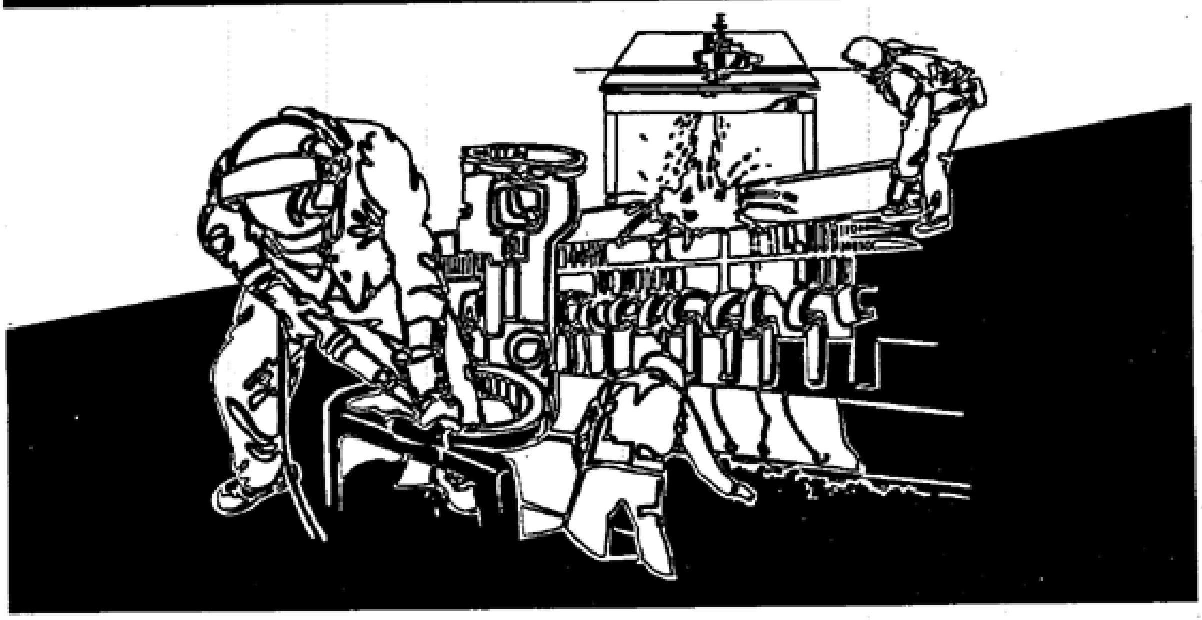
CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

NIOSH HEALTH HAZARD EVALUATION REPORT

HETA 93-0784-2350
BLACKSHERE ELEMENTARY SCHOOL
MANNINGTON, WEST VIRGINIA



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

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

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

KEYWORDS: SIC 8211 (Elementary and Secondary Schools): indoor environmental quality, IEQ, indoor air quality, IAQ, ventilation, carbon dioxide, relative humidity, temperature, formaldehyde, carbon monoxide, hydrogen sulfide, West Virginia.

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Blackshere Elementary School
Mannington, West Virginia
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I. SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation at Blackshere Elementary School, Mannington, West Virginia in response to a request from the Superintendent of Schools for Marion County. Teachers in the school were concerned about the adequacy of the ventilation in their work areas and about symptoms they were experiencing at work. In addition, parents of children who attend Blackshere felt that their children were experiencing health problems related to the school. Seventy-three percent of teachers felt that classroom attendance was lower this year than in previous years that they had taught the same grade. The questionnaire survey showed that many employees had experienced symptoms, including fatigue, eye irritation or strain, nasal congestion, and headache while in the building. Most of the symptomatic employees reported that their symptoms tended to resolve when they were away from the building. Forty-seven percent of the employees at Blackshere Elementary School reported having experienced one or more such "building-related" symptoms during the 4 weeks preceding the administration of the questionnaire. The most common environmental complaint was that of too little air movement, reported by 63% of survey respondents. Temperature control was also a problem, with 32% of employees reporting being too hot and 34% reporting being too cold at work at some time during the four weeks preceding the survey.

The air sampling results for formaldehyde, volatile organic compounds, carbon monoxide and hydrogen sulfide were non-detectable. Carbon dioxide levels measured within the facility, both during the morning and afternoon hours, were above the maximum recommended ASHRAE criteria for indoor environments.

Based on the results of this investigation, the NIOSH investigators have concluded that during the time of this evaluation, a health hazard did not exist at Blackshere Elementary School. Carbon dioxide measurements used to assess the capabilities of the air handling systems, suggest insufficient outside air is provided to occupied spaces that would affect occupant comfort. The principle recommendations made to address the indoor environmental quality issues at this school include modifying the ventilation system to provide sufficient outside air to the occupied spaces.

