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Kingwood Elementary School
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I. SUMMARY

On February 25, 1993, March 25, 1993, and June 23, 1993, industrial hygienists from the National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation (HHE) at the Kingwood Elementary School, in Kingwood, West Virginia. The evaluation was requested by the Superintendent of Preston County Schools as a result of employee and parental concerns regarding the indoor environmental quality (IEQ) in the school. Health complaints reported included upper and lower respiratory problems.

Environmental measurements for temperature, relative humidity, carbon dioxide (CO_2), carbon monoxide (CO), and volatile organic compounds (VOCs) were collected. An IEQ questionnaire was distributed to all employees to characterize any building comfort or health complaints. An inspection and assessment of building conditions and the heating, ventilating, and air-conditioning (HVAC) system were also conducted.

Results from the self-administered questionnaire distributed during the survey indicated that the majority of the building's occupants had complaints with the indoor environmental quality at the Kingwood Elementary School. Occupant complaints appeared related to poor air circulation and temperature regulation.

Carbon dioxide measurements were used as a surrogate measure of the dilution capabilities of the building's ventilation system. Measurements of CO_2 at the school exceeded the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) criteria of 1,000 parts per million (ppm) and were indicative of a ventilation system that did not adequately supply or distribute fresh air to the building.

Temperature and relative humidity were measured to evaluate thermal comfort. Some of the temperatures measured during the environmental surveys were not in accordance with the thermal comfort guidelines for winter, as published by the ASHRAE. Most measurements of relative humidity were below the recommended ASHRAE criteria of 30%. Concentrations of CO and VOCs were either not detected or were well below evaluation criteria.

Although no health hazards were specifically identified, the questionnaire revealed that a majority of employees have experienced common building-related complaints. An evaluation of the HVAC system identified a number of concerns. Providing a ventilation system that will meet criteria for occupant comfort and outdoor air ventilation rates are among the recommendations provided in Section VII of this report to optimize employee comfort.

Keywords: SIC 8211 (Educational Facilities, Elementary and Secondary), indoor environmental quality, schools, carbon dioxide, temperature, relative humidity, ventilation, volatile organic compounds.

II. INTRODUCTION

On January 7, 1993, the Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request to investigate employee and parental concerns regarding the indoor environmental quality (IEQ) at the Kingwood Elementary School in Kingwood, West Virginia. Complaints of upper and lower respiratory problems had been filed by the Air Quality Committee (composed of concerned building staff and parents) related to the IEQ in the building. The HHE request was submitted by the Superintendent of Preston County Schools.

On February 25, 1993, a site visit was conducted by a NIOSH investigator. An opening conference was held with school officials, an employee representative of the Air Quality Committee, and a concerned parent. The meeting topics included an overview of the NIOSH HHE program and a review of the issues which prompted the HHE request. After the meeting, a walk-through survey of the school was conducted. Carbon dioxide (CO_2) concentrations were measured with a direct-reading instrument and short-term detector tubes were utilized to determine if carbon monoxide (CO) was present. Temperature and relative humidity measurements were also obtained. The heating, ventilation, and air-conditioning (HVAC) system was inspected and an indoor environmental quality questionnaire was distributed to all employees.

On March 2, 1993, NIOSH sent the Superintendent of Preston County Schools a letter containing several recommendations based on the February 25, 1993, NIOSH site visit. The recommendations included: (1) permanently repair the leaking roof; (2) replace water damaged interior furnishings, including damaged and missing ceiling tiles; and (3) operate the HVAC system in accordance with the recommendations of the current American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) standards, particularly with reference to the supply and distribution of fresh outdoor air to occupied spaces.

On March 25, 1993, additional environmental sampling was conducted based on the building conditions that were encountered during the January 25, 1993, walk-through survey. Carbon dioxide concentrations were determined using both short-term and real-time sampling. Carbon monoxide, volatile organic compounds (VOCs), temperature and relative humidity measurements were also taken.

On June 23, 1993, a ventilation evaluation was conducted with the building unoccupied. A video endoscope probe was used to examine the internal condition of the supply air ductwork. The HVAC system and mechanical spaces were also reinspected.

III. BACKGROUND

Kingwood Elementary School consists of the Price Street building and the adjacent Annex building which are structurally connected. The Price Street and Annex buildings are situated on the campus of Kingwood Elementary School, a public educational facility located in Kingwood, West Virginia. There are approximately 450 students in the building ranging from 3rd through the 6th grade. Thirty-nine employees work at the facility, the majority of these are teachers who work 7.5 hours per day, 5 days per week, 9 months per year.

The Price Street building is a large single story structure of 18,355 square feet. It was constructed in 1977. Located in the building are: four third grade classrooms, three fourth grade classrooms, four fifth grade classrooms, five special education classrooms, a library, a copy room, a speech room, a janitorial storage area, and an HVAC mechanical room. The school was originally built with open instructional areas as classrooms. There have been modifications in the open area classrooms which include the construction of metal partitions creating more traditional classrooms.

An Annex building was built adjacent to the Price Street structure in 1985. The Annex building was connected via a corridor. Located in the Annex are: a gymnasium, a boiler room, a teachers lounge, a guidance office, two special education classrooms, four sixth grade classrooms, and a music room.

