HETA 93-391
MIFFLIN ALTERNATIVE MIDDLE SCHOOL
COLUMBUS, OHIO

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I. INTRODUCTION

On April 27, 1993, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from teachers at the Mifflin Alternative Middle School in Columbus, Ohio. The teachers were concerned about recurring illnesses and lack of proper ventilation in their classrooms.

II. BACKGROUND AND DESCRIPTIVE INFORMATION

The Mifflin Alternative Middle School is located in a suburban and residential area in the city of Columbus, Ohio. The building was first constructed in 1924 and, according to the principal, additional sections had been added in 1940, 1949 and 1974. The building has approximately 85,000 square feet (ft^2) and contained approximately 850 students with 51 teachers, 2 secretaries, 8 cafeteria workers, 5 day custodians, 1 principal and an assistant principal. There are three floors, all which are above ground. The building is constructed of brick masonry with a single ply membrane roof. The floors are constructed of either tile or wood. Many of the older classrooms have wood floors, while the newer classrooms have tile floors. Figures 1a, 1b, and 1c depict the layout of each floor. Smoking occurs in the smoking lounge and the boiler room.

There is one central heating, ventilating, and air-conditioning (HVAC) unit which services approximately seventy percent of the building. It is a single duct, variable air volume (VAV), reheat unit and is located in a mechanical room above the gymnasium. This unit provides conditioned air to most of the newer parts of the building including the auditorium, the offices, the library, the cafeteria, and a portion of the classrooms in the older part of the building. Air enters the air handling unit (AHU) through two sets of dampers located on the roof of the building. One set of dampers is 84 inches by 208 inches and the other set of dampers is 144 inches by 84 inches. These dampers are automatically controlled based upon outside air temperature with a minimum set point of 58°F. Air is initially passed through a 12 feet by 8 feet fiberglass roll filter and then through a number of 3 feet by 3 feet fiberglass bag filters. The mixed filtered air passes through the fan, cooling coil, supply air ductwork, and a VAV box before being delivered to the occupied area through square ceiling diffusers. A return air fan draws air into the plenum above the dropped ceiling through a combination of high sidewall grills and ceiling grills. Air is exhausted from the restrooms by a small fan controlled by a key activated switch.

In addition to the main AHU, most of the classrooms in the old part of the building have several fan-coil, unit ventilators that draw fresh air through the exterior wall. Hot water is provided to these units from the central boiler, and air volume can be controlled at the source by adjusting the speed of the fan. Ventilation in the kitchen is supplemented by a roof-mounted single-duct, constant volume package unit. This unit was designed to provide 5,280 cfm of supply air and 6,000 cfm of exhaust air.