II. INTRODUCTION

On March 16, 1993, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Superintendent of Marion County Schools, Fairmont, West Virginia to conduct a health hazard evaluation (HHE) at the Blackshere Elementary School, located in Mannington, West Virginia. This request was made because of complaints filed by the staff and parents relating to the indoor environmental quality (IEQ) within the school. In addition, during the spring of 1993, a reoccurring sewer gas odor within the school was noted by staff and students. At times the odor was sufficient to cause students to become ill and have to leave school. The odor problem was traced to an un-trapped main sewer line that allowed gas to build up and exhaust out the sewer vents on the buildings' roof. The vented sewer gas was then pulled into the air handling systems and distributed throughout the facility. Before the NIOSH investigation, a wet-trap had been installed on the main sewer line and the vent stack elevated above the intakes for the air handlers. This, according to staff, has resolved the sewer gas problems. Finally, staff had recently complained of an odor that they stated smelled like "burning wires". County maintenance personnel investigated the complaints and found no wires burning. However, IEQ complaints have continued.

On May 19, 1993, NIOSH investigators held an initial meeting at the Marion County Board of Education office to discuss the HHE request. Attending that initial meeting was the superintendent, administrative and maintenance representatives of the school district, and state and county health department officials. After the meeting, a site visit was conducted at the Blackshere Elementary School.

On May 27 - June 1, 1993, NIOSH investigators returned to the elementary school to conduct a comprehensive indoor environmental quality investigation. During those three days, area air samples for formaldehyde, volatile organic compounds, carbon monoxide, hydrogen sulfide, carbon dioxide, relative humidity, and temperature were collected daily in ten randomly selected classrooms and three fixed locations throughout the school. In addition, the heating, ventilating, and air conditioning (HVAC) systems were inspected. On May 28, 1993, a teacher and a parent representative were invited to assist and observe the environmental sampling being conducted at the school.

The medical component of the survey consisted of a questionnaire asking employees about their medical history, work, and any work-related symptoms they may have experienced. In addition, phone interviews were conducted with teachers asking about student absenteeism and number and frequency of children leaving school during the day due to illness.

Sampling results and recommendations for corrective action to improve the indoor environmental quality at Blackshere Elementary School are contained in this report. This report will serve to close-out this investigation at the Blackshere Elementary School.

III. BACKGROUND AND DESCRIPTIVE INFORMATION

Blackshere Elementary School was opened in September 1992 to serve grades K - 4. The school is located in a rural/agricultural area near Mannington, Marion County, West Virginia. During this survey there were approximately 450 students and staff assigned to the school.

Construction materials of the approximately 60,000 ft^2, single story, T-shaped, facility consist of exterior brick and cinder block perimeter walls. The roof is flat and is covered with a rubber membrane. Interior walls are constructed of both cinder block and drywall. A suspended drop ceiling of fiberglass and mineral wool tiles is consistent throughout the facility. The space above the suspended ceiling serves as a return air plenum. Most classrooms and hallways and areas such as the multi-purpose room, kitchen and restrooms are tiled with either vinyl or ceramic tiles. The media center and a few offices and classrooms are carpeted.

The school is designed with most classrooms located on an outside wall. This design allows access to windows (though inoperable) and an exit door to the outside. The heating, ventilating, and air conditioning (HVAC) systems at Blackshere are unique in design and control technology. Each room has its own individual heat pump, located above the false ceiling, to provide tempered air to the room. Room temperature is controlled through individual thermostats that are preset and locked to prevent un-authorized adjustments.

Supply air for the heat pumps is provided from two roof top unitary (package) HVAC units (labeled HW-1 and HW-2 on design specifications). Each unit supplies a different amount of supply air to different locations within the facility. Unit HW-1 draws 100% outside air into the system and is designed to deliver 5225 cubic feet per minute (cfm). The exhaust side of unit HW-1 removes 4375 cfm from the school and discharges it from the facility. Unit HW-2 is also designed to provide 100% outside air at 5435 cfm and exhausts 5170 cfm. Supply air from the two roof top units is ducted to the heat pumps through rigid and flexible ductwork. Figure 1 illustrates a typical room HVAC configuration. Tempered air is delivered to the room from the heat pump through four 2'x2' ceiling diffusers at a rate of approximately 300 cfm/diffuser, or 1200 cfm total.