Kingwood Elementary School is a smoke free building, as required by West Virginia State law. Use of all tobacco products was recently prohibited on school property.

IV. METHODS

Temperature, relative humidity, CO_2 and CO were measured in classrooms and mechanical areas on the afternoon of February 25, 1993. Since these measurements were taken to evaluate the adequacy of the ventilation system, they were taken in the afternoon, before the end of school, when worst-case situations were expected. On March 25, 1993, these measurements were obtained over the entire school day and in addition, volatile organic compounds sampling was conducted.

A. Heating, Ventilation, and Air-conditioning System Evaluation

An evaluation was conducted of the HVAC system which included a visual inspection of the air handling units (AHUs), coal-fired boiler, radiators, hot water piping, thermostats, and individual unit ventilators. The AHUs and the mechanical space were visually examined for microbial contamination, standing water, position of the outside air intake dampers, general cleanliness, and particulate filter condition. A video endoscope probe was utilized to examine the interior of supply ductwork. In addition, the building was visually inspected for any indications of water leakage or mold growth.

B. Industrial Hygiene Evaluation

1. Temperature and Relative Humidity

Real-time temperature and relative humidity measurements were obtained using a Vaisala, Model HM 34, battery-operated meter. This meter is capable of providing direct readings for dry-bulb temperature and relative humidity, ranging from -4 to 140°F and 0 to 100% respectively. Measurements were taken to evaluate thermal comfort parameters at various locations within the building.

2. Carbon Dioxide

a. Short-term Measurements

Short-term CO_2 concentrations were measured using a Riken Keiki Model RI-411A (CEA Instruments), portable CO_2 meter. This portable, battery-operated instrument uses a non-dispersive infrared absorption detector to measure CO_2 in the range of 0-4975 parts per million (ppm) with a sensitivity of ±25 ppm. Measurements were averaged over 1 minute intervals. Instrument calibration and zeroing were performed prior to use with zero air and a known concentration of CO_2 span gas (800 ppm).

b. Real-time Measurements

Two Riken Keiki Model RI-411A CO_2 meters each equipped with a Metrosonics dl-714 data logger, and a Gastech Model 3252 portable CO_2 detection monitor (range: 0-10,000 ppm) equipped with a similar data logger were utilized to collect real-time data over the school day in three classrooms (Rooms 4, 52, and 56). These classrooms were selected since they were to be continually occupied during most of the school day. Instrument zeroing and calibration were performed prior to use.

c. Full-shift Measurements

Full-shift (integrated) time-weighted average (TWA) CO_2 concentrations were measured using Dräger direct reading carbon dioxide diffusion tubes. These tubes have a relative standard deviation of 20% (at 0.5% CO_2). Measurements were taken in classrooms to determine if occupational exposure criteria were approached.

3. Carbon Monoxide

a. Short-term Measurements

Short-term CO concentrations were determined using Dräger direct reading carbon monoxide colorimetric detector tubes. These tubes have a relative standard deviation of ±10 to 15%. Measurements were obtained near the coal-fired boiler and adjacent areas.

b. Real-time Measurements

An Interscan Series 4000 CO monitor (range: 0-100 ppm) equipped with a Metrosonics dl-714 data logger was utilized to collect real-time data over the school day in the boiler room. The coal-fired boiler was the only source of combustion gas within the school. Instrument zeroing and calibration were performed prior to use.

4. Volatile Organic Compounds

Thirty area air samples were collected for VOCs at different locations in the school. Samples were collected by drawing air through 150 milligram charcoal tubes at a sampling rate of 100 cubic centimeters per minute (cc/min) for a period of approximately 4 hours. Qualitative analysis was performed on bulk air samples that were obtained from the janitorial storage closet, the copying room, the boiler room, and the HVAC mechanical room. These bulk air samples were collected on charcoal tubes at a sampling rate of 200 cc/min for 8 hours. Quantitative analysis of the compounds identified from the bulk air analysis was performed on the 30 area samples. The charcoal tube samples were prepared and analyzed using a combination of NIOSH Methods 1003 and 1401.[1,2] Gas chromatography with mass spectrometry detection (GC/MS) was used for qualitative analysis and a flame ionization detector (GC/FID) was used for quantitative analysis.

C. Indoor Environmental Quality Questionnaire

A self-administered questionnaire was distributed to all school employees which included questions concerning length of employment at Kingwood Elementary School, smoking status, and the complaints associated with IEQ. The questionnaire asked if the employee had experienced, while at work for the past month, any symptoms (irritation, nasal congestion, headaches, etc.) commonly reported by occupants of "problem buildings." The questionnaire also asked about environmental comfort complaints (too hot, too cold, unusual odors, etc.) experienced while employees were working in the building.

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 prevalences of symptoms among occupants of office buildings.[3-7] Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[8,9] Among these factors are imprecisely defined characteristics of the 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.[10-

15) 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.(16-18) Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.(18-21)

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, CO 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 CO 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.(22-24) With few exceptions, pollutant concentrations observed in non-industrial indoor environments fall well below these published occupational standards. The ASHRAE has published recommended building ventilation design criteria and thermal comfort guidelines.(25,26) 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.(27)

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 listed below.