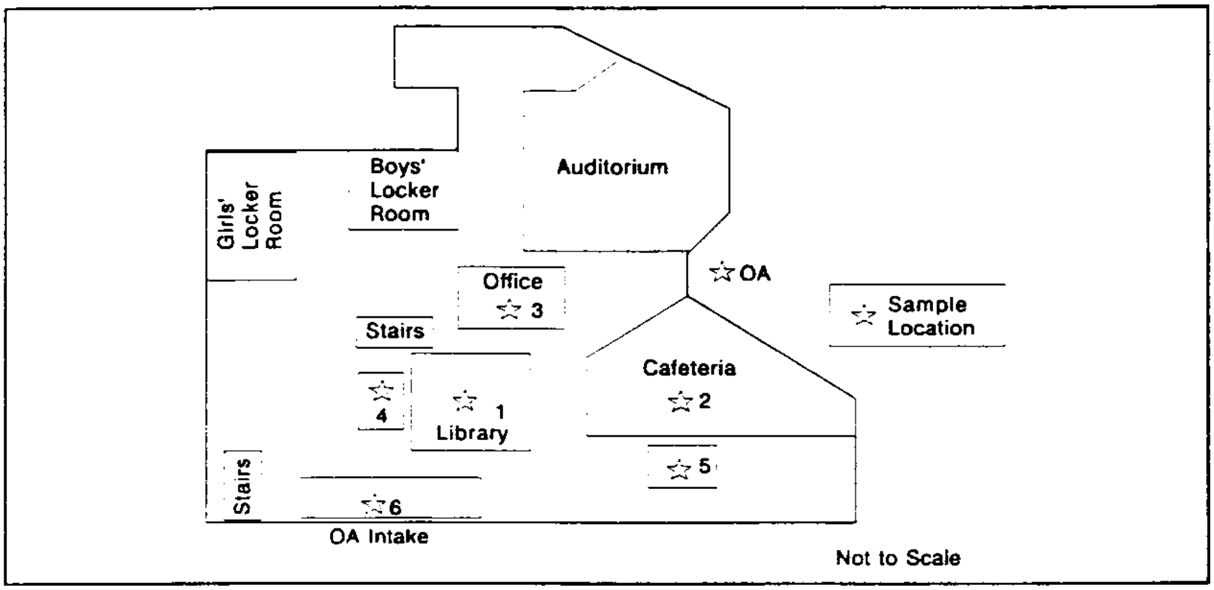

Figure 1a - Mifflin Alternative Middle School
(1st Floor)
Columbus, Ohio
HETA 93-391

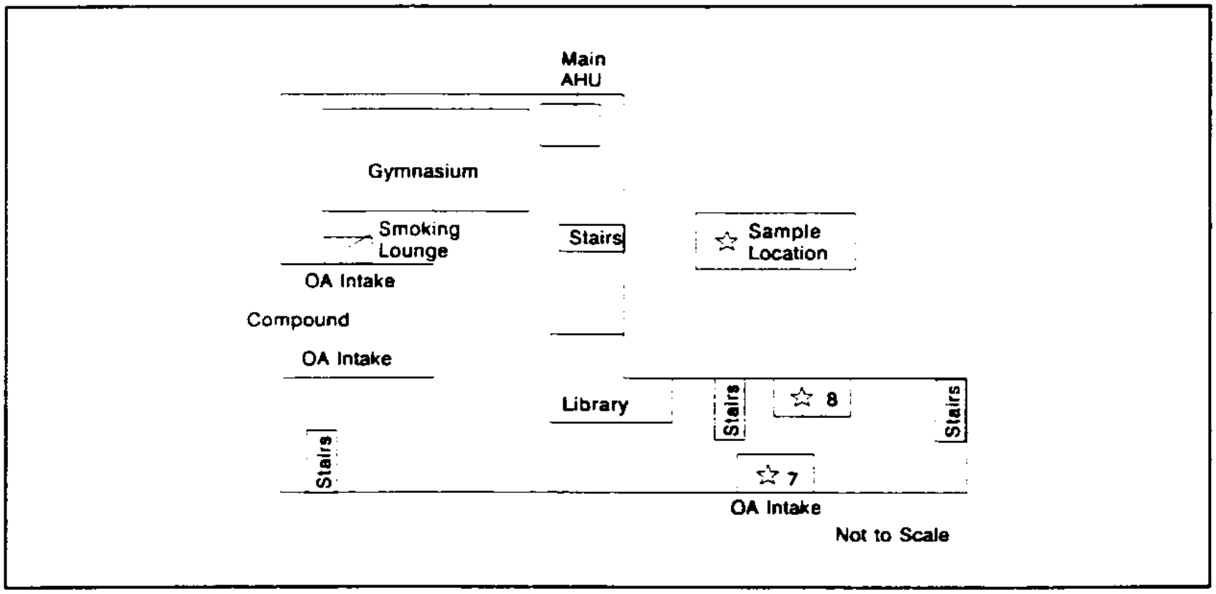

Figure 1b - Mifflin Alternative Middle School
(2nd Floor)
Columbus, Ohio
HETA 93-391