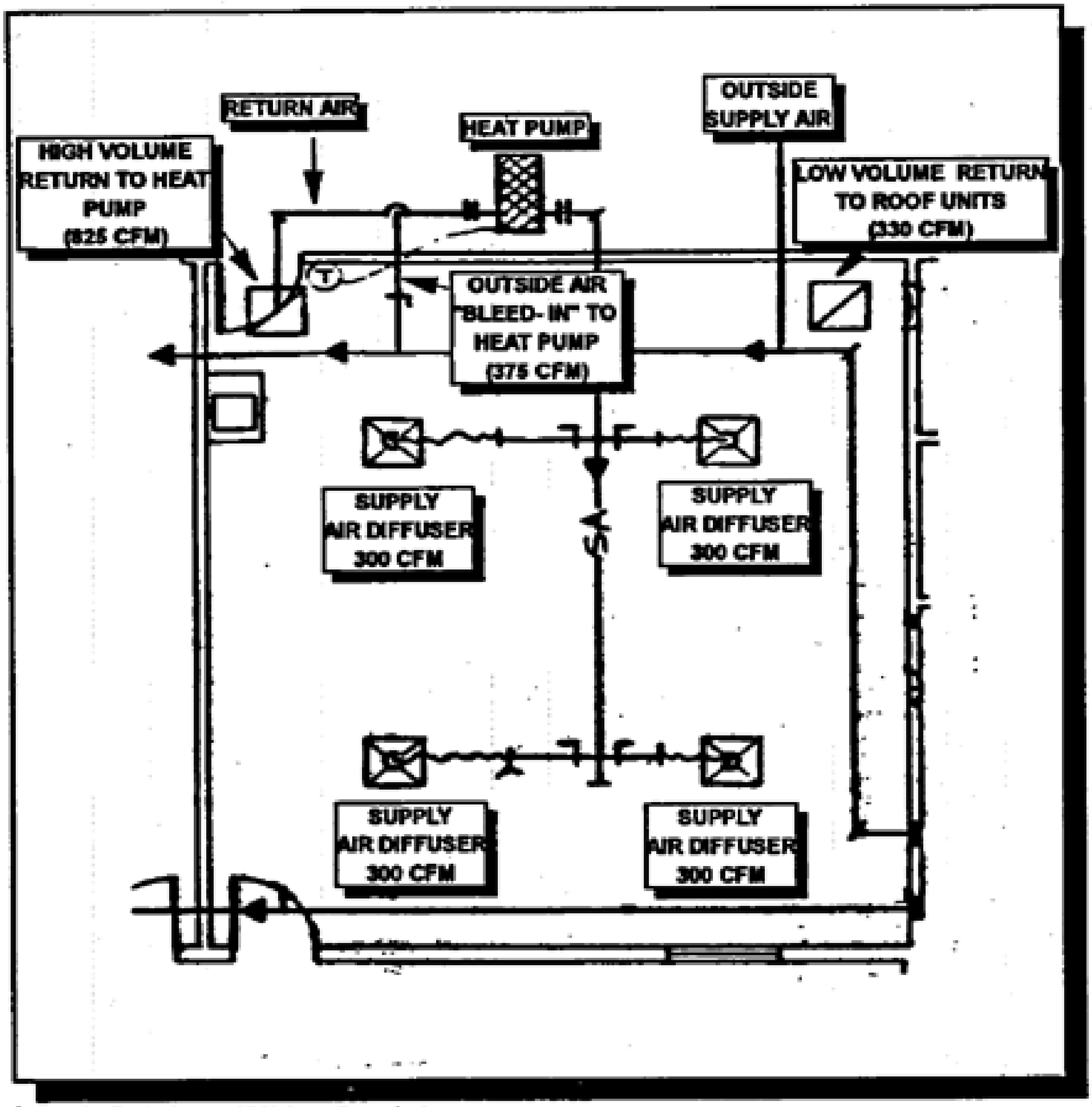

Figure 1. Typical room HVAC configuration

The 1200 cfm of supply air delivered to the room is made up of both recirculated room air and outside air. Each heat pump has a high volume, high pressure intake designed to recirculate approximately 825 cfm of room air back through the unit. To provide the additional make up air, outside air is introduced into the system at a rate of 375 cfm. The outside air ducts are connected to the high volume, high pressure intake side of the heat pump. This configuration allows the outside air to be mixed with the recirculated room air, which then passes through the unit for tempering before being delivered to the supply diffusers. Each room has a thermostat which is set and locked to prevent unauthorized adjustments. The multi-purpose room and the media center have their own central air handling system located in the penthouse mechanical room. This central unit is separate from the classroom units described above.

When heat or cooling is required (according to the thermostat set points), the heat pumps are activated. When activated, a damper opens to allow outside air to enter the unit. That outside air is mixed with recirculated room air which passes through the unit and is returned to the supply diffusers. When the thermostats' temperature conditions are met, the unit is deactivated When deactivated, the outside air damper closes, the heat pump turns off and no air is circulated through the unit. The HVAC systems were last tested and balanced in July 1992, prior to the school opening.

There is no smoking allowed within the facility or on the grounds at Blackshere Elementary School.

IV. EVALUATION METHODS

Medical Evaluation

Between June 1-6, 1993, telephone interviews were conducted with 23 (70%) of the 33 active teachers at Blackshere Elementary. At least two attempts were made to contact each of the ten remaining teachers. These interviews focused on observations the teachers had made over the past year regarding their students. Teachers were asked to estimate how many days in the last month and in the last year a child in their class had to leave school during the day because of illness, whether more than one child had ever had to leave in a given day, and the maximum number of children that had to leave early in a given day. Teachers were also asked to indicate whether classroom attendance in the past year had been higher, lower, or about the same, and whether student behavior had been better, worse, or about the same as that in other years that they had taught the same grade.

On May 31, 1993, the NIOSH Indoor Air Quality and Work Environment Symptoms Survey was mailed to all 47 individuals, including teachers and support personnel, listed on the Blackshere employee roster as supplied by the Marion County Superintendent's Office. The questionnaire asked the employee had experienced, while at work on the day of the survey, any of the symptoms (irritation, nasal congestion, headaches, etc.) commonly reported by occupants of "problem buildings." The questionnaire also asked about the frequency of occurrence of these symptoms while at work in the building during the four weeks preceding the survey, and whether these symptoms tended to get worse, stay the same, or get better when they were away from work. The final section of the questionnaire asked about environmental comfort (too hot, too cold, unusual odors, etc.) experienced while the employees were working in the building during the four weeks prior to completing the questionnaire.

Environmental Evaluation

During the environmental evaluation, information was collected using standardized checklists and inspection forms. These forms were grouped to address the whole building, the evaluation area, and the HVAC system. Descriptive information for the building (age, size, construction, location, etc.), the area to be evaluated (size, type of office space, cleaning policies, furnishings, pollutant sources, etc), and the HVAC systems (type, specifications, maintenance schedules, etc.) were included. Inspections of the evaluated area and HVAC systems were conducted to determine current conditions. The purpose of the environmental investigation was to obtain information required to classify the building, determine the condition of building systems, and document its current indoor environmental status.

In addition to collecting the standardized information described above, indicators of occupant comfort were measured. These indicators were carbon dioxide concentration (CO_2), temperature (T), and relative humidity (RH). Environmental air samples were also collected for formaldehyde, volatile organic compounds, carbon monoxide (CO) and hydrogen sulfide (H_2S). Chemical smoke was used to visualize airflow in the evaluated area and to determine potential pollutant pathways in the selected locations.

The locations sampled during this investigation are shown in Figure 2. To evaluate the entire school, instead of focusing on only a few areas or classrooms, sampling sites (where each days samples were to be collected) were randomly selected before the start of the field investigation. Each room within the school was assigned a number and a random number generator used to select sites. Using this method of site selection, the possibility existed that some rooms might be sampled more than once and others not at all.

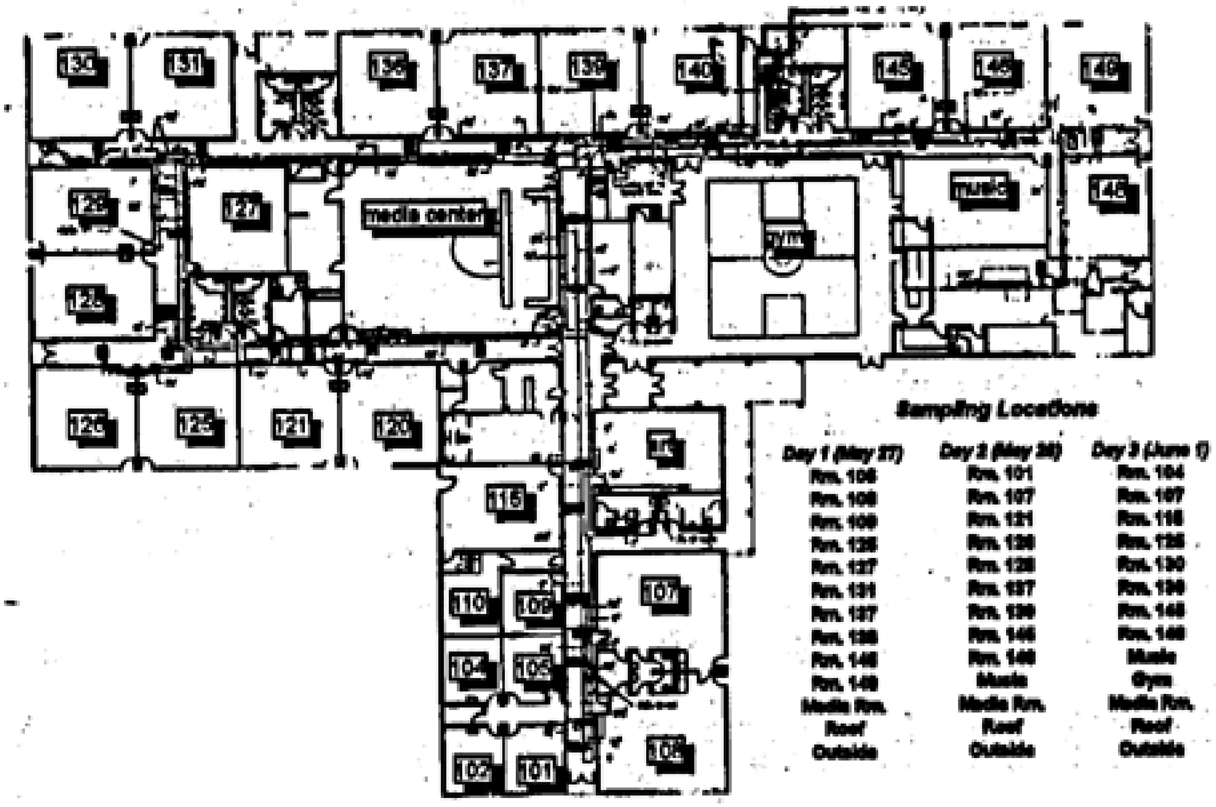

Figure 2. Sampling Locations

In addition to the random sites, three fixed sampling sites (roof, media center, outside background) were also selected to serve as control areas. The following outlines the environmental sampling methods used during this investigation at Blackshere Elementary School.

Carbon Dioxide

Carbon dioxide (CO_2) is a normal constituent of exhaled breath and, if monitored, can be used as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. Indoor CO_2 concentrations are normally higher than the generally constant outdoor CO_2 concentrations (range 300-350 ppm). When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. CO_2 concentrations in this range do not represent a health hazard. However, they do indicate that the air concentrations of other contaminants normally present in office environments may also be elevated and, in combination, may be contributing to health complaints, such as, headaches, fatigue, and eye and throat irritation.

Real-time CO_2 concentrations were measured using a Riken Kikei RI-411A CO_2 indicator. This portable, battery-operated instrument uses a solid-state, non-dispersive infrared sensor to measure CO_2 in the range of 0-4975 ppm, with a repeatability of ± 25 ppm. Instrument zeroing and calibration were performed prior to use with nitrogen and a known concentration of CO_2 span gas (1000 ppm).

Temperature and Relative Humidity

Real-time temperature and humidity measurements were made 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°F and 0 to 100% respectively.

Formaldehyde

Area sampling for formaldehyde was performed using an impinger series containing a 1% sodium bisulfite ($NaHSO_4$) collection media and analyzed according to NIOSH Analytical Method 3500[1]. Samples were collected at a flow rate of 200 cubic centimeters per minute (cc/minute) for 7-8 hours. After sampling, the collection media from each impinger was transferred to polyethylene vials for shipment to the laboratory. Analysis consists of adding a chromotropic acid-sulfuric acid solution to the absorbing solution which causes formaldehyde to react forming a colored chromogen. The absorbance of the colored solution was read by spectrophotometry and is proportional to the quantity of formaldehyde in the solution. This is the most sensitive analytical method for formaldehyde to date.

Volatile Organic Compounds

Volatile organic compounds (VOC's) were collected at flow rates of 50 and 200 cc/min on 100mg/50mg coconut shell charcoal tubes. Sampling times varied between 7-8 hours. VOC samples were qualitatively and quantitatively analyzed according to NIOSH Analytical Method 1501 using a gas chromatography/mass spectrometry (GC/MS).[11] Bulk air samples were collected at a much higher flow rate to saturate the sampling tube. These bulks are qualitatively screened using a gas chromatography equipped with a flame ionization detector (GC/FID). If no hydrocarbon peaks are detected on the high flow rate samples during the initial screening; then no peaks would be expected to be detected on the lower flow (50 cc/min) samples. If hydrocarbon peaks are indentified from the screening, then the lower flow sample would be analyzed and quantitated by the GC/MS for the specific compounds detected during the screening. Identification is made by matching the sample spectra to reference spectra. Once identified, the peaks are converted to concentration for each hydrocarbon collected.

Carbon Monoxide

Samples for the estimation of carbon monoxide (CO) were collected using Dräger 50/a-D long-term diffusion indicator tubes (Cat.#67 33191). These tubes operate on the basis of the diffusion processes in gases. Carbon monoxide molecules to be measured flow into the tube and chemically react with a reagent layer in the tube. This chemical reaction results in a color change of the reagent layer. The mean concentration of carbon monoxide is then calculated from the length of discoloration of the reagent layer, divided by the exposure time. The limit of detection for the detector tubes was 6 ppm.

Hydrogen Sulfide

Samples for the estimation of hydrogen sulfide (H_2S) were collected using Dräger 10/a-D long-term diffusion indicator tubes (Cat.#67 33091). These tubes operate on the basis of the diffusion processes in gases. Hydrogen sulfide molecules to be measured flow into the tube and chemically react with a reagent layer in the tube. This chemical reaction results in a color change of the reagent layer. The mean concentration of hydrogen sulfide is then calculated from the length of discoloration of the reagent layer, divided by the exposure time. The limit of detection for the detector tubes was 1.3 ppm.

V. EVALUATION CRITERIA

Indoor environmental quality (IEQ) is affected by the interaction of a complex set of factors which are constantly changing. Four elements involved in the development of IEQ problems are:

- sources of odors or contaminants,
- problems with the design or operation of the HVAC system,
- pathways between contaminant sources and the location of complaints,
- and the activities of building occupants.

A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems.

The symptoms and health complaints reported to NIOSH by non-industrial 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. Usually, the workplace environment has been implicated because workers report that their symptoms lessen or resolve when they leave the building.

A number of published studies have reported high prevalence of symptoms among occupants of office buildings.[2-6] Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[7,8] Among these factors are imprecisely defined characteristics of heating, ventilating, and air-conditioning (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.[9-14] Indoor environmental pollutants can arise from either outdoor sources or indoor sources.

There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related than any measured indoor contaminant or condition to the occurrence of symptoms.[16-17] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[17-20]

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 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 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, these problems could not be directly linked to the reported health effects.

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.[21-23] These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

With few exceptions, pollutant concentrations observed in non-industrial indoor environments fall well below these published occupational standards or recommended exposure limits. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended building ventilation design criteria and thermal comfort guidelines.[24,25] The ACGIH has also developed a manual of guidelines for approaching investigations of building-related complaints that might be caused by airborne living organisms or their effluents.[26]

Measurement of indoor environmental contaminants has rarely been helpful in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proven relationship between contaminants and specific building-related illnesses. The low-level concentrations of particles and mixtures of organic materials usually found are difficult to interpret and usually impossible to causally link to observed and reported health symptoms. However, measuring ventilation and comfort indicators such as CO_2, temperature and relative humidity, has proven useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems. The basis for measurements made during this evaluation are outlined below.

Carbon Dioxide

Carbon dioxide is a normal constituent of exhaled breath and, if monitored, may be useful as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. The ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 15 cubic feet per minute per person (cfm/person) for classroom spaces.[24] Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 300-350 ppm). When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased.

Temperature and Relative Humidity

The perception of comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures. Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. ANSI/ASHRAE Standard 55-1981 specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[25]

Formaldehyde

Formaldehyde and other aldehydes may be released from foam plastics, particle board, plywood, and textile fabrics, and carbonless paper. Symptoms of exposure to low concentrations of formaldehyde include irritation of the eyes, throat and nose, headaches, nausea, congestion, skin rashes, and, in some individuals who may develop hypersensitivity (allergy), asthma. It is difficult to ascribe specific health effects to specific concentrations of formaldehyde to which people are exposed, because individuals vary in their subjective responses and complaints. Irritant symptoms may occur in people exposed to formaldehyde at concentrations as low as 0.1 parts per million (ppm), but more frequently in exposures of 1.0 ppm and greater. Some sensitive children and the elderly, those with pre-existing allergies or respiratory diseases, 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. However, cases of formaldehyde-induced asthma and bronchial hyperactivity developed specifically to formaldehyde are relatively uncommon.[27-28]

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.[29]

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."[30]

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. 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.[31]

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 NASA, and the Federal governments of Canada, West Germany, and the United Kingdom.[29] An indoor air formaldehyde concentration of less than 0.05 ppm is of limited or no concern according to the World Health Organization (WHO).[31]

Volatile Organic Compounds

Volatile organic compounds (VOCs) describe a large class of chemicals which are organic (i.e, containing carbon) and have sufficiently high vapor pressure to allow some of the compounds to exist in the gaseous state at room temperature. VOCs are monitored in indoor environmental quality (IEQ) investigations to provide a qualitative understanding of the variety of chemicals which exist in the indoor environment. VOCs found in indoor environments result from numerous indoor sources including, but not limited to, carpeting, cleaning compounds, perfumes, waxes, paints, furnishings, and various occupant activities. Not all hydrocarbons exhibit the same toxicological effects; therefore, exposure criteria is dependant on the particular hydrocarbon and toxic effect.

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless gas, slightly lighter than air. It is produced whenever incomplete combustion of carbon-containing compounds occurs. Typical environmental sources of carbon monoxide exposure are poorly vented heating systems, automobile exhaust, and cigarette smoke. The combination of incomplete combustion and inadequate venting often results in overexposure.[32]

The danger of this gas derives from its affinity for the hemoglobin of red blood cells, which is 300 times that of oxygen. The hazard of exposure to CO is compounded by the insidiousness with which high concentrations of carboxyhemoglobin (CO-Hb) can be obtained without marked symptoms.[33]

Intermittent exposures are not cumulative in effect and, in general, symptoms occur more acutely with higher concentrations of CO.[33] The OSHA industrial criterion for exposure to CO is 50 ppm averaged over an 8-hour work shift, 40 hours per week, with a ceiling level (a level which should not be exceeded anytime during the workday) of 200 ppm. The NIOSH recommended expsoure level (REL) for carbon monoxide is 35 ppm for a TWA exposure. The ACGIH threshold limit value (TLV) is 25 ppm. ACGIH has also proposed a biological exposure index (BEI) of <8% CO-Hb in blood at the end of a work shift.

Hydrogen Sulfide

Hydrogen sulfide (H_2S) is a colorless gas at room temperature and has a characteristic rotten egg odor. Although it has a rather low odor threshold (0.13 ppm), it can cause olfactory fatigue in 2 to 15 minutes at 100 ppm. Hydrogen sulfide gas is a rapidly acting systemic poison which causes respiratory paralysis with consequent asphyxia at high concentrations. It irritates the eyes and respiratory tract at low concentrations. Inhalation of high concentrations of hydrogen sulfide, 1000 to 2000 ppm, may cause coma after a single breath and may be rapidly fatal; convulsions may also occur. Exposure to concentrations of hydrogen sulfide above 50 ppm for one hour may produce acute conjunctivitis with pain, lacrimation, and photophobia; in severe form this may progress to keratoconjunctivitis and vesiculation of the corneal epithelium. In low concentrations, hydrogen sulfide may cause headache, fatigue, irritability, insomnia, and gastrointestinal disturbances; in somewhat higher concentrations, it affects the central nervous system, causing excitement and dizziness. Prolonged exposure to 250 ppm of hydrogen sulfide may cause pulmonary edema. Prolonged exposure to concentrations of hydrogen sulfide as low as 50 ppm may cause rhinitis, pharyngitis, bronchitis, and pneumonitis. Repeated exposure to hydrogen sulfide results in increased susceptibility, so that eye irritation, cough, and systemic effects may result from concentrations previously tolerated without any effect. Rapid olfactory fatigue can occur at high concentrations.[32]

The ACGIH TLV for H_2S recommends a TWA value of 10 ppm. They also recommend a short-term exposure limit (STEL) not to exceed 15 ppm for any 15-minute sampling period. The OSHA standard states that the acceptable ceiling concentration is 15 ppm. NIOSH recommends a ceiling concentration not to exceed 10 ppm, in a 10-minute sample during a 10-hour work shift.

VI. MEDICAL RESULTS

Telephone interviews were conducted with 23 teachers. Eight of the teachers interviewed taught special classes or programs such as art, speech, or multimedia, and either did not have a full class or did not have a unique class assigned to them for the entire day. As these teachers did not have primary responsibility for attendance records and generally sent students who reported feeling ill back to their regular teacher, their responses are not included in this discussion of the telephone interviews.

The fifteen teachers who were assigned to a regular classroom had a mean of 15.2 years of teaching experience. Two taught second grade, four taught third grade, and three respondents taught each of the first and fourth grades and kindergarten. Mean class size was 23.2 students. Teachers reported that a child had left school during the day because of illness an average of 5.9 days in the last month and 45.1 days in the entire school year. Thirteen (87%) of teachers had more than one child leave in a given day because of illness, with a maximum of 17 children from one class having left early. Eleven (73%) of teachers reported that classroom attendance was lower this year than in previous years that they had taught the same grade. While six (40%) of teachers felt that student behavior this year was worse than in previous years that they had taught the same grade, an equal number reported that it was about the same.

Questionnaires were mailed to the 47 Blackshere Elementary School employees listed on a roster supplied by the Marion County Superintendent's Office. Forty-two questionnaires were returned, and 38 were suitable for analysis. There were three male and 35 female respondents. The median age of respondents lay in the range of forty to forty-nine years of age. Four currently smoked cigarettes, three were former smokers, and 31 had never smoked. Respondents worked at the school an average of 37 hours per week (range 10-45). Only nine individuals reported using a computer as part of their work, with computer use averaging 1.1 hours/day.

The questionnaire results are shown in Table I. The first column of Table I shows the percentage of the 38 respondents who reported the occurrence of symptoms while at work on the day of the survey. Unusual fatigue, eye irritation or strain, and nasal congestion are the most commonly reported symptoms.

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

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

The reported "building-related" frequent symptom prevalence shown in column 3, are consistently lower than the corresponding symptom prevalence over the last 4 weeks shown in the second column, and are highest for unusual fatigue, eye irritation, and headache. Overall, eighteen of thirty-eight (47%) respondents reported having one or more symptoms that had occurred at work one or more days a week during the preceding 4 weeks and tended to get better when away from work.

Table II shows results of employee reports regarding environmental conditions at their workstations on the day of the survey and during the four weeks preceding the survey. Column one shows the results for the day of the survey. It shows that 63% of the respondents perceived that the ventilation system was not providing sufficient air movement, 32% thought it was too hot, and 18% felt that it was too cold during at least part of their work day.

Table I

Symptoms Experienced At Work
BLACKSHERE ELEMENTARY SCHOOL, MANNINGTON, WEST VIRGINIA
HETA 93-784

Symptoms Of 38 Workers	Experienced On Days of Survey While At Work	Frequently Experienced Last 4 weeks While at work	Have Frequent Symptoms that Improve When Away from Work
Dry, itching, or irritated eyes	37%	39%	29%
Tired or strained eyes	37%	29%	18%
Stuffy nose, or sinus congestion	34%	45%	18%
Sneezing	11%	16%	11%
Sore or dry throat	21%	21%	16%
Dry or itchy skin	24%	24%	11%
Unusual fatigue or drowsiness	45%	55%	34%
Headache	29%	26%	24%
Tension, irritability or nervousness	26%	29%	21%
Difficulty with memory or concentration	21%	18%	8%
Nausea or upset stomach	5%	8%	8%
Feeling depressed	8%	13%	5%
Pain or stiffness in back, shoulders, or neck	26%	26%	16%
Dizziness or light headedness	11%	13%	11%
Cough	18%	16%	8%
Chest tightness	5%	0%	0%
Wheezing	0%	3%	0%
Shortness of breath	5%	5%	5%

The second column shows the responses to the questions about environmental comfort conditions experienced in the facility during the 4 weeks preceding the survey. Adverse environmental conditions (too hot, too cold, odors, etc.) were considered "frequent" if they were reported to occur at work once a week or more often. The results are generally the same or somewhat higher than those shown in the first column for work station environmental conditions experienced during the day of the survey. Sixty-three percent of respondents perceived insufficient air movement, 32% frequently were too hot, 34% were frequently too cold, 16% perceived frequent chemical odors in the workplace, and 18% frequently sensed other unpleasant odors.

Table II
Description Of Workplace Conditions
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Conditions	Experienced At work During Days of the Survey 38 workers	Frequently Experienced While at work During previous 4 weeks 38 workers
Too much air movement	5 %	3 %
Too little air movement	63 %	63 %
Temperature too hot	32 %	32 %
Temperature too cold	18 %	34 %
Air too humid	5 %	5 %
Air too dry	18 %	26 %
Tobacco smoke odors	0 %	0 %
Chemical odors (e.g., paint, cleaning fluids, etc.	16 %	21 %
Other unpleasant odors (e.g., body odor, food odor, perfume)	18 %	18 %

VII. ENVIRONMENTAL RESULTS/FINDINGS

HVAC Systems

Because of the sewer gas problems and more recent odors described as "burning wires", the decision was made to override the HVAC systems automatic timer to operate the systems 24 hours a day, seven days a week. At the request of the NIOSH investigators, the HVAC systems were placed back in the automatic timed mode for this investigation. The sampling protocol was designed to sample during normal operating conditions. Since the final day of sampling was to occur after the three-day Memorial weekend, the HVAC systems were turned off as would normally be done on the weekend.

As previously outlined, heat pumps are controlled by room thermostats. When the thermostat calls for heat or cooling, the pump is activated. While activated, outside air is mixed with recirculated room air and returned to the room. When the thermostat is satisfied, the unit is deactivated. During that period, no mixed air is discharged into the room. This is called an "all or nothing" condition.

It was observed that a few heat pumps, while deactivated, discharged air out the intake grill. That air is likely the outside air that is introduced into the system for mixing. It appears that a control valve that closes and opens the outside air damper is malfunctioning. That air, which comes from the roof units, is not tempered sufficiently to prevent hot or cold spots in the school. This condition could explain why some staff complained that their rooms are too hot in the summer and too cold in the winter

Filters used in the HVAC systems are low efficiency in regards to ASHRAE dust spot criteria. These filters are designed primarily to protect the mechanical systems from dust which could clog or damage the systems. These filters offer little in the way of filtering small particulate, to which some individuals with pre-existing medical conditions such as asthma or allergies, may be sensitive. Low efficiency fiberglass filters were also installed on the high pressure, high volume exhaust grill in each room. The filters observed were clean and appeared to be changed regularly. Finally, it was observed that the ridged ductwork throughout the facility is lined with a 1" acoustical fiberglass liner. This material is used to reduce the mechanical noises from the system.

Four rooms were randomly selected and airflow measurements made to compare to the HVAC design specifications. For three of the rooms selected, the measured supply airflows were within 5% of the HVAC design specifications. One room, Room 108, showed a discrepancy from the design specification. The supply air measured was 36% below design specifications.

Carbon Dioxide, Temperature and Relative Humidity

Summary data for CO_2, temperature and relative humidity are presented in Table III. Prior to the discussion of carbon dioxide results, it is important to stress that measurements were made to determine the effectiveness of the ventilation systems for providing outside air and not to determine whether exposure concentrations in individual classrooms were hazardous or not. Carbon dioxide is used as a surrogate measure in determining the effectiveness of ventilation systems.

Overall carbon dioxide concentrations on June 1, 1993 ranged from 550 to 2850 ppm with a mean of 1231 ppm. Morning concentrations ranged from 550 to 2850 ppm and averaged 1339 ppm during the measurement period (10:00 a.m.). Afternoon concentrations ranged from 500 to 1975 ppm and averaged 1230 ppm (3:00 p.m.). The outdoor concentration was 250 ppm at both times. The highest CO_2 concentration was 2850 ppm, measured in room 149 during the morning period. That measurement was taken during a class with 22 students. During that class period, it was observed that the room door was kept closed. The room was hot and stuffy, and the heat pump was off with no air circulating.

Most measurements of CO_2 were in excess of the ASHRAE upper limit recommendation of 1000 ppm. These measurements indicate that adequate outside air is not being supplied or distributed within the school.

Temperatures ranged from 70.1 to 75.0 °F with an average of 72.9 °F during the morning period. Afternoon temperatures ranged from 72.0 to 76.2 °F with an average of 73.7 °F. The average temperature throughout the day was 73.3 °F. Outdoor temperature increased from 74 to 83 °F between the two measurement times.

The relative humidity ranged from 38.3 to 53% and averaged 43.7% during the morning period. Afternoon measurements ranged from 33.3 to 44.7% and averaged 41.3%. The average relative humidity level throughout the day was 41.3%. The outdoor RH fell from 61.2 to 44% between the morning and afternoon measurements.

Both temperature and relative humidity averages for the day were within the ASHRAE recommendations for thermal comfort.

Table III.

Results of Carbon Dioxide, Temperature and Relative Humidity Measurements

Blackhere Elementary School
Mannington, WV
June 1, 1993

HETA 93-784

	CARBON DIOXIDE (ppm)		TEMPERATURE (Fahrenheit)		RELATIVE HUMIDITY (Percent)	
Classroom	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.
108	825	1125	70.1	73.7	44.3	37.0
107	875	625	71.6	72.8	41.4	33.3
101/102	775	625	71.8	73.4	41.1	34.9
104	550	500	72.0	73.4	38.3	33.2
ART	1300	1425	72.0	72.5	43.6	42.9
115	875	900	72.1	74.3	39.8	35.9
120	2100	1425	73.1	73.9	48.7	42.8
121	1125	1125	73.4	73.9	44.7	41.3
125	1150	1700	73.2	74.3	44.0	44.7
126	2875	1975	73.2	76.2	51.3	43.9
128	1275	975	73.2	74.7	45.6	38.4
129	1200	875	75.0	73.5	39.5	35.4
130	975	1350	73.9	74.4	39.4	39.0
131	850	925	73.0	74.3	40.3	34.9
136	1150	1050	73.1	74.4	43.3	34.2
137	1025	925	73.3	74.9	40.7	34.2
139	1100	1150	73.1	74.4	41.5	40.6
140	1525	1750	73.3	73.1	45.0	44.3
145	1800	975	73.1	72.1	43.0	40.9
146	2400	750	73.0	72.0	51.1	40.7
149	2850	1750	73.5	72.7	53.0	44.0
148	1500	1100	74.0	73.3	44.1	39.3
MUSIC	1100	850	73.6	73.1	42.3	37.6