A. Temperature and Relative Humidity

The American National Standards Institute (ANSI)/ASHRAE Standard 55-1981, Thermal Environmental Conditions for Human Occupancy, specifies conditions in which 80% or more of building occupants would be expected to find the environment thermally acceptable. The conditions for thermal comfort are summarized in the following table:

Acceptable Ranges of Temperature and Relative Humidity During Winter and Summer

Relative Humidity (%)	Winter Temperature (°F)	Summer Temperature (°F)
30	68.5 - 76.0	74.0 - 80.0
40	68.5 - 75.5	73.5 - 79.5
50	68.5 - 74.5	73.0 - 79.0
60	68.0 - 74.0	72.5 - 78.0

Acceptable temperatures range from 68.0°F to 76.0°F in the winter and from 72.5°F to 80.0°F in the summer dependent on the relative humidity. The difference between winter and summer is largely due to seasonal clothing selection. In a separate document (ASHRAE Standard 62-1989), ASHRAE also recommends that relative humidity be maintained between 30% and 60%. Excessive humidity can support the undesirable growth of pathogenic and allergenic microorganisms.

B. Carbon Dioxide (CO_2)

Carbon dioxide is a normal constituent of exhaled breath and its measurement can be used as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. Carbon dioxide concentrations are normally higher indoors than the generally constant ambient (outdoor) CO_2 concentration which typically ranges from 300 to 350 ppm. When indoor CO_2 concentrations exceed 1,000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected and widespread complaints can be anticipated. Carbon dioxide concentrations at this level do not represent a health hazard, but suggest that other indoor contaminants may also be elevated. In combination, these may contribute to health complaints such as headache, fatigue, and eye and throat irritation.

The ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends that indoor CO_2 levels be less than 1,000 ppm. This criterion is based on a correlation with odor perception and comfort that is far below the established industrial criteria and the levels at which adverse health effects would be expected. The ASHRAE Standard 62-1989 regarding educational institutions recommends outdoor air supply rates of 15 cubic feet per minute per person (cfm/person) in classrooms, given a maximum number of occupants per 1,000 ft^2 of occupied area. By ventilating the building with the proper amount of outdoor air, ASHRAE believes that CO_2 levels can be kept less than 1,000 ppm and that other contaminants, except for unusual sources, will be kept at acceptable levels.

The current OSHA Permissible Exposure Limit (PEL) for CO_2 is 5,000 ppm for an 8-hour TWA exposure. OSHA had raised the PEL to 10,000 ppm in 1989 under the Air Contaminants Standard. In July 1992, the 11th Circuit Court of Appeals vacated this standard. OSHA is currently enforcing the 5,000 ppm standard; however, some states operating their own OSHA approved job safety and health programs will continue to enforce the upper limit of 10,000 ppm. The NIOSH Recommended Exposure Level (REL) for a 10-hour time-weighted average (TWA) exposure is 5,000 ppm and the ACGIH Threshold Limit Value (TLV) is 5,000 ppm for an 8-hour TWA exposure. It would be extremely unusual to encounter CO_2 concentrations near these criteria in a non-industrial, educational environment. In general, CO_2 data is obtained to evaluate the HVAC system performance.

C. Carbon Monoxide (CO)

Carbon monoxide is a colorless, odorless gas, slightly lighter than air. It is produced whenever incomplete combustion of carbon-containing compounds occurs. Major sources of exposure to CO are engine exhaust, tobacco smoke, and inadequately vented combustion products from appliances and heaters that use natural gas, propane, kerosene, or similar fuels. On inhalation, CO acts as a metabolic asphyxiant, causing a decrease in the amount of oxygen delivered to the body's tissues. CO combines with hemoglobin (the oxygen carrier in the blood) to form carboxyhemoglobin (CO-Hb), which reduces the oxygen-carrying capacity of the blood. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered.

The current OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure. OSHA had lowered the PEL to 35 ppm in 1989, but this standard was vacated in 1992. OSHA is currently enforcing the 50 ppm standard; however, some states operating their own OSHA approved job safety and health programs will continue to enforce the lower limit of 35 ppm. OSHA continues to encourage employers to follow the 35 ppm limit. The NIOSH REL is 35 ppm TWA over a 10-hour work shift, with a ceiling level of 200 ppm which should not be exceeded for any length of time. The ACGIH TLV is 25 ppm TWA. ACGIH has also proposed a biological exposure index (BEI) of <8% CO-Hb in blood at the end of a work shift. It is extremely rare for occupational standards for CO to be exceeded (or even approached) in public and commercial buildings, including those experiencing indoor air quality problems.

D. Volatile Organic Compounds (VOCs)

Volatile organic chemicals are emitted in varying concentrations from numerous indoor sources (carpeting, fabrics, adhesives, solvents, photocopier toners, paints, cleaners, waxes, cigarettes, kerosene heaters, and other fuel-fired heating devices). Studies conducted in newly constructed office buildings have identified hundreds of these organic compounds present in the indoor air. Some organic species (formaldehyde and benzene) have been determined to be carcinogenic in animal studies. Total indoor VOC concentrations typically exceed corresponding outdoor levels except in locations immediately impacted by industrial or combustion source emissions. Recent laboratory studies evaluating human responses during controlled exposures to varying VOC mixtures reported test subject health symptoms similar to those reported by workers in large office buildings.[28,29]

VI. RESULTS AND DISCUSSION

A. Building Evaluation

During the February 25 and March 25, 1993, surveys, roof leaks were evident, and broken, missing, or water-stained ceiling tiles were observed in numerous locations. Ceiling tiles had been removed in the areas of frequent roof leakage, in an effort to catch dripping water into various containers. The roof had been leaking for approximately five years in the area along the roof seam that connects the Price Street and the Annex buildings. The roof was leaking with such intensity that classes were cancelled on March 24, 1993. Since floor coverings were carpet throughout the structure, damp areas were observed during the NIOSH surveys.

Fire protection equipment was also inspected as part of the building evaluation. All fire extinguishers inspected indicated that they were fully charged. Some classrooms that are along the exterior wall had outside doors marked "EXIT." Some of these "EXIT" signs were not illuminated. Several more classrooms had outside doors, but these were not provided with an "EXIT" sign.

B. Heating, Ventilation and Air-conditioning System Evaluation

The HVAC system consisted of three air handling units (AHUs) and was a constant volume system. This HVAC system only serves the Price Street section of the structure. Therefore, no fresh outside air is mechanically supplied to the Annex. The fresh air intake, located on the rear of the Price Street building, had louvered openings which were automatically adjustable according to ambient temperature. Outside air entered the louvered wall openings into the mechanical room and was mixed with recirculated air. The mixed air then flowed through fiberglass filters located in the AHUs. The mixed, filtered air passed through the heating or cooling coils into the supply ductwork and was delivered to the occupied spaces through square supply diffusers located in the ceiling (approximately four diffusers per room). Air from the occupied areas entered the return plenum above the dropped ceiling through square ceiling grills and was returned to the mechanical room. The intake louvers were providing a minimum of fresh air (approximately 15%) to the HVAC system during the NIOSH survey on February 25, 1993, and varied from a minimum of 15% to approximately 100% during the March 25, 1993, survey. The HVAC mechanical room was free of debris and the AHUs appeared in good repair. Air filters were a medium efficiency fiberglass material and are replaced as needed (approximately four times per year).

The school was heated via hot water from a coal-burning boiler located in the Annex building. Individual radiators are located in each Annex classroom and heat exchangers are located in the ductwork of the Price Street building. Temperatures in the Price Street building was controlled by three area thermostats which were secured to prevent unauthorized occupant use. Thermostats were last calibrated in September 1992 and were set to 72°F for heating and cooling. The HVAC system operated on a setback cycle; ventilation began at 5:00 a.m. and ended at 3:30 p.m. on a daily basis.

On June 23, 1993, an additional ventilation evaluation was conducted with the building unoccupied. A video endoscope probe was used to examine the internal condition of the supply air ductwork. All ducts examined were heavily loaded with dust and other particulate matter. The ductwork in the area of severe roof leakage was free from visible biological contamination. The HVAC system and mechanical spaces were also reinspected. The AHU filters, which were heavily loaded with dust, were the only deficiency noted.

C. Industrial Hygiene Evaluation

Measurements were taken on February 25, 1993, and March 25, 1993. The coal-fired boiler was supplying the building with heat during both surveys.

1. Temperature and Relative Humidity.

The results of temperature and relative humidity measurements at each location monitored are presented in Tables 1-3. On the afternoon of February 25, 1993, classroom temperatures in the Price Street building ranged from 69.4 to 75.3°F with an average building temperature of 72.4°F. Relative humidity ranged from 17.6 to 22.9% with an average 20.1%. In the Annex building temperatures ranged from 65.0°F in the gymnasium to 76.7°F in a 6th grade classroom. The average temperature in the Annex building was 72.7°F. Relative humidity ranged from 20.4 to 42.9% with an average of 34.6%. At 30% relative humidity, ASHRAE recommends an acceptable winter temperature range of 68.5-76.0°F. All relative humidity measurements in the Price Street building were below the recommended criteria of 30%. Low relative humidity levels may cause drying and irritation of the mucous membranes. It is not unusual for RH to be very low in cold climates in heated buildings because outside winter air which often is already low in moisture content is dried out further during the normal building heating process. The same situation would occur in peoples homes that are not humidified.

On March 25, 1993, temperature and relative humidity measurements were obtained in the morning (see Tables 2a and 2b) and afternoon (see Tables 3a and 3b). In the morning, temperatures averaged 74.6°F with 42.0% relative humidity in the Price Street building and averaged 73.1°F with 48.8% relative humidity in the Annex. In the afternoon, temperatures averaged 73.7°F with 37.8% relative humidity in the Price Street building and averaged 74.9°F with 42.2% relative humidity in the Annex. All temperatures and relative humidities were within accordance with the ASHRAE recommendations for winter thermal comfort.

2. Carbon Dioxide

a. Short-term Measurements

The results of the short-term CO_2 measurements are also presented in Tables 1-3. On February 25, 1993, afternoon CO_2 measurements in the Price Street building (see Table 1a) were observed to range from 1,300 ppm in a third grade classroom to 1,825 ppm in a special education classroom and the library. The average CO_2 level in the school was 1,531 ppm. In the Annex section (see Table 1b) the levels were much higher and ranged from 650 ppm in the unoccupied boiler room to 4,375 in the music room. The average CO_2 level in the Annex building was 3,123 ppm. The ambient (outdoor) CO_2 concentration was 375 ppm.