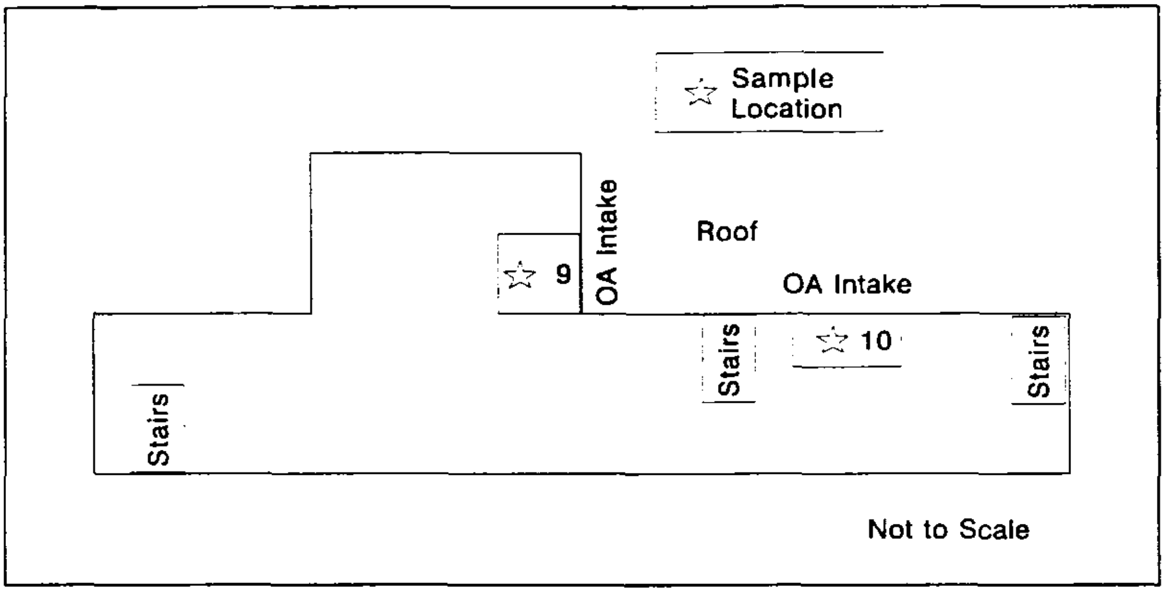

Figure 1c - Mifflin Alternative Middle School (3rd Floor)
Columbus, Ohio
HETA 93-391

Other unevaluated areas of the building, such as the girls' and boys' locker rooms and the gymnasium are provided with ventilation from several different dedicated AHUs located in mechanical rooms on the first floor of the building.

The evaluated area of the building consisted primarily of classrooms in the old section of the building. The classrooms varied depending on which floor and side of the building they were located. Classrooms 311 and 305 were located on the third floor. They had windows that overlooked the roof and unit ventilators located beneath the windows. Classrooms 203 and 204 were evaluated on the second floor. Classroom 203 had no windows or unit ventilators but had four supply, ceiling diffusers. Classroom 204 was located on the exterior of the building and had large windows and two supply, ceiling diffusers. The remainder of the evaluated areas were located on the first floor. Classrooms 107 and 115 were located on the interior of the building and had no windows or unit ventilators. The Home Economics classroom was on the first floor on the exterior of the building and had windows, and through-the-wall unit ventilators. Each of the classrooms with windows had blinds to help control the solar radiant heat load through the windows. Most of the classrooms had between 20 and 30 desks for students; however, when measurements were taken, most of the classrooms had between 10 and 20 students. Room 115 was used as a computer room and had approximately 27 computer workstations.

III. EVALUATION METHODS

Medical Evaluation

During the site visit on April 27-28, 1993, interviews were held with 12 randomly selected teachers. In addition, questionnaires were distributed to 67 employees (including teachers, cafeteria and office staff) working at the school on that day. The questionnaire asked if the employee had experienced, while at work on the day of the survey, any of the 13 symptoms (irritation, nasal congestion, headaches, etc.) commonly reported by occupants of "problem buildings." The questionnaire also asked about the frequency of occurrence of these 13 symptoms while at work in the building during the four weeks preceding the survey, and whether these symptoms tended to get worse, stay the same, or get better when they were away from work. The final section of the questionnaire asked about environmental comfort (too hot, too cold, unusual odors, etc.) experienced while the employees were working in the building during the four weeks preceding the questionnaire administration.

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 (an indicator of outside air exchange), and temperature (T) and relative humidity (RH). Chemical smoke was used to visualize airflow in the evaluated area and to determine potential pollutant pathways to this area. These measurements were made in individual teacher's classrooms as well as in the school office, library, and cafeteria.

Real-time CO_2 concentrations were measured using a Gaztech Model 1310, portable CO_2 indicator. This portable, battery operated instrument uses a non-dispersive infrared absorption detector to measure CO_2 in the range of 0-1999 ppm, with a sensitivity of +/- 1 ppm. Instrument zeroing and calibration were performed prior to use with zero air and a known concentration of CO_2 span gas (800 ppm).

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. Instrument calibration is performed monthly using primary standards.

IV. 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.[1-5] Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[6,7] 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.[8-13] 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.[14-16] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[16-19]

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.[20-22] 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.[23,24] 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.[25]

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.

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 20 cubic feet per minute per person (cfm/person) for office spaces, laboratories, training shops and conference rooms, and 15 cfm/person for reception areas, auditoriums, libraries, and classrooms, and provides estimated maximum occupancy figures for each area.[23]

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.[24]

V. MEDICAL RESULTS

During this site visit, interviews were conducted with 12 employees. Several of the interviewed employees reported experiencing health symptoms while in the building. Commonly reported symptoms included frequent headaches, sinus problems, nasal congestion, and severe fatigue at work. Three employees voiced concerns about the seemingly high frequency of upper respiratory infections occurring among the staff. Five employees reported no symptoms while in the building. Many of the employees reported frequently experiencing thermal discomfort while working in the building. They felt that their classroom alternated between being too cold and too hot (seldom just right). Employees working near the smoking lounge in the building also reported that tobacco smoke odors entered the second floor when the door to the smoking room was opened.

In addition to the interviews, a total of 68 questionnaires were distributed to all of the school employees at work on the day of the evaluation. Forty-two employees or 62% (10 male, 31 female with one missing gender response) returned questionnaires. Forty percent of the respondents were below the age of 40 and 82% were below the age of 50. Eight currently smoked cigarettes, 12 were former smokers, and 21 had never smoked. Respondents had worked in the building for an average of 6 years and worked an average of 37 hours per week (range 8-60).

The questionnaire results are shown in Table I. The first column of Table I shows the percentage of the 21 respondents who reported the occurrence of symptoms while at work on the day of the survey. Eye irritation or strain, fatigue, dry skin, sore throat, headache, and nasal congestion are the most commonly reported symptoms.

Table I

Symptoms Experienced At Work
Mifflin Alternative Middle School, Columbus Ohio
HETA 93-391

Symptoms of 42 Employees	Experienced on Day of Survey while at Work	Frequently Experienced in Last 4 Weeks while at Work	Have Frequent Symptoms that Improve when Away from Work
Dry, itching, or irritated eyes	31 %	33 %	21 %
Wheezing	7 %	10 %	7 %
Headache	17 %	36 %	24 %
Sore throat	21 %	36 %	21 %
Unusual fatigue or drowsiness	14 %	43 %	31 %
Chest tightness	2 %	19 %	12 %
Stuffy nose, or sinus congestion	31 %	41 %	21 %
Cough	14 %	26 %	14 %
Tired or strained eyes	31 %	31 %	21 %
Difficulty with memory or concentration	5 %	17 %	12 %
Dizziness or lightheadedness	7 %	7 %	2 %
Tension	17 %	27 %	19 %
Sneezing	14 %	24 %	14 %
Dry skin	33 %	36 %	16 %
Shortness of breath	2 %	10 %	7 %

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. These symptom prevalences are generally greater than those experienced on the day of the survey.

The third column shows the percentage of employees who reported experiencing the respective symptom once a week or more often while at work during the four weeks preceding the survey and also reported that the symptom tended to get better when they were away from work. This latter criterion has, in some studies of indoor air quality, been used to define a "building-related" symptom, but it is possible that a symptom which does not usually improve when away from the building could also be due to conditions at work. The reported "building-related" symptom prevalence shown in column 3 are somewhat lower than the corresponding symptom prevalence over the last 4 weeks shown in the second column, and are highest for eye irritation or strain, headache, nasal congestion and fatigue. Overall, twenty (48% of the 42 employees responding to the questionnaire) 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. Forty-one percent of the respondents perceived that the ventilation system was not providing sufficient air movement, 14% thought it was too hot, and 21% felt that it was too cold during at least part of their work day.

The second column shows the responses to the questions about environmental comfort conditions experienced in the facility during the 4 weeks preceding the survey. Adverse environmental conditions (too hot, too cold, odors, etc.) were considered frequent if they occurred at work once a week or more often. The results are generally somewhat higher than those reports shown in the first column for work station environmental conditions experienced during the day of the survey. Forty-one percent of respondents frequently perceived insufficient air movement, 24% frequently were too hot, 29% frequently were too cold, and 31% frequently perceived unpleasant odors in the workplace.

Table II

Description Of Workplace Conditions
Mifflin Alternative Middle School Columbus, Ohio
HETA 93-391

Conditions	Experienced at Work During Day of the Survey 42 employees	Frequently Experienced While at Work During previous 4 Weeks 42 employees
Too much air movement	5 %	2 %
Too little air movement	41 %	41 %
Temperature too hot	14 %	24 %
Temperature too cold	21%	29 %
Air too humid	5 %	5 %
Air too dry	19 %	24 %
Tobacco smoke odors	5 %	10 %
Chemical odors (e.g., paint, cleaning fluids, etc.)	5 %	7 %
Other unpleasant odors (e.g., body odor, food odor, perfume)	33 %	31 %

VI. ENVIRONMENTAL RESULTS AND OBSERVATIONS

The classrooms evaluated and the mechanical equipment serving these areas was generally in good condition; however, because of the age of the building, much of it was worn. Areas were generally well lighted by the fluorescent ceiling fixtures and natural light in the rooms with windows. There were a number of areas within the building which were potential pollutant sources. The school maintained a home economics classroom with four gas burning stoves. These were not vented to the outside and a faint odor of natural gas was evident in the classroom. Two of the stoves were of an older design that utilized pilot lights and two stoves had electronic ignitions. Two electric stoves were also installed in the classroom. Natural gas combustion can form nitrogen dioxide, a respiratory irritant, as well as carbon monoxide. Additionally, gasoline, oil, and lawn equipment, which was being stored near the metal shop, could potentially be a source of volatile organic compounds, another pollutant. Finally, there was a smoking lounge located near the gymnasium that was not equipped with any ventilation system except for ventilation provided by opening a window. This lounge was a source of environmental tobacco smoke in the surrounding area.

Inspection of the HVAC system revealed some deficiencies. Preventive maintenance was inadequate; there was no written program or documentation for scheduled inspections and maintenance of the HVAC system. Discussions with maintenance administration indicated that maintenance of the HVAC system had been deferred due to a lack of personnel, money, and equipment. Contract personnel indicated that recently as many as 35 to 40 percent of the control valves in the ductwork had been repaired. During evaluation of the classrooms, it appeared that additional work was needed because some of the supply air diffusers were not providing air. Another problem had to do with the lack of access to the drain pan for the main air handling unit. The drain pan and cooling coils should be regularly cleaned; however, that would be very difficult on this unit because there were no access panels to this area.

Other potential problems were found with the unit ventilators on many of the outside rooms. Many of the rooms located around the area known as the "compound" could be drawing contaminated air into the building. This area was being used for parking vehicles, whose exhaust contains carbon monoxide and other potentially irritating compounds. Other first floor air intakes for unit ventilators were located at ground level and potentially could draw pesticides or other contaminants into the building.

Environmental measurements are presented in Figures 2-4. Measurements were made in ten different locations at three different times in the building. See Figures 1a-1c for measurement locations. The only exception to this was that an afternoon measurement could not be taken at location nine. Carbon dioxide measurements ranged from 530 to 577 ppm during the morning measurement period, from 645 to 1527 ppm during the middle of the day, and from 570 to 1360 ppm near the end of the day. The outdoor air CO_2 concentration ranged from 505 to 516 ppm. These levels are slightly elevated for ambient air and could be due to calibration of the Gaztech model 1310, portable CO_2 indicator. The highest measurement of 1527 ppm was taken in room 311 at approximately 11:00 AM in the morning. Several classroom measurements taken during the middle and end of the day exceeded the ASHRAE guideline of 1,000 ppm, suggesting that an inadequate amount of outside air may be provided.

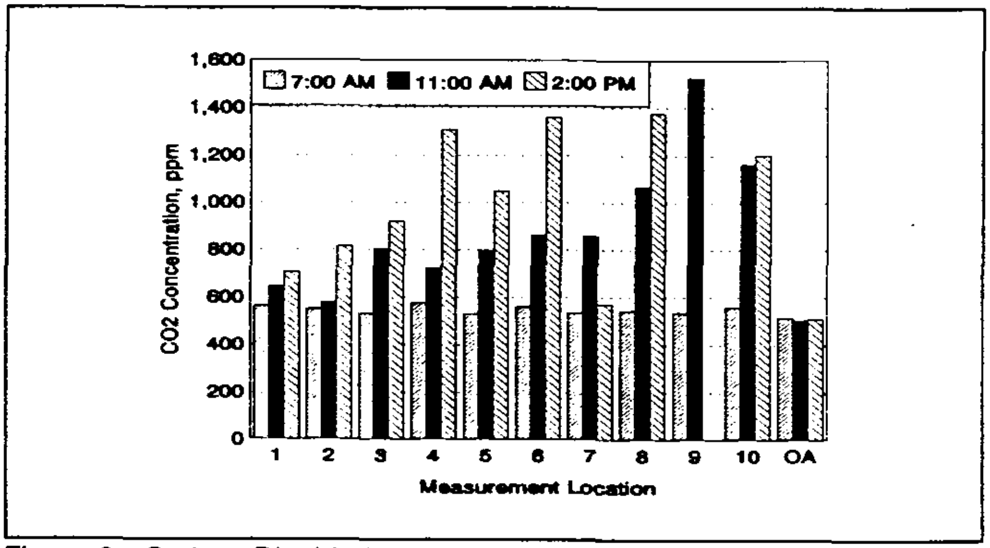

Figure 2 - Carbon Dioxide Measurement Results
Mifflin Alternative Middle School
HETA 93-391

Temperatures ranged from 68.8 °F to 74.3 °F during the morning period, 73.5 °F to 78.3 °F during the afternoon, and 74.3 °F to 78.9 °F near the end of the day. Outdoor air temperatures ranged from 53.8 °F to 72.1 °F. Relative humidity indoors ranged from 22.5% to 29.5% in the morning, 22.3% to 31.7% during the afternoon, and 23.0% to 31.9% near the end of the school day. Outdoor relative humidity measurements ranged from 36.2% in the morning to 25.0% near the end of the day.

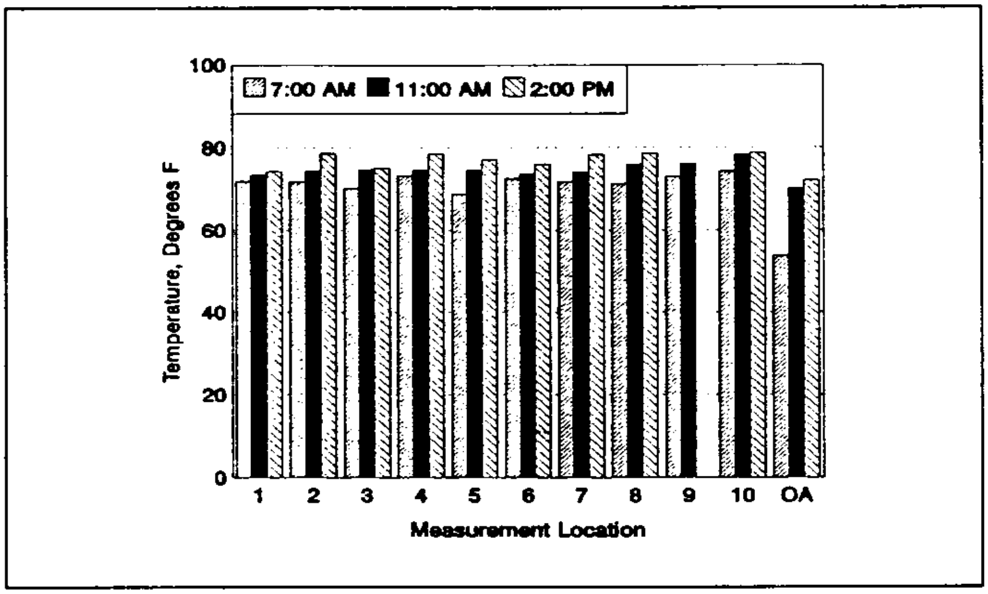

Figure 3 - Temperature Measurement Results
Mifflin Alternative Middle School
HETA 93-391

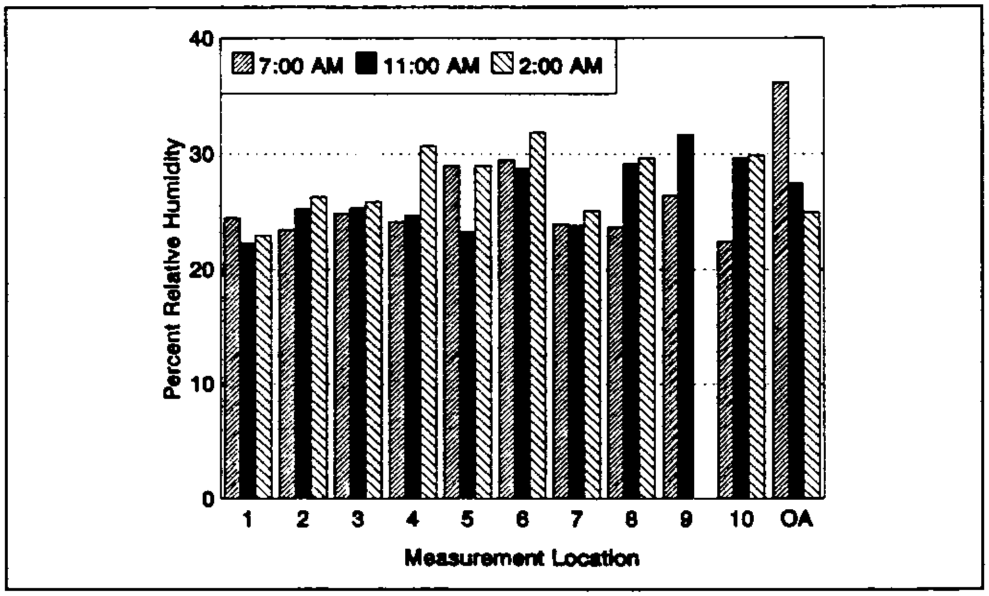

Figure 4 - Relative Humidity Measurement Results
Mifflin Alternative Middle School
HETA 93-391

VII. SUMMARY

NIOSH conducted a survey at the Mifflin International Alternative Middle School in response to a request by teachers who were concerned about the adequacy of the ventilation in their work areas and about symptoms they were experiencing at work. The questionnaire that NIOSH distributed to employees at the school on April 28, 1993 showed that many employees had frequently experienced symptoms (e.g. fatigue, dry skin, headache) while in the building. A significant proportion of the symptomatic employees reported that their symptoms tended to get better when they were away from the building. Forty-eight percent of the Mifflin Alternative Middle School employees reported having frequently experienced one or more such "building-related" symptoms during the 4 weeks preceding the administration of the questionnaire.

Environmental measurements of CO_2, T, and RH were generally within the guidelines recommended. However, midday and afternoon CO_2 concentrations exceeded, in some areas, the 1000 ppm guideline used to determine the adequacy of ventilation. Potential environmental contaminants found in the school included the natural gas used in the home economics room, environmental tobacco smoke, and compounds related to the storage of petroleum products. The impact of these contaminants, however, was on the immediate surrounding areas and no sources of indoor contaminants that would be suspected to cause most of the reported symptoms were identified during environmental inspections.

Reports of building related health complaints have become increasingly common in recent years; unfortunately the causes of these symptoms have not been clearly identified. As discussed in the criteria section of this report, many factors are suspected (e.g. volatile organic compounds, formaldehyde, microbial proliferation within buildings, inadequate amounts of outside air to dilute the products of human metabolism, etc.). While it has been difficult to identify concentrations of specific contaminants that are associated with the occurrence of symptoms, it is felt by researchers in the field that the occurrence of symptoms associated with presence in interior environments can be lessened by providing a properly maintained interior environment.

VIII. CONCLUSIONS AND RECOMMENDATIONS

Although there were no clear environmental causes for the complaints and symptoms reported by the school employees, the NIOSH evaluation identified some environmental deficiencies at the school. Based on the results and observations of this evaluation, the following recommendations are offered to correct those deficiencies and optimize employee comfort.

1. Communication between school management, teachers and custodial staff should be increased to facilitate the exchange of concerns about environmental conditions

at the building. Employees should be made aware of the problems with the building and decisions that are made by school and building managers to address those problems.

2. Exposure to ETS is one of the most important indoor air quality problems, contributing both particulates and gaseous contaminants. A smoking cessation program may be necessary to assist those employees who are current smokers. If smoking is permitted, it should be restricted to designated smoking lounges.[26] These lounges should be provided with a *dedicated exhaust system* (room air directly exhausting to the outside), an arrangement which eliminates the possibility of re-entrainment and recirculation of any secondary cigarette smoke. In addition, *the smoking lounge should be under negative pressure relative to surrounding occupied areas*. The ventilation system supplying the smoking lounge should be capable of providing at least 60 cfm of outdoor air per person.[23] This air can also be obtained from the surrounding spaces (transfer air).

3. The fan for the main air handling unit should remain "on" when the building is occupied.

4. The gas stoves in the home economics room should be ventilated. Natural gas combustion results in the formation of nitrogen dioxide and carbon monoxide which might accumulate in a closed classroom. If venting is not possible, then electric stoves should be substituted. All other potential sources of air contaminants, such as petroleum products, should be removed from the building or placed in an area which is under negative pressure to avoid dispersion throughout the building.

5. A regular HVAC inspection and maintenance program should be implemented and records should be kept to document inspection and maintenance activities. School district management should develop a training program for the custodial staff regarding the maintenance and operation of the school heating and ventilation systems. The main systems should be tested and balanced on a regular basis.

6. All valves and dampers in the supply ducts and unit ventilators should be inspected to ensure that they are operational and that adequate supply air is being provided to all classrooms in accordance with ASHRAE guidlines.[23] This is particularly important for those classrooms on the interior of the building with no windows.

7. An access panel should be provided on the main air handling unit so that the coils and condensate pan can be cleaned and maintained on a regular basis.

8. Teachers should be instructed on the proper operation of the unit ventilators in their rooms and what their responsibilities are.

9. Consideration should be given to the potential for drawing vehicle exhaust into the building near the area called the "compound", as well as, contamination from pesticide application or lawn care activities that could be drawn into the building by outside air intakes near the base of the building.

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X. INVESTIGATORS AND ACKNOWLEDGEMENTS

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XI. DISTRIBