain lines should run downhill from all of the units.

   i) Vent pipes should be installed at the junction between each unit's condensate drain line and the central drain line.

j) Vent pipes should be at least 6" higher than the top of the highest condensate pan connected to the central condensate drain line.

k) Central drain lines should have cleanouts. Cleanouts at the connection with each unit's drain with the central drain line are also suggested.

l) All drain lines should be insulated to prevent condensation on the outside of the drain lines.

9. A formal preventive maintenance schedule should be drawn up in consultation with the manufacturers of the equipment. Preventative maintenance on the mechanical systems should be documented and the documentation kept in a file according to the unit which was maintained.

10. Maintenance manpower requirements should be reviewed in consultation with current maintenance personnel and equipment manufacturers.

11. Central files should be developed for all of the heat pump units according to type. These files should contain specifications, design drawings, product literature, operational parameters, theory of operation, and other important information needed to assure continuity between mechanical personnel.

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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
6. U.S. Congressman John Boehner
7. Ohio State Representative Gene Krebs
8. OSHA

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 2

Reported Levels of Formaldehyde in Private Residences

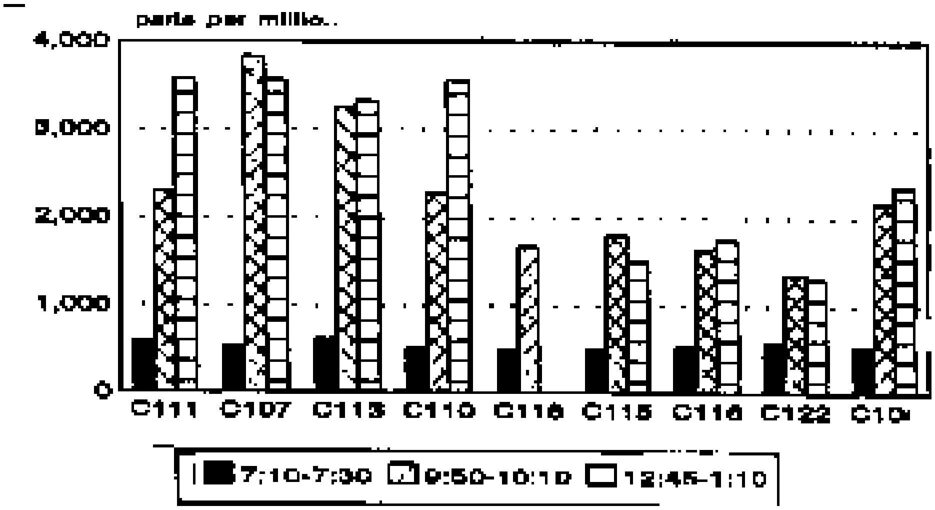
Tri-County North School
Lewisburg, Ohio
HETA 93-011

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

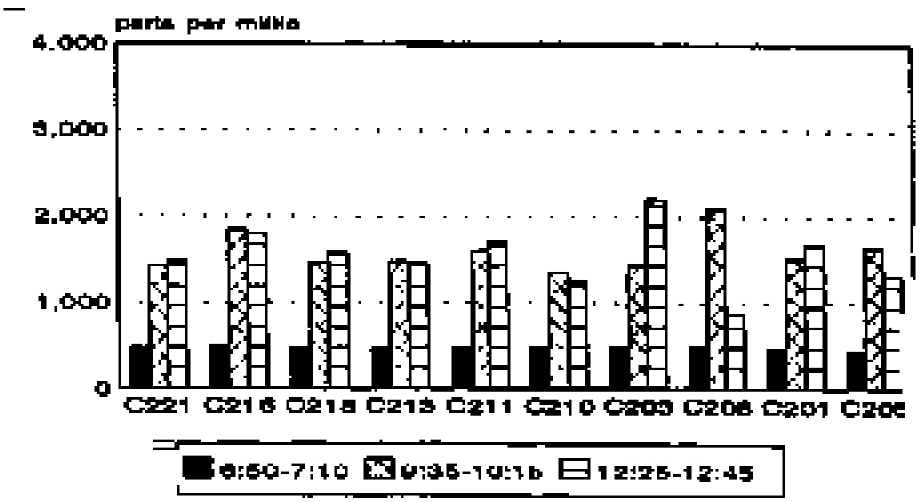
Source for table: Gammage RB, Hawthorne AR. "Current Status of Measurement Techniques and Concentrations of Formaldehyde in Residences." Turoski V. Formaldehyde: analytical chemistry and toxicology. Page 125. "Developed from a symposium sponsored by the Division of Environmental Chemistry at the 187th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

Table 3
Carbon Dioxide Levels, 10/28/92
Tri-County North School, HETA 93-011

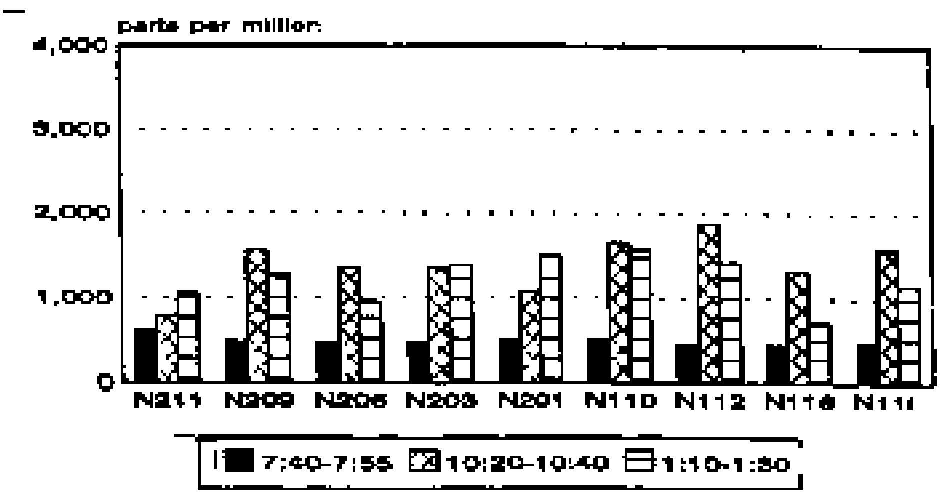
1st Floor - Central Pod



2nd Floor - Central Pod

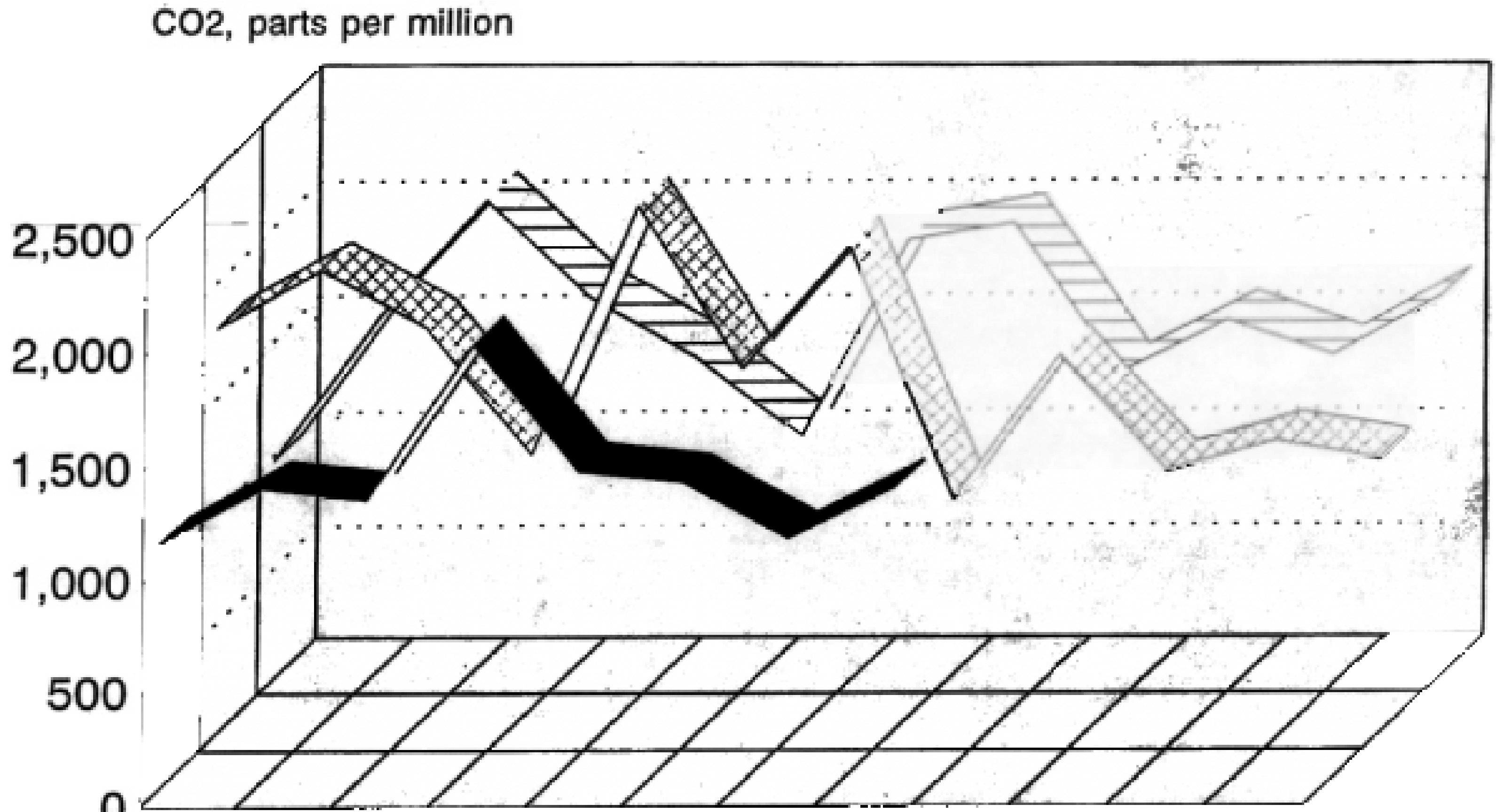


1st and 2nd Floor - North Pod



CO2 Levels Outside = 425 ppm

Table 4
Carbon Dioxide Levels, 2/25/93
Tri-County North School, Lewisburg, Ohio



Sampling Locations and Sampling Times

■ C-Pod[a] (11:15-11:30 am) ▨ C-Pod[b] (1:20-1:45pm) ▤ N-Pod (2:25-2:50pm)

Comments:
a = Central Pod, 1st floor
b = Central Pod, 2nd floor

Table 5
Temperature and Relative Humidity Levels, 10/28/92
Tri-County North School
HETA 93-011

6:50am -- 7:55am	Temperature (°F)				Relative Humidity (%)		
Locations	Range	Mean	Standard Deviation		Range	Mean	Standard Deviation
1st Floor, Central Pod	71 → 74	73	.95		33 → 45	39	4.4
2nd Floor, Central Pod	70 → 72	71	.82		29 → 40	33	3.5
1st Floor, North Pod	72 → 74	73	.96		32 → 36	34	1.8
2nd Floor, North Pod	73 → 74	73	.45		31 → 35	32	1.7

9:35am -- 10:40am	Temperature (°F)				Relative Humidity (%)		
Locations	Range	Mean	Standard Deviation		Range	Mean	Standard Deviation
1st Floor, Central Pod	73 → 75	74	0.65		39 → 54	46	4.9
2nd Floor, Central Pod	72 → 77	75	1.3		38 → 42	40	1.8
1st Floor, North Pod	73 → 74	73	0.50		40 → 43	41	1.5
2nd Floor, North Pod	73 → 74	73	0.45		37 → 40	38	1.6

12:25pm -- 1:35pm	Temperature (°F)				Relative Humidity (%)		
Locations	Range	Mean	Standard Deviation		Range	Mean	Standard Deviation
1st Floor, Central Pod	73 → 74	74	0.70		43 → 54	48	4.0
2nd Floor, Central Pod	72 → 76	74	1.3		35 → 45	40	3.0
1st Floor, North Pod	72 → 74	73	0.82		34 → 42	39	3.3
2nd Floor, North Pod	74 → 76	74	0.89		35 → 42	39	3.3

Comments:

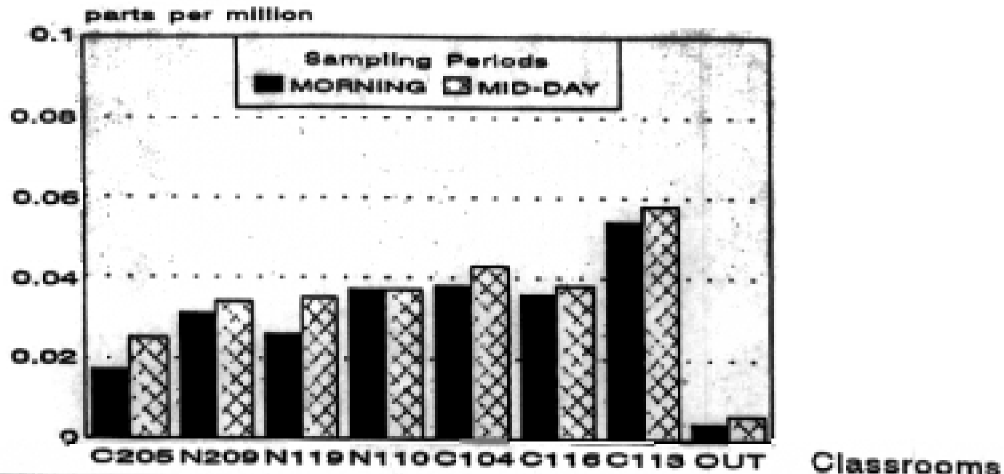
1. Outside temperature measurements on 10/28/92: 61 °F at 10:45 am; 64 °F at 1:32 pm.
2. Outside relative humidity measurements on 10/28/92: 40 % at 10:45 am; 35 % at 1:32 pm.
3. ANSI/ASHRAE Standard 55-1981 specific conditions in which 80% or more of the occupants would be expected to find the environment thermally acceptable. Assuming slow air movement and 50% RH, the operative temperatures recommended by ASHRAE range from 68-74°F in the summer. ASHRAE also recommends that RH be maintained between 30 and 60%.

Table 6

Formaldehyde Levels: 10/28/92 and 2/25/93
Tri-County North School, HETA 93-011

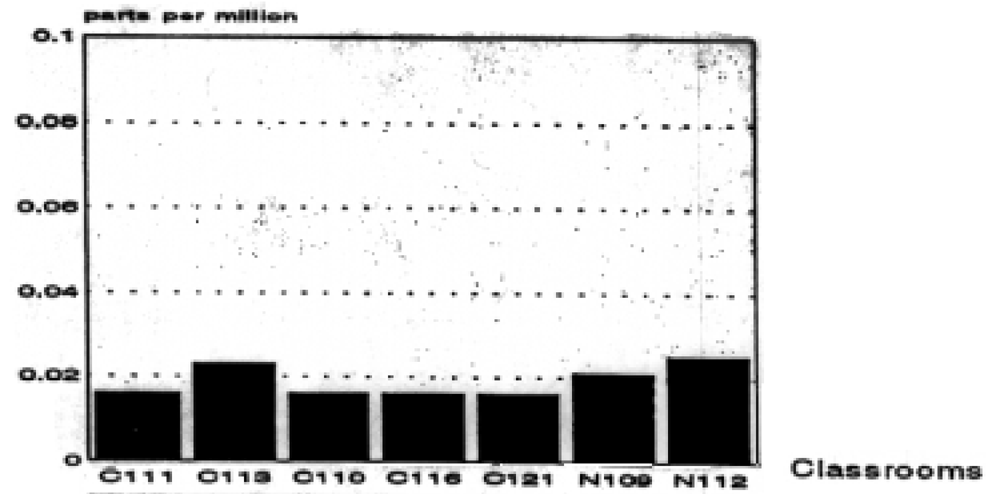
Survey Dates:

10/28/92



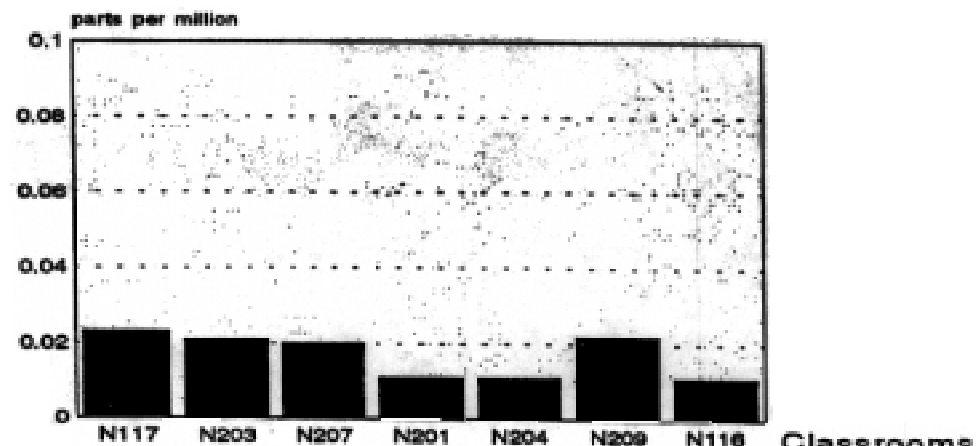
	C205	N209	N119	N110	C104	C116	C113	OUT	
MORNING	0.017	0.031	0.026	0.037	0.038	0.036	0.054	0.004	PPM
MID-DAY	0.025	0.034	0.035	0.037	0.043	0.038	0.058	0.006	PPM

2/25/93



C111	C113	C110	C116	C121	N109	N112
0.016	0.023	0.016	0.016	0.016	0.021	0.025

2/25/93



N117	N203	N207	N201	N204	N209	N116
0.023	0.021	0.02	0.011	0.011	0.022	0.011

Comments:

1. Samples collected using NIOSH Method No. 3500 (sodium bisulfite-filled impingers).
2. The Minimum Detectable Concentration (assuming a 100 liter sample size) = 0.004 ppm.
3. The Minimum Quantifiable Concentration (assuming a 100 liter sample size) = 0.011 ppm.
4. NIOSH considers formaldehyde to be a potential occupational carcinogen.
5. Formaldehyde levels in the range of 0.02 to 0.04 ppm have been measured in other indoor environmental quality evaluations.
6. No outside air samples were collected on 2/25/93 due to the cold weather. Ambient formaldehyde levels were assumed to be similar to those measured on 10/28/92

Table 7
Results of Qualitative Samping for
Volatile Organic Compounds
Thermal Desorption Tubes - Peak Identification
Tri-County North Local School
HETA 93-011

1) Air/CO_2*

2) Chlorodifluoremethane (Freon 22)

3) Dichlorodifluoremethane (Freon 12)

4) Acetaldehyde*

5) C_4H_8/C_4H_{10} aliphatics

6) Ethanol

7) Acrolein?

8) Acetone

8A) Methylene chloride (spikes only)

9) C_5H_8/C_5H_{10} aliphatics

10) Trichlorofluoromethane (Freon 11)

11) C_5H_8 isomer, pentadiene

12) Dichloroethylene isomer

13) 1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)

14) Alkyl sulfate?*

15) n-Propanol

16) C_6H14/C_6H_{12} aliphatics

17) Methyl ethyl ketone (MEK)

18) n-Hexane

19) 1,1,1-Trichloroethane

20) Benzene*

20A) Internal standard (spikes only)

21) Carbon tetrachloride

22) C_7H_{14}/C_7H_{16} aliphatics

23) Acetic acid

24) MIBK (spikes only)

25) Trichloroethylene

26) Toluene

27) Hexamethylcyclotrisiloxane*

28) Xylene/ethyl benzene isomers

29) Styrene

30) Branched alkanes, mostly C_{10}-C_{12} aliphatics (pattern identical to liquid dispersant in copiers)

31) Octamethylcyclotetrasiloxane*

32) p-Dichlorobenzene

33) Limonene

34) Decamethylcyclopentasiloxane

* Also present in blanks.
(Samples collected on 10/28/92)

Table 8

Quantitation of Selected Volatile Organic Compounds
October 28, 1992
Tri-County North School, Lewisburg, Ohio
HETA 93-011

Sample No.	Location	Sample Period	Sample Volume (liters)		Concentration, ppb (parts per billion)			
					1,1,1 Trichloroethane	Trichloroethylene	Toluene	N-Hexane
CT-1	Room C205	8:10 am to 3:15 pm	42.5		ND	ND	[8.1]	ND
CT-2	Room N209	8:17 am to 3:16 pm	42.4		16.9	12.3	[10.0]	[2.7]
CT-3	Room N119	8:22 am to 3:19 pm	41.7		ND	[4.9]	[10.2]	[1.4]
CT-4	Room N110	8:24 am to 3:18 pm	41.4		ND	[3.6]	[8.9]	ND
CT-5	Room C104	8:28 am to 3:29 pm	42.1		ND	[3.1]	[13.9]	6.1
CT-6	Administration Offices for High School	8:29 am to 3:24 pm	42.5		13.4	[4.4]	[12.5]	[2.7]
CT-7	Room C115	8:33 am to 3:34 pm	42.1		[10.0]	[4.4]	[13.9]	[2.0]
CT-8	Outside the school	8:40 am to 3:21 pm	40.1		ND	ND	[7.3]	ND
CT-9	Room C113	8:43 am to 3:30 pm	40.7		ND	[4.1]	[18.3]	[2.8]
CT-10	Multi-purpose Room (Elementary Section)	8:45 am to 3:34 pm	40.9		ND	ND	[8.4]	ND
Minimum *Detectable* Concentration (assuming a 40 liter air sample)					4.6	3.3	6.6	1.4
Minimum *Quantifiable* Concentration (assuming a 40 liter air sample)					13.4	10.3	19.9	4.3

Comments:

1. ND = Below current detection limit.
2. Benzene, carbon tetrachloride, and siloxane were not detected in these air samples.
3. [ ] Values shown in brackets are between the Minimum Detectable Concentration and Minimum Quantifiable Concentration for this sample set.

Table 9

Quantitation of Selected Volatile Organic Compounds by Thermal Desorption
Follow-up Survey, February 25, 1993
Tri-County North School, Lewisburg, Ohio
HETA 93-011

Sample No.	Location	Sample Period	Sample Volume (liters)		Concentration (parts per billion)							
					Acetone	Methyl Chloroform	Carbon Tetrachloride	Benzene	Toluene	Total Xylene	Hexane	Decane
TD-7	Photocopier room adjacent to the High School Administrative Office (Central Pod)	8:56 am to 2:17 pm	32.1		17	3	1	3	6	3	10	145*
TD-9	Classroom C104	9:01 am to 2:19 pm	31.8		30	2	1	1	6	8	15	31
TD-12	Outside the school building	9:10 am to 2:06 pm	29.6		3	‡	‡	1	1	1	1	1
TD-16	Elementary School Administrative Office (North Pod)	10:26 am to 3:27 pm	30.1		8	1	‡	1	2	1	4	154*
Minimum Detectable Concentration (assuming a 32 liter air sample)					1.0	0.3	0.2	0.5	0.4	0.4	0.4	0.3

Comments:

1. Compounds analyzed for but not detected by this analytical method included trichloroethene, 4-methyl-2-pentanone, methyl cellosolve, cellosolve, butyl cellosolve, Freon 22, pentane, and tetrahydrofuran.
2. Methyl chloroform is also called 1,1,1 trichloroethane.
3. Total xylene includes all isomers.

‡ Below current detection limit.
* Value reported is an estimation due to the high concentration of this analyte. The actual amount of decane may be higher.

Table 10

Quantitation of Photocopier Toner Fluid/Xylene Mixture
October 28, 1992
Tri-County North School, Lewisburg, Ohio
HETA 93-011

Sample No.	Location	Sample Period	Sample Volume (liters)		Concentration, mg/m³ (milligrams per cubic meter)
					Photocopier Toner Fluid/Xylene
CT-1	Room C205	8:10 am to 3:15 pm	42.5		1.6
CT-2	Room N209	8:17 am to 3:16 pm	42.4		6.5
CT-3	Room N119	8:22 am to 3:19 pm	41.7		7.3
CT-4	Room N110	8:24 am to 3:18 pm	41.4		7.7
CT-5	Room C104	8:28 am to 3:29 pm	42.1		18.3
CT-6	Administration Offices (High School)	8:29 am to 3:24 pm	42.5		7.2
CT-7	Room C115	8:33 am to 3:34 pm	42.1		4.1
CT-8	Outside the school	8:40 am to 3:21 pm	40.1		ND
CT-9	Room C113	8:43 am to 3:30 pm	40.7		8.8
CT-10	Multi-purpose Room (Elementary)	8:45 am to 3:34 pm	40.9		10.4
Minimum *Detectable* Concentration (assuming a 40 liter air sample)					0.4
Minimum *Quantifiable* Concentration (assuming a 40 liter air sample)					1.3

Comment:

Since the xylene peaks eluted in the same area as the Toner fluid, the results of the xylene peaks were added with those of the Toner fluid.

Table 11

Quantitation of Photocopier Toner Fluid/Xylene Mixture
Follow-up Survey, February 25, 1993
Tri-County North School, Lewisburg, Ohio
HETA 93-011

Sample No.	Location	Sample Period	Sample Volume (liters)		Concentration, mg/m^3 (milligrams per cubic meter)
					Photocopier Toner Fluid/Xylene
CT-6	Photocopier Room (High School Administrative Office, Central Pod)	8:56 am to 2:17 pm	32.1		26.2
CT-15	Administrative Office (Elementary School, North Pod)	9:54 am to 3:27 pm	33.3		20.0
CT-8	Room C104	9:01 am to 2:19 pm	31.8		0.9
CT-10	Room C108	9:04 am to 2:15 pm	31.1		ND
CT-11	Outside the school building	9:10 am to 2:06 pm	29.6		ND
CT-13	Room N107	9:50 am to 3:26 pm	34.6		ND
CT-14	Room N111	9:42 am to 3:29 pm	34.7		ND
CT-17	Room N209	10:18 am to 3:24 pm	30.6		ND
CT-18	Room C116	9:08 am to 2:16 pm	30.8		ND
Minimum *Detectable* Concentration (assuming a 30 liter air sample)					0.9
Minimum *Quantifiable* Concentration (assuming a 30 liter air sample)					3.1

Comment:

Since the xylene peaks eluted in the same area as the Toner fluid, the results of the xylene peaks were added with those of the Toner fluid.

Table 12

Results of Bioaerosol Sampling
Date of Sample Collection: 11/9/92
Tri-County North School, Lewisburg, Ohio
HETA 93-011

Sample #	Location	Sample Start Time	FUNGI				BACTERIA			
			Non-respirable Fraction		Respirable Fraction		Non-respirable Fraction		Respirable Fraction	
			Total CFU/m³	Identifications	Total CFU/m³	Identifications	Total CFU/m³	Identifications	Total CFU/m³	Identifications
1	C-218	9:27	77	Yea > Pen > Alt	88	Yea > Pen	231	S. hominis > S. kloosii	81	B. insolitus > S. hominis
2	C-218*	9:47	4	Pen	58	Yea > Pen	88	E. asburiae > M. luteus	130	E. asburiae
3	C-218*	10:04	88	Yea	39	Yea > Clad	95	E. asburiae	123	E. asburiae
4	outside*	10:48	137	Clad > Alt > Pen > Yea > As	490	Clad > Pen > Yea	21	S. hominis > S. kloosii	11	B. pasteurii > S. kloosii
5	outside*	11:10	188	Alt > Clad	1,043	Clad > Alt – Asp	ND	[illegible]	ND	
6	outside*	11:26	133	Alt > Clad > Yea > Asp	459	Clad > Yea > Alt – Asp > Pe	ND		ND	
7	outside*	11:42	176	Alt > Clad > Asp	1,285	Clad > Asp – Pen	35	Coryne	ND	
8	C-108	13:03	35	Yea > Alt	67	Yea > Clad – Pen	ND		25	E. asburiae
9	C-108	13:20	67	Yea > > Epi – Alt – Asp	224	Yea > > Clad > Pen	84	S. hominis	28	S. hominis
10	C-108*	13:36	130	Yea > > Clad – Alt – Pen – Epi	123	Yea > Pen > Clad	118	S. hominis	63	S. hominis
11	S-106B*	14:27	83	Yea > Pen – Clad	105	Pen – Clad > Asp	11	B. pasteurii	14	B. pasteurii
12	S-106B	14:44	7	Yea	25	Pen – Clad > Asp	18	B. pasteurii	ND	
13	S-106B*	15:01	25	Yea > Alt	49	Yea > Clad > Pen > Asp	21	B. pasteurii	14	E. asburiae
14	N-115*	15:27	39	Yea > Alt	67	Yea > Clad	28	Coryne	105	Coryne
15	N-115*	15:43	28	Yea > Clad	119	Yea > Clad > Pen – Asp	ND		ND	
16	N-115	16:01	28	Yea > Alt	133	Yea > Clad > Pen	18	B. pasteurii	ND	

The limit of detection was 4 CFU/m³. Abbreviations: ND = none detected, Clad = Cladosporium, Pen = Penicillium, Alt = Alternaria, Asp = Aspergillus, Epi = Epicoccum, Yea = unidentified yeasts, B. = Bacillus, Coryne = Corynebacterium species, S. = Staphylococcus, M. = Micrococcus, E. = Enterobacter.

* Indicates that Thermoactinomyces were detected.

Table 13

Symptoms Experienced While At Work
On The Day Of The Questionnaire Survey
Tri-County North School
HETA 93-011

Symptoms	Middle & High School 42 workers	Elementary School 33 workers	Cafeteria 10 workers	Building Maintenance 7 workers	All Respondents 92 workers
Dry, itching, or irritated eyes	7 %	19 %	0 %	0 %	10 %
Wheezing	5 %	0 %	0 %	0 %	2 %
Headache	21 %	28 %	10 %	0 %	21 %
Sore throat	10 %	22 %	10 %	0 %	13 %
Unusual tiredness, fatigue or drowsiness	21 %	22 %	0 %	0 %	18 %
Chest tightness	2 %	6 %	0 %	0 %	3 %
Stuffy or runny nose, or sinus congestion	33 %	34 %	10 %	0 %	29 %
Cough	17 %	13 %	0 %	0 %	12 %
Tired or strained eyes	26 %	22 %	0 %	0 %	20 %
Difficulty remembering things or concentrating	5 %	13 %	0 %	0 %	7 %

Dry throat	12 %	25 %	10 %	0 %	15 %
Dizziness or lightheadedness	7 %	3 %	0 %	0 %	4 %
Shortness of breath	0 %	3 %	0 %	0 %	1 %

Table 14

Symptoms Experienced At Work One or More Days Per Week
During the Four Weeks Prior to the Survey
Tri-County North School
HETA 93-011

Symptoms	Middle & High School 42 workers	Elementary School 33 workers	Cafeteria 10 workers	Building Maintenance 7 workers	All Respondents 92 workers
Dry, itching, or irritated eyes	7 %	18 %	20 %	14 %	13 %
Wheezing	2 %	3 %	0 %	14 %	3 %
Headache	19 %	39 %	10 %	14 %	25 %
Sore throat	7 %	15 %	0 %	14 %	10 %
Unusual tiredness, fatigue or drowsiness	29 %	33 %	10 %	14 %	27 %
Chest tightness	0 %	9 %	0 %	14 %	4 %

Stuffy or runny nose, or sinus congestion	24 %	42 %	10 %	14 %	28 %
Cough	14 %	18 %	0 %	14 %	14 %
Tired or strained eyes	21 %	21 %	20 %	14 %	21 %
Difficulty remembering things or concentrating	7 %	15 %	10 %	14 %	11 %
Dry throat	10 %	30 %	20 %	14 %	18 %
Dizziness or lightheadedness	7 %	3 %	20 %	14 %	8 %
Shortness of breath	0 %	6 %	20 %	14 %	5 %

Table 15

**Symptoms Experienced While At Work One Or More Days Per Week
During The Last Month That Tended To Be Less Severe When Away From Work
Tri-County North School
HETA 93-011**

Symptoms	Middle & High School 42 workers	Elementary School 33 workers	Cafeteria 10 workers	Building Maintenance 7 workers	All Respondents 92 workers
Dry, itching, or irritated eyes	7 %	6 %	0 %	0 %	5 %
Wheezing	0 %	0 %	0 %	0 %	0 %
Headache	10 %	27 %	0 %	0 %	14 %
Sore throat	7 %	9 %	0 %	0 %	7 %
Unusual tiredness, fatigue or drowsiness	17 %	9 %	10 %	0 %	12 %
Chest tightness	0 %	0 %	0 %	0 %	0 %
Stuffy or runny nose, or sinus congestion	7 %	3 %	0 %	0 %	4 %
Cough	2 %	3 %	0 %	0 %	2 %
Tired or strained eyes	12 %	12 %	0 %	0 %	10 %

Table 16

Number Of Employees Reporting Symptoms That Occur At Work One Or More Days A Week And Get Better When Away From Work Tri-County North School HETA 93-011

Number Of "Work Related" Symptoms Reported	Middle & High School 42 workers	Elementary School 33 workers	Cafeteria 10 workers	Building Maintenance 7 workers	All Respondents 92 workers
No Symptoms	30	20	9	7	66
One Symptom	4	6	0	0	10
Two Symptoms	5	4	0	0	9
Three Symptoms	0	3	1	0	4
Four Symptoms	2	0	0	0	2
Five Symptoms	1	0	0	0	0

Table 17

Description Of Workplace Conditions Tri-County North School HETA 93-011

Conditions Frequently Experienced	Middle & High School 42 workers	Elementary School 33 workers	Cafeteria 10 workers	Building Maintenance 7 workers	All Respondents 92 workers
Too much air movement	5 %	12 %	10 %	0 %	8 %
Too little air movement	7 %	15 %	30 %	0 %	12 %
Temperature too hot	5 %	12 %	30 %	14 %	11 %
Temperature too cold	15 %	21 %	10 %	0 %	15 %
Air too humid	7 %	6 %	10 %	0 %	7 %
Air too dry	2 %	12 %	20 %	0 %	8 %
Tobacco smoke odors	0 %	3 %	0 %	0 %	1 %
Chemical odors (e.g., paint, cleaning fluids, etc.)	0 %	3 %	0 %	0 %	1 %
Other unpleasant odors (e.g., body odor, food odor, perfume)	10 %	12 %	10 %	0 %	10 %

Difficulty remembering things or concentrating	0 %	0 %	0 %	0 %	0 %
Dry throat	7 %	6 %	0 %	0 %	5 %
Dizziness or lightheadedness	2 %	0 %	10 %	0 %	2 %
Shortness of breath	0 %	0 %	10 %	0 %	1 %

TABLE 19
Tri-County North School
Lewisburg, Ohio
HETA 93-011

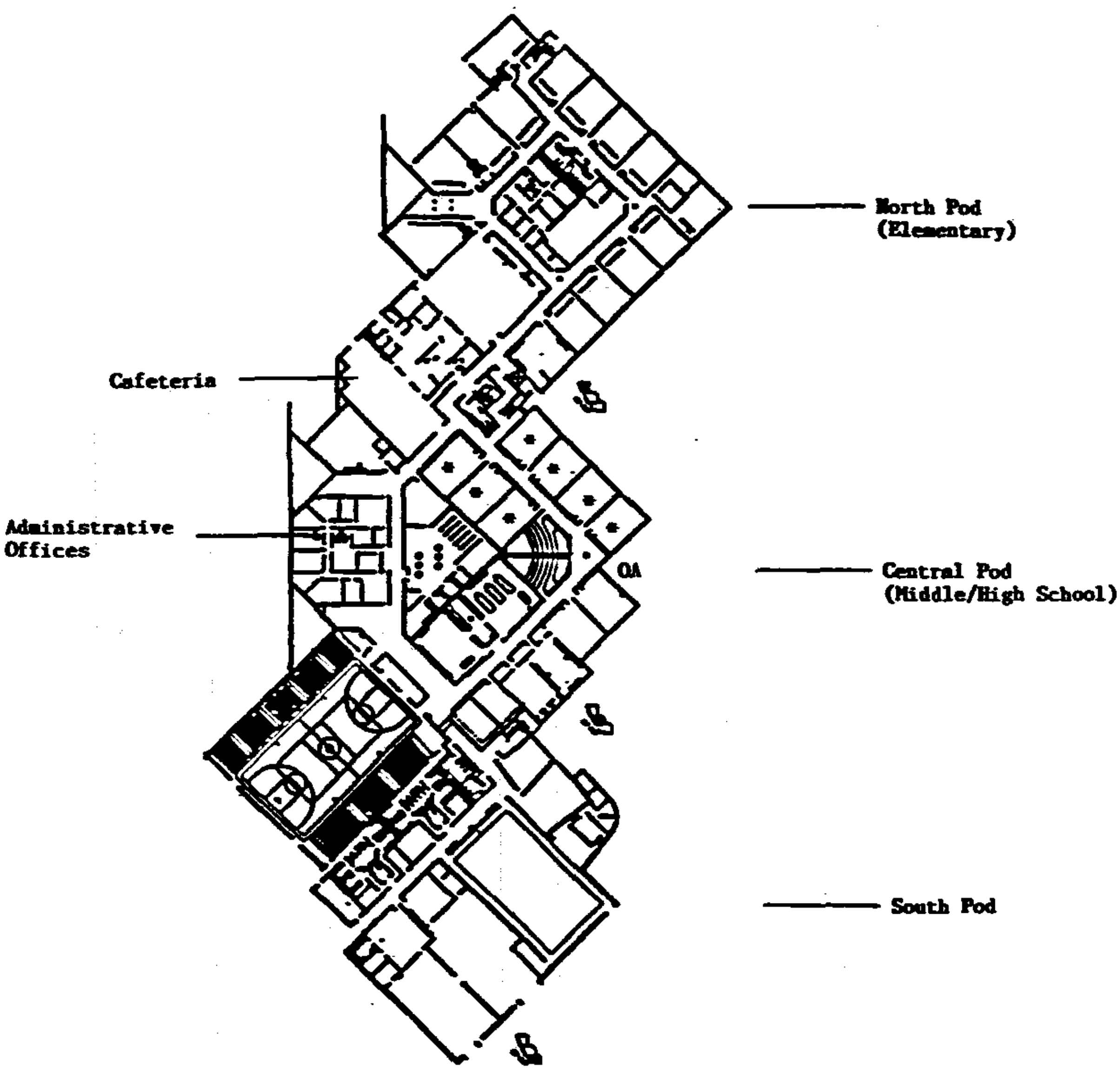
Room	Outside Air Flow	Average Occupants w/Outside Recess	Average Occupants w/o Outside Recess	(Outside Air Flow)/ (Average Occupants w/o Outside Recess)	(Outside Air Flow)/ (Average Occupants w/o Outside Recess)	Notes
N112	134	14	16	10	9	
N113	135	17	19	8	7	
N105	*110*	17		6		1
N106	142	19		7		
N107	128	20		6		
N108	140	17		8		
N109	119	11	12	11	10	
N110	140	16	18	9	8	
N111	144	17	19	9	8	
N114B,C	95	3		33		
N115	135	4		37		
N116	156	15	17	10	9	
N117	158	17	18	10	9	
N118	156	15	17	11	9	
N119	149	14	16	10	9	
N201	154	15	16	11	9	
N202	152	17	19	9	8	
N203	144	15	17	10	9	
N204	151	15	17	10	9	
N205	101	6		17		
N206	160	6		26		
N207	151	17	19	9	8	
N208	163	15	17	11	9	
N209	152	16	18	9	8	
N210	149	16	18	9	8	2
C202	158	17		9		
C204	170	17		10		
C211	115	18		7		
C212	110	18		6		
C213	118	16		7		
C214	111	20		6		
C217	318	17		18		3
C219						
C218	314	18		17		3

1 **Air flow in italics is a design value. An actual measurement value was not available.**
2 **One heat pump unit supplies both of these rooms; however, N216B is a hallway. Therefore, actual outside air per person is expected to be less than shown.**
3 **Two heat pumps supply C217 and C129, and C218 and C219, respectively. Both C217 and 218 are laboratories, and C219 is a room connected to C217 and C218 and contains a fume hood. Therefore, outside air flows per person may be less than shown.**

Figure 1

Tri-County North
First Floor Diagram

HETA 93-011



* First floor classrooms with carbon dioxide concentrations in excess of 2500 ppm on 10/28/92.

OA Location of outside air intake which supplied these classrooms.

Figure 2

Reconstructed Chromatogram: Qualitative Analysis for Volatile Organic Compounds
Sample Location: C107
Date of Sample Collection: 10/28/92
Tri-County North Local School

HETA 93-011

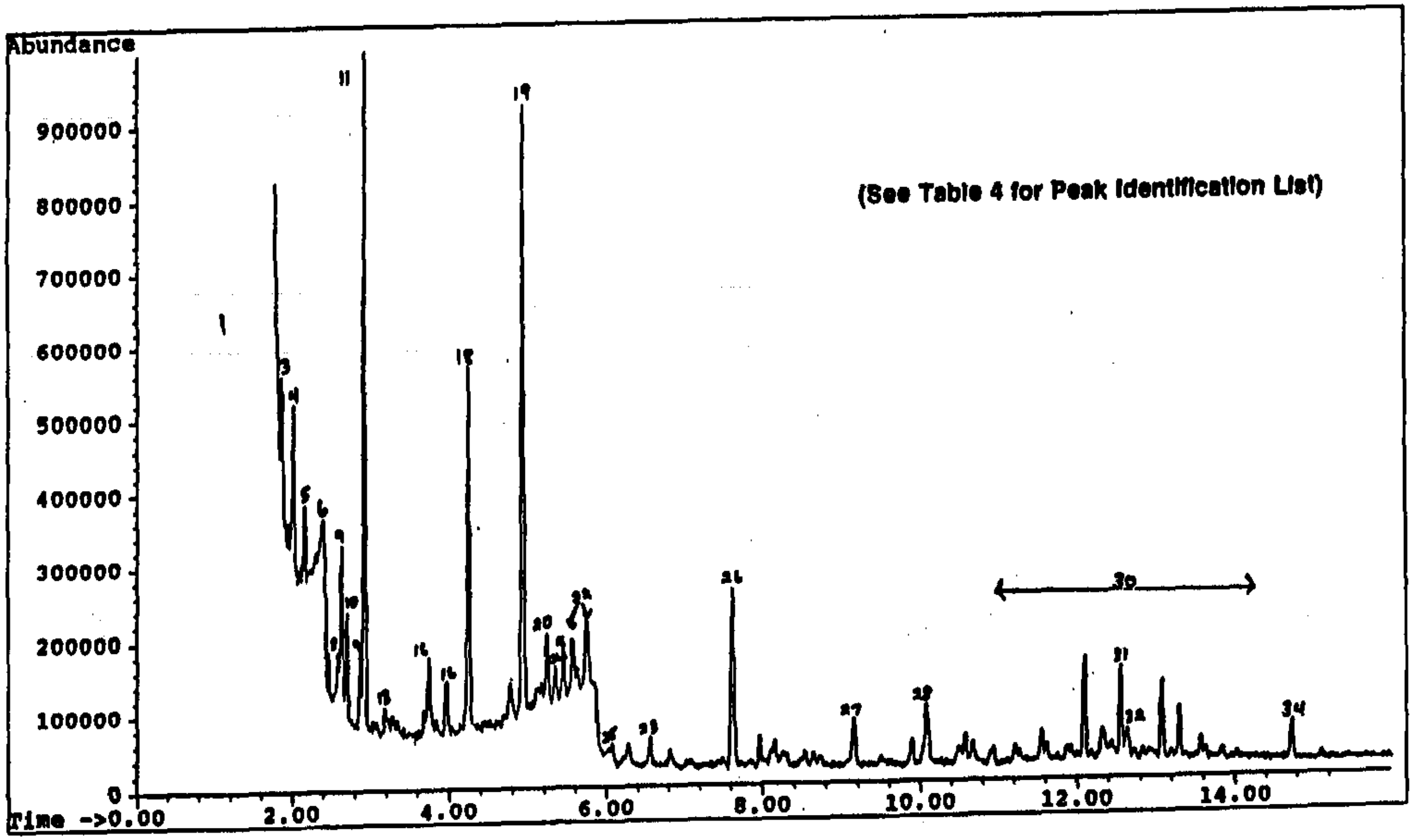


Figure 2, continued

Reconstructed Chromatogram: Qualitative Analysis for Volatile Organic Compounds
Sample Location: C113
Date of Sample Collection: 10/28/92
Tri-County North Local School

HETA 93-011

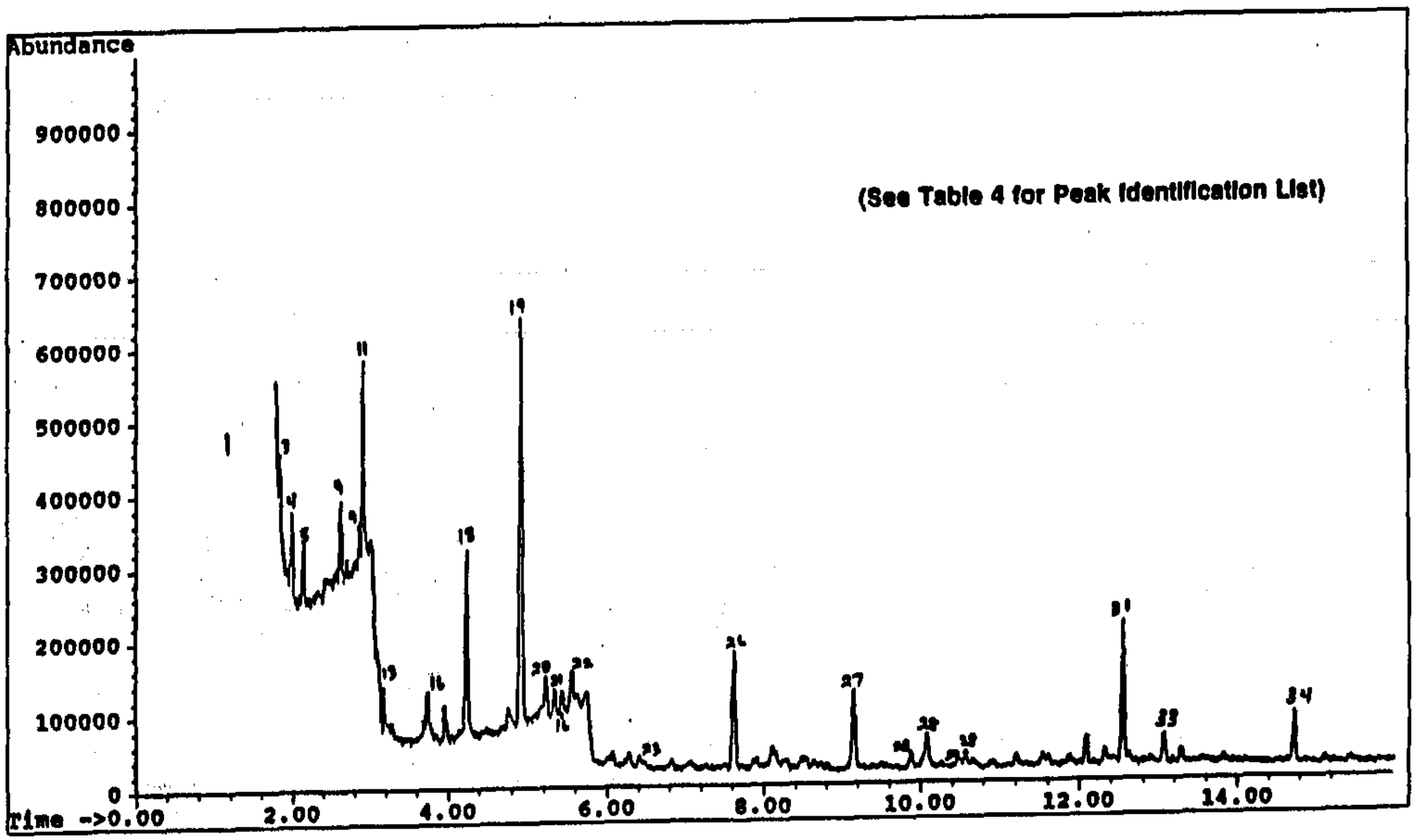


Figure 2, continued

Reconstructed Chromatogram: Qualitative Analysis for Volatile Organic Compounds
Sample Location: C218
Date of Sample Collection: 10/28/92
Tri-County North Local School

HETA 93-011

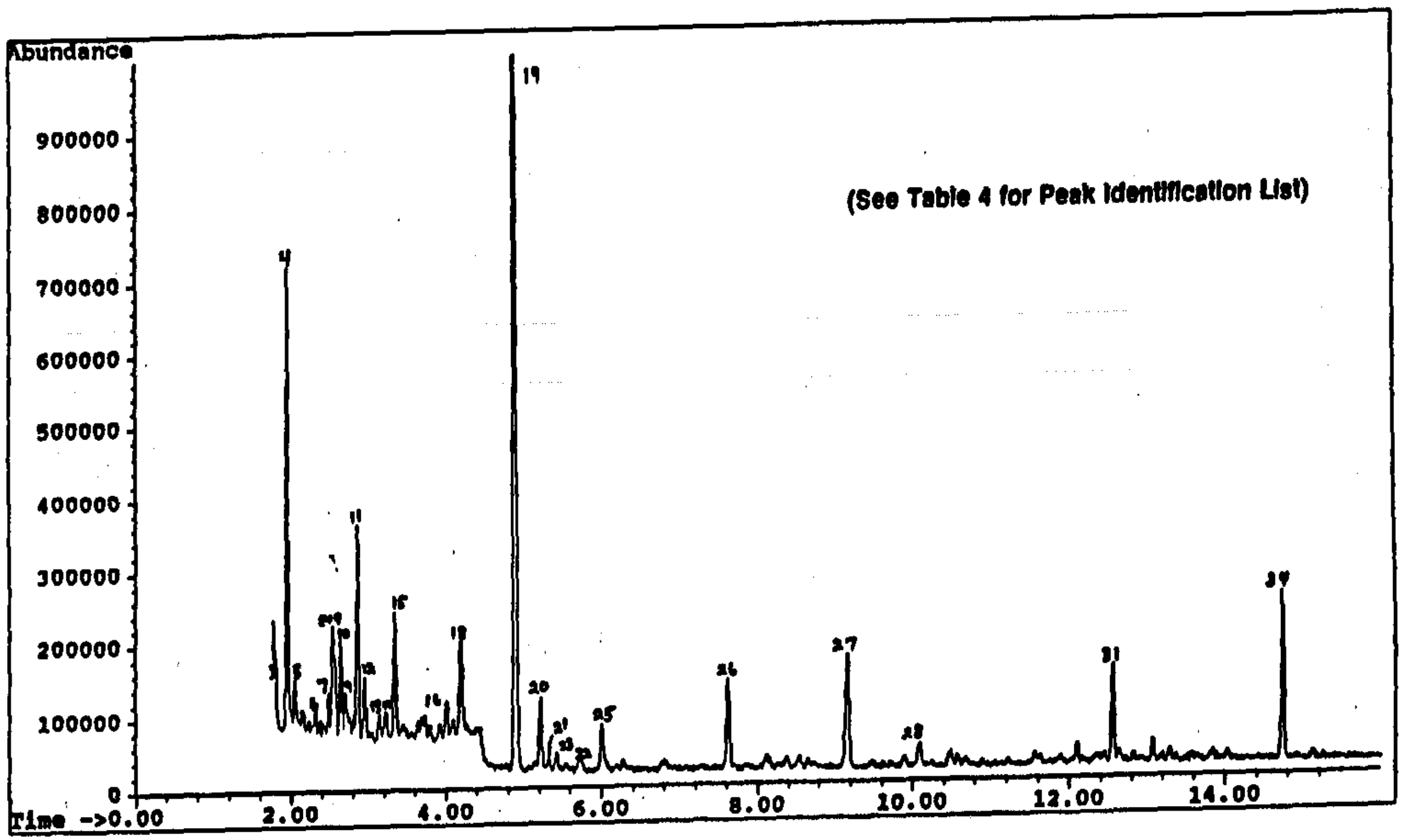


Figure 2, continued

Reconstructed Chromatogram: Qualitative Analysis for Volatile Organic Compounds
Sample Location: Classroom N112
Date of Sample Collection: 10/28/92
Tri-County North Local School

HETA 93-011

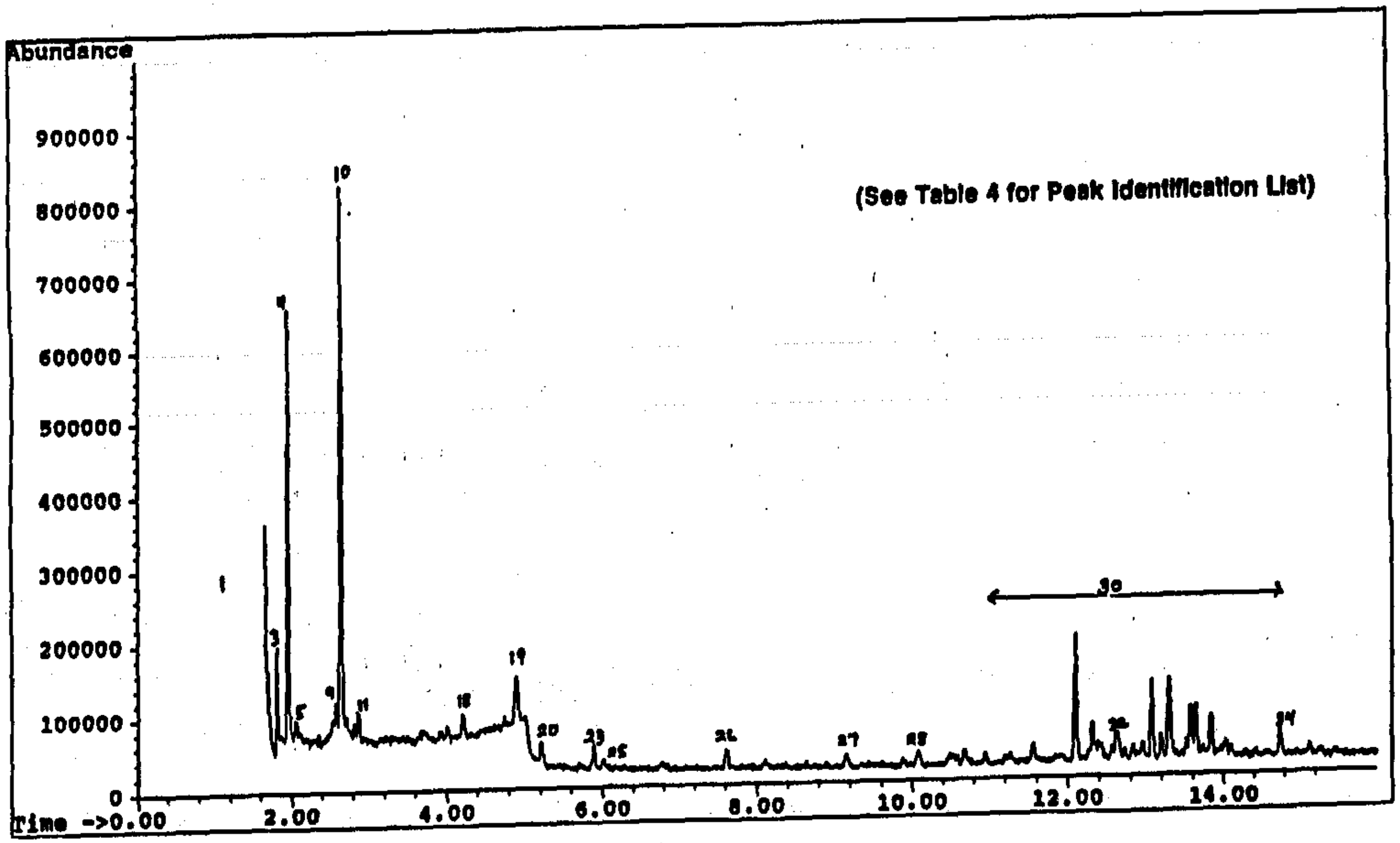


Figure 2, continued

Reconstructed Chromatogram: Qualitative Analysis for Volatile Organic Compounds
Sample Location: N119
Date of Sample Collection: 10/28/92
Tri-County North Local School

HETA 93-011

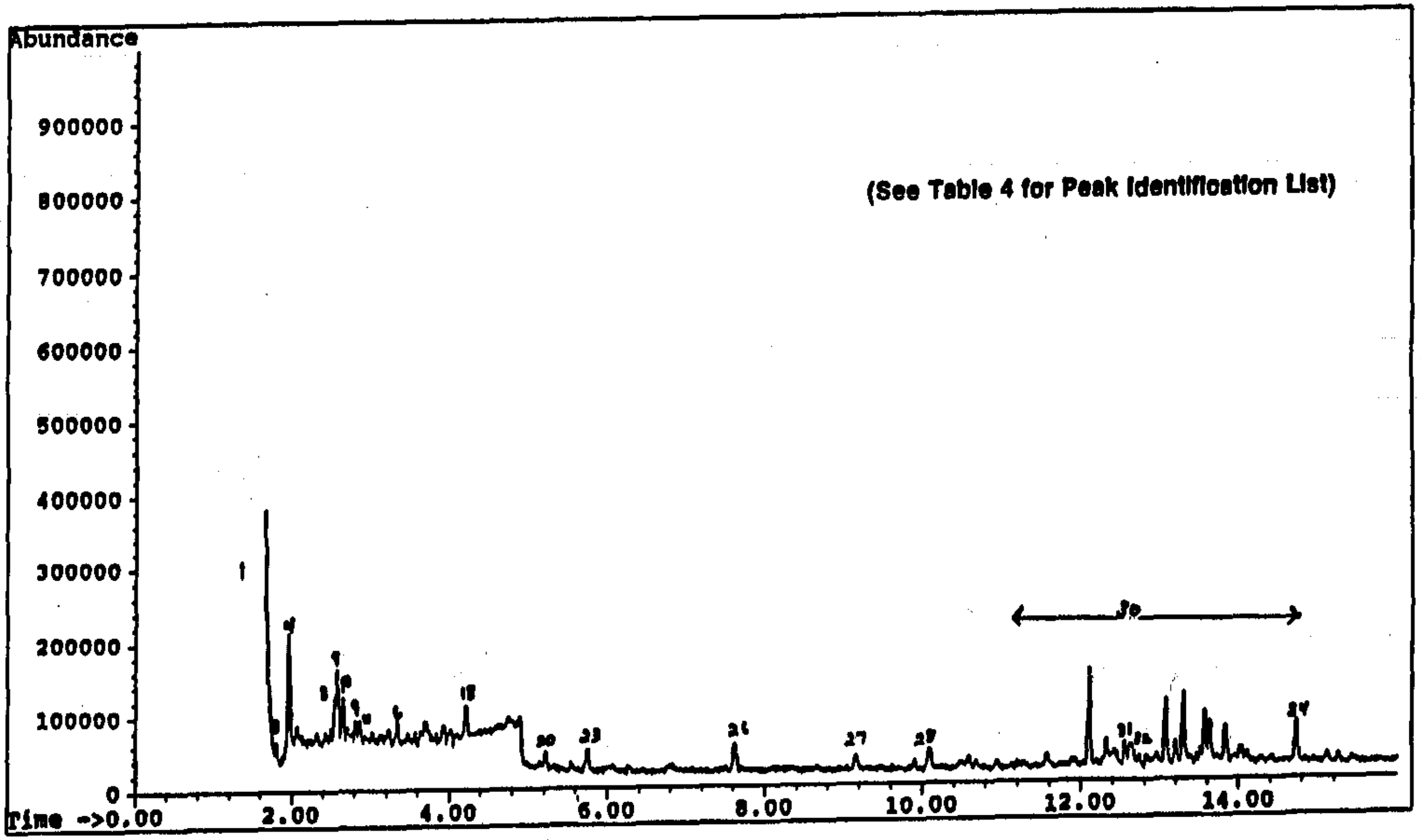


Figure 3

Airborne Fungi Concentrations
Date of Sample Collection: 11/9/92

Tri-County North Schools
Lewisburg, Ohio
HETA 93-011

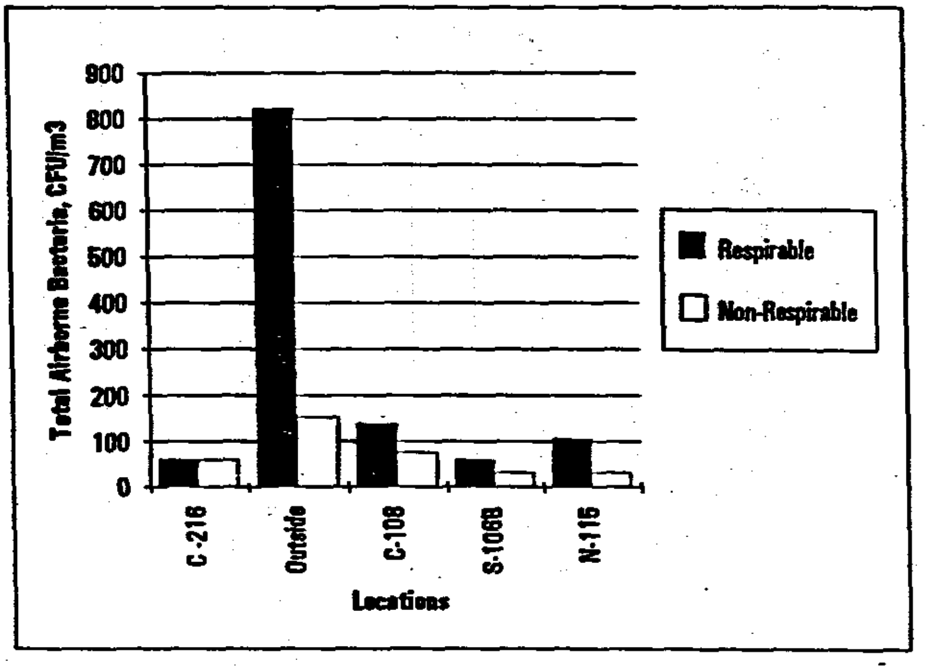
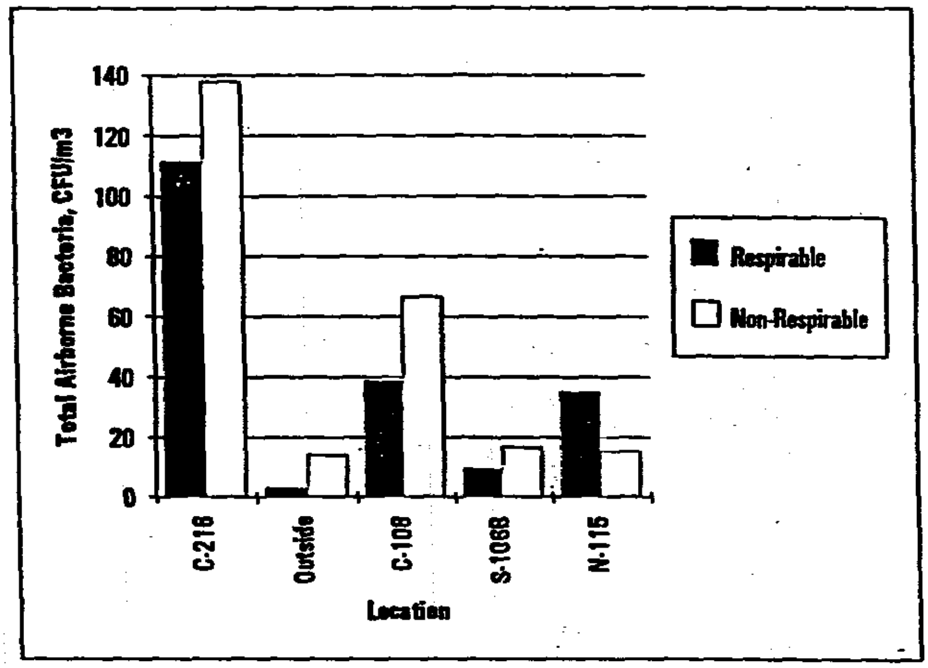


Figure 4
Airborne Bacteria Concentrations
Date of Collection: 11/9/92

Tri-County North Schools
Lewisburg, Ohio
HETA 93-011



August 6, 2001
HETA 93-011

Dr. Philip E. Dubbs
Superintendent
Tri-County North Local Schools
436 North Commerce Street
Lewisburg, Ohio 45338

Dear Dr. Dubbs:

This National Institute for Occupational Safety and Health (NIOSH) interim report contains information gathered during the environmental and medical evaluations conducted at the Tri-County North school in October, 1992. To summarize the content of this report, carbon dioxide, temperature, and relative humidity measurements were collected on October 28, 1992. In addition, air samples were collected for volatile organic compounds (VOCs) and formaldehyde at various locations within the school and ___ questionnaires were distributed to employees. Finally, as part of the follow-up survey on October 28, 1992, the ventilation systems were evaluated by a NIOSH ventilation engineer. A portion of this ventilation assessment has been included in this interim report.

Subsequent NIOSH reports will contain the results of samples collected on November 9, 1992, for airborne bioaerosols (bacteria, fungi, thermophilic actinomycetes). Air sampling for acetaldehyde was also conducted during this second follow-up survey at the school.

At this time no additional site visits by NIOSH investigators are anticipated. The NIOSH final report will discuss all of the results from the environmental, medical, and ventilation assessments conducted as part of this evaluation. 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. Wilcox).

Sincerely yours,

Gregory A. Burr, C.I.H.
Supervisory Industrial Hygienist
Industrial Hygiene Section

Thomas G. Wilcox, M.D.
Medical Officer
Hazard Evaluations and Technical
Assistance Branch
Division of Surveillance, Hazard
Evaluations and Field Studies

Enclosure

cc:
Mr. Leroy Banks, Tri-County North Teachers Association
Ms. Bonnie Price, President, Ohio Public School Employees Union