On March 25, 1993, CO_2 measurements were obtained during the morning and afternoon. In the morning (see Tables 2a and 2b), CO_2 measurements averaged 1,143 ppm in the Price Street building and 1,585 ppm in the Annex. In the afternoon (see Tables 3a and 3b), CO_2 measurements averaged 561 ppm in the Price Street building and 1,083 ppm in the Annex. These afternoon levels were generally much lower than those observed during the morning or on February 25, 1993. The weather was much warmer outside on this day and as the fresh air intake louvers began to open, the HVAC system was providing the building with increasing quantities of outside air. In addition windows and doors were opened.

Many of these indoor CO_2 measurements exceed the ASHRAE recommendation of 1,000 ppm and are indicative of a building in which fresh air is not being adequately supplied or distributed.

b. Real-time Measurements

The plots of real-time CO_2 measurements taken on March 25, 1993, are presented in Figures 1-3. Figure 1 displays the CO_2 concentrations in special education classroom #4 of the Price Street building. As class began the CO_2 level rose steadily from 400 ppm to over 1,000 ppm before the lunch hour. The HVAC system began to supply the building with increasing quantities of fresh air as the weather warmed outside and the doors and windows of the building were opened. Thus the CO_2 levels dropped dramatically below 600 ppm after lunch. This illustrates the effect of increasing ventilation on CO_2 levels.

Figure 2 displays the CO_2 concentrations in music room #52 of the Annex building. The CO_2 level began at 600 ppm before classes started and during the morning dramatically increased to over 2,500 ppm. The level then dropped to 1,200 ppm during lunch period when the room was unoccupied. After lunch, the fire exit door was successively opened and closed during each of the afternoon class periods. Since this classroom is located in the Annex building and not provided with mechanical ventilation (only hot water radiator heat) the CO_2 levels were in excess of 1,000 ppm during most of the school day and reflect inadequate ventilation. While opening the exterior door provided a two-fold reduction in CO_2 levels this is an inappropriate means of providing ventilation and can only be utilized when weather permits.

Figure 3 displays the CO_2 concentrations in 6th grade classroom #56, which is also located in the Annex building. As classes began, the CO_2 level remained below 500 ppm and then increased markedly to approximately 2,500 ppm. During a class break and the lunch period the level dropped below 1500 ppm. After class resumed the window was opened and levels were maintained between 1,000 and 1,500 ppm. Afterwards the fire exit door was also opened for increased ventilation reducing levels still further to between 600 and 1,000 ppm.

c. Full-shift Measurements

The results of integrated CO_2 sampling over the entire school day are presented in Table 4. Measurements ranged from 686 ppm TWA in a special education classroom to 2,751 ppm TWA in a 6th grade classroom. None of these measurements exceed the occupational exposure criteria for carbon dioxide, however most are indicative of insufficient ventilation and poor air exchange with the outside.

3. Carbon Monoxide

a. Short-term Measurements

Carbon monoxide measurements were conducted on February 25, 1993, near the furnace boiler. Since hot water for the heating system was generated via the combustion of coal, CO was considered a potential building contaminant. All short-term measurements indicated that CO was not present in the boiler room or adjacent areas.

b. Real-time Measurements

Real-time CO measurements were conducted in the boiler room on March 25, 1993. On this day the boiler was providing the building with hot water for heat. Figure 4 displays the CO concentrations in the boiler room. The CO level was 1.2 ppm TWA. This level was well below the occupational exposure criteria and did not represent a health hazard to building occupants.

4. Volatile Organic Compounds

Bulk air samples collected from the janitorial storage closet and the copy room indicated 1,1,1-trichloroethane, C_7 alkanes, toluene, dichlorobenzene, butyl cellosolve (2-buthoxyethanol), a siloxane, xylene, and C_{11}-C_{12} alkanes were present in low concentrations. Samples collected from the boiler room contained traces of toluene only.

Quantitative analysis of the thirty VOC samples collected in the classrooms was based upon the GC/MS qualitative analysis. Dichlorobenzene, toluene, and butyl cellosolve were not detected on the samples. 1,1,1-trichloroethane was only detected on three samples in amounts less than the limit of quantification (approximately 0.5 mg/m^3). C_7 alkanes were detected in four of the samples (range: 0.20-2.04 mg/m^3), the majority of the samples were between the limit of detection (0.04 mg/m^3) and the limit of quantification. VOCs were not detected in the outdoor air at or above the limit of detection. The VOC samples that were collected in the school did not exceed (or even approach) occupational exposure criteria and do not indicate a health hazard.

D. Indoor Environmental Quality Questionnaire

During the survey, questionnaires were distributed to all 39 Kingwood Elementary School employees. Twenty-eight employees (25 female, 3 male) completed and returned questionnaires for a response rate of 72%. Respondents had worked at the school for periods ranging from 6 months to 15 years.

The questionnaire results are shown in Table 5. The first column shows the symptoms which employees regarded as "significant" and believed were associated with the work environment. The second column shows the number and percentage of employees who reported the respective symptoms during the past month preceding the survey. Twenty of the respondents (71%) indicated experiencing health complaints related to the work environment. The most frequently reported symptoms that employees believed to be associated with their work environment were sinus congestion (50%), headache (43%), dry skin (36%), eye irritation (32%), and throat irritation (25%). Eight employees (29%) reported no health complaints with the work environment.

Table 6 shows the questionnaire responses to environmental complaints related to the current work environment. Adverse environmental conditions were only reported by building occupants if they were considered "significant." Eighty-six percent (24/28) of the respondents reported significant complaints related to their current work environment. The most frequently reported complaints included: unusual odors (57%), stuffy feeling (54%), lack of air circulation (50%), temperature too cold (46%), temperature too hot (43%), air too dry (36%), and dust in the air (36%). The unusual odors that were reported included: a musty or damp smell, odors from the boiler room, vehicle exhaust, or odors emitted from the restrooms. Four of the respondents (14%) reported no complaints with the work environment.

VII. CONCLUSIONS and RECOMMENDATIONS

Results from the questionnaire distributed during the survey indicated that many of the building's occupants have complaints with the indoor environmental quality at the Kingwood Elementary School. Many of the occupant complaints appear to be related to an insufficient outside air supply rate and temperature extremes (especially during the heating season).

CO_2 measurements exceeded ASHRAE recommendations for acceptable IEQ. The CO_2 levels measured in the Annex building were elevated about twice those measured in the Price Street Building. This is consistent with the fact that only the Price Street building is supplied with mechanical ventilation. These CO_2 measurements do not indicate a health hazard, but that the building is at times not supplied with sufficient conditioned fresh air.

The following recommendations should be implemented to improve the indoor environmental quality and safeguard the occupational safety and health of school employees, as well as students:

1. The leaking roof should be permanently repaired in order to prevent damage to interior furnishings, as well as to protect the health of building occupants. To effectively prevent the potential of microbial contamination, water-damaged porous furnishings, including carpets and ceiling tiles should be discarded rather than disinfected (porous surfaces cannot be effectively disinfected). When carpet is replaced, disinfect the floor surface with household bleach before resurfacing with new carpet. In susceptible persons, exposure to certain microbial contamination can result in a potentially severe health condition known as hypersensitivity pneumonitis as well as, other disorders, including allergic rhinitis and conjunctivitis.

2. Water-stained ceiling tiles should be replaced so that if additional leaks develop, they can be located and corrected in a timely manner. Inspecting for leaks should become a routine maintenance procedure.

3. A mechanical firm should balance and adjust the HVAC system in the Price Street building to ensure that it is operating according to the ASHRAE recommended standards for outdoor air supply and indoor temperature. Once adjustments are completed, the mechanical firm should submit a certified report that the system has been tested, adjusted, and balanced in accordance with the latest building industry standards.

4. The Annex portion of the building should be provided with a HVAC system that supplies mechanical ventilation to the occupied spaces. A ventilation contractor should be retained to determine the most feasible method for providing adequate amounts of outdoor air to the

building in accordance with ASHRAE recommendations. The required total volume of outdoor air should be calculated using criteria that will result in providing at least 15 cfm/person.[25] The maximum occupancy of employees and students per classroom should be used to calculate an appropriate total volume of outdoor air. Until this is accomplished, employees should be permitted to open doors and windows to increase the amount of outside air brought into the facility.

5. Consideration should be given to cleaning the large quantity of dust and particulate matter in the AHUs, supply ductwork, and the supply air diffusers. Care should be taken not to moisten acoustic liners in the AHUs. These liners should be cleaned using a high efficiency particulate arrestance (HEPA) filtered vacuum to remove particulate matter. After cleaning, all wet surfaces should be dried immediately before the system is put back into service.

6. Consideration should be given to changing the filters on all AHUs on a time basis, rather than a visual observation basis. Also consider increasing the efficiency of the HVAC system filters to remove the fine dust particles from the air supplied to the classrooms. The most efficient filters whose pressure drop the system can handle should be used.

7. The National Fire Protection Association (NFPA) Code 101, the Life Safety Code, should be followed to ensure the safety of building occupants. All exterior doors that are fire exits should be provided with an "EXIT" sign. Fire exit signs should be illuminated at all times.

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4. Building Air Quality Committee
5. West Virginia Department of Health and Human Resources
6. Preston County Health Department
7. West Virginia State Fire Marshall's Office
8. Occupational Safety and Health Administration, Region III

For the purpose of informing affected employees, 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.

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Table 1a. Carbon Dioxide, Temperature, and Relative Humidity Data
Kingwood Elementary School - Price Street Building
Kingwood, West Virginia
February 25, 1993
HETA 92-362

Sampling Location	*Carbon Dioxide (ppm)*	*Temperature (°F)*	*Relative Humidity (%)*
Reception Area	*1375*	*69.6*	*20.3*
Special Ed. Room #01	*1350*	*69.4*	*18.3*
Special Ed. Room #02	*1525*	*69.5*	*21.8*
Special Ed. Room #04	*1800*	*71.4*	*20.2*
5th Grade Room #09	*1575*	*75.3*	*18.5*
5th Grade Room #10	*1475*	*75.1*	*19.2*
5th Grade Room #11	*1750*	*74.6*	*22.9*
5th Grade Room #12	*1450*	*74.8*	*17.6*
3rd Grade Room #13	*1375*	*72.5*	*19.0*
3rd Grade Room #14	*1375*	*72.8*	*18.9*
3rd Grade Room #15	*1450*	*72.0*	*19.6*
3rd Grade Room #16	*1300*	*70.3*	*22.0*
4th Grade Room #17	*1575*	*71.6*	*21.0*
4th Grade Room #18	*1675*	*70.2*	*22.5*
4th Grade Room #20	*1425*	*73.0*	*20.8*
Resource Room #21	*1425*	*73.5*	*19.7*
Special Ed. Room #22	*1825*	*73.5*	*19.1*
Library Room #25	*1825*	*74.0*	*20.5*
Average of all Measurements	*1531*	*72.4*	*20.1*

Outdoor conditions on the afternoon of February 25, 1993, were as follows:
Carbon Dioxide: 375 ppm
Temperature: 28.1°F
Relative Humidity: 10.5%

Note: Measurements were taken in the afternoon before the end of school.

Table 1b. Carbon Dioxide, Temperature, and Relative Humidity Data
Kingwood Elementary School - Annex Building
Kingwood, West Virginia
February 25, 1993
HETA 92-362

Sampling Location		***Carbon Dioxide (ppm)***	***Temperature (°F)***	***Relative Humidity (%)***
Main Hallway		*2900*	*71.6*	*34.7*
Boiler Room	*Room #48*	*650*	*69.1*	*20.4*
Gymnasium	*Room #49*	*2250*	*65.0*	*34.9*
Special Ed.	*Room #51*	*3150*	*74.0*	*33.1*
Music	*Room #52*	*4375*	*75.0*	*36.8*
Special Ed.	*Room #53*	*3700*	*74.9*	*34.2*
6th Grade	*Room #54*	*3950*	*72.9*	*39.5*
6th Grade	*Room #55*	*4175*	*73.1*	*42.9*
6th Grade	*Room #56*	*2925*	*76.7*	*32.6*
6th Grade	*Room #57*	*3150*	*75.1*	*36.4*
Average of all Measurements		*3123*	*72.7*	*34.6*

Outdoor conditions on the afternoon of February 25, 1993, were as follows:

Carbon Dioxide:	*375 ppm*
Temperature:	*28.1°F*
Relative Humidity:	*10.5%*

Note: Measurements were taken in the afternoon before the end of school.

Table 2a. Morning Carbon Dioxide, Temperature, and Relative Humidity Data
Kingwood Elementary School - Price Street Building
Kingwood, West Virginia
March 25, 1993
HETA 92-362

Sampling Location		***Carbon Dioxide (ppm)***	***Temperature (°F)***	***Relative Humidity (%)***
Reception Area		*1150*	*75.7*	*41.6*
Special Ed.	*Room #01*	*1000*	*73.3*	*43.0*
Special Ed.	*Room #02*	*1500*	*72.6*	*49.9*
Special Ed.	*Room #04*	*1100*	*73.4*	*42.3*
5th Grade	*Room #09*	*1125*	*74.2*	*42.3*
5th Grade	*Room #10*	*1150*	*74.3*	*42.3*
5th Grade	*Room #11*	*1050*	*74.7*	*41.3*
5th Grade	*Room #12*	*1150*	*74.6*	*41.5*
3rd Grade	*Room #13*	*1025*	*74.1*	*41.5*
3rd Grade	*Room #14*	*1075*	*74.1*	*41.9*
3rd Grade	*Room #15*	*1000*	*74.8*	*40.7*
3rd Grade	*Room #16*	*1050*	*74.4*	*41.1*
4th Grade	*Room #17*	*1100*	*75.0*	*40.2*
4th Grade	*Room #18*	*1100*	*75.6*	*39.4*
4th Grade	*Room #20*	*1100*	*76.6*	*38.4*
Resource	*Room #21*	*1300*	*75.3*	*43.9*
Special Ed.	*Room #22*	*1300*	*75.5*	*41.6*
Library Room #25		*1300*	*75.1*	*42.8*
Average of all Measurements		*1143*	*74.6*	*42.0*

Outdoor conditions on the morning of March 25, 1993, were as follows:

Carbon Dioxide:	*425 ppm*
Temperature:	*60.8°F*
Relative Humidity:	*57.1%*

Note: Measurements were taken in the morning before the lunch period.

Table 2b. Morning Carbon Dioxide, Temperature, and Relative Humidity Data
Kingwood Elementary School - Annex Building
Kingwood, West Virginia
March 25, 1993
HETA 92-362

Sampling Location		***Carbon Dioxide (ppm)***	***Temperature (°F)***	***Relative Humidity (%)***
Main Hallway		*1500*	*70.5*	*51.2*
Boiler Room	*Room #48*	*525*	*73.0*	*47.8*
Gymnasium	*Room #49*	*1950*	*69.0*	*65.3*
Special Ed.	*Room #51*	*1650*	*74.5*	*46.7*
Music	*Room #52*	*2275*	*74.7*	*49.5*
Special Ed.	*Room #53*	*875*	*74.0*	*43.5*
6th Grade	*Room #54*	*1175*	*72.1*	*48.4*
6th Grade	*Room #55*	*3525*	*72.1*	*53.9*
6th Grade	*Room #56*	*1350*	*75.1*	*41.8*
6th Grade	*Room #57*	*1025*	*75.6*	*39.8*
Average of all Measurements		*1585*	*73.1*	*48.8*

Outdoor conditions on the morning of March 25, 1993, were as follows:
Carbon Dioxide: 425 ppm
Temperature: 60.8°F
Relative Humidity: 57.1%

Note: Measurements were taken in the morning before the lunch period.

Table 3a. Afternoon Carbon Dioxide, Temperature, and Relative Humidity Data
Kingwood Elementary School - Price Street Building
Kingwood, West Virginia
March 25, 1993
HETA 92-362

Sampling Location	***Carbon Dioxide (ppm)***	***Temperature (°F)***	***Relative Humidity (%)***
Reception Area	*500*	*70.5*	*43.0*
Special Ed. Room #01	*575*	*73.6*	*35.9*
Special Ed. Room #02	*775*	*73.9*	*41.0*
Special Ed. Room #04	*525*	*72.8*	*37.0*
5th Grade Room #09	*500*	*73.0*	*37.1*
5th Grade Room #10	*600*	*73.9*	*35.7*
5th Grade Room #11	*525*	*74.3*	*37.8*
5th Grade Room #12	*575*	*74.5*	*35.1*
3rd Grade Room #13	*475*	*73.5*	*36.9*
3rd Grade Room #14	*550*	*74.3*	*37.8*
3rd Grade Room #15	*500*	*73.0*	*39.1*
3rd Grade Room #16	*575*	*74.2*	*42.0*
4th Grade Room #17	*575*	*73.9*	*39.1*
4th Grade Room #18	*575*	*73.7*	*38.5*
4th Grade Room #20	*575*	*73.7*	*38.1*
Resource Room #21	*575*	*74.9*	*35.5*
Special Ed. Room #22	*575*	*74.9*	*35.9*
Library Room #25	*550*	*74.6*	*34.9*
Average of all Measurements	*561*	*73.7*	*37.8*

Outdoor conditions on the afternoon of March 25, 1993, were as follows:

Carbon Dioxide: 350 ppm
Temperature: 65.6°F
Relative Humidity: 41.5%

Note: Measurements were taken in the afternoon before the end of school.

Table 3b. Afternoon Carbon Dioxide, Temperature, and Relative Humidity Data
Kingwood Elementary School - Annex Building
Kingwood, West Virginia
March 25, 1993
HETA 92-362

Sampling Location		***Carbon Dioxide (ppm)***	***Temperature (°F)***	***Relative Humidity (%)***
Main Hallway		*525*	*71.2*	*39.9*
Boiler Room	*Room #48*	*425*	*78.2*	*36.9*
Gymnasium	*Room #49*	*2250*	*75.5*	*56.0*
Special Ed.	*Room #51*	*600*	*74.0*	*38.6*
Music	*Room #52*	*925*	*75.0*	*40.6*
Special Ed.	*Room #53*	*900*	*75.9*	*37.3*
6th Grade	*Room #54*	*2225*	*75.5*	*53.5*
6th Grade	*Room #55*	*1775*	*74.6*	*46.2*
6th Grade	*Room #56*	*575*	*74.5*	*36.8*
6th Grade	*Room #57*	*625*	*74.9*	*36.2*
Average of all Measurements		*1083*	*74.9*	*42.2*

Outdoor conditions on the afternoon of March 25, 1993, were as follows:

Carbon Dioxide: 350 ppm
Temperature: 65.6°F
Relative Humidity: 41.5%

Note: Measurements were taken in the afternoon before the end of school.

Table 4. Full-shift Area Carbon Dioxide Concentrations
Kingwood Elementary School - Price Street and Annex Buildings
Kingwood, West Virginia
March 25, 1993
HETA 92-362

Sampling Location	Carbon Dioxide Time-weighted Average (ppm)
Special Ed. Room #04	686
Music Room #52	1260
Special Ed. Room #53	1379
6th Grade Room #54	2751
6th Grade Room #56	1160
6th Grade Room #57	1374

Table 5. Symptoms Experienced at Work
Kingwood Elementary School
Kingwood, West Virginia
February 25, 1993
HETA 92-362

Symptoms of 28 Workers	***Number of Workers who Frequently Experienced Symptoms at Work during the Past Month***
Sinus congestion	*14 (50%)*
Headache	*12 (43%)*
Dry skin	*10 (36%)*
Eye irritation	*9 (32%)*
None	*8 (29%)*
Throat irritation	*7 (25%)*
Cough	*5 (18%)*
Lightheadedness	*4 (14%)*
Fatigue	*3 (11%)*
Flu-like symptoms	*3 (11%)*
Chest tightness	*2 (7%)*
Difficulty breathing	*2 (7%)*
Wheezing	*2 (7%)*
Nausea	*1 (4%)*
Skin irritation	*1 (4%)*

Table 6. Descriptions of Workplace Conditions
Kingwood Elementary School
Kingwood, West Virginia
February 25, 1993
HETA 92-362

Conditions Reported by 28 Workers	*Number of Workers who Frequently Experienced these Conditions at Work During the Past Month*
Unusual odors	*16 (57%)*
Stuffy feeling	*15 (54%)*
Lack of air circulation	*14 (50%)*
Temperature too cold	*13 (46%)*
Temperature too hot	*12 (43%)*
Air too dry	*10 (36%)*
Dust in the air	*10 (36%)*
None	*4 (14%)*
High humidity	*2 (7%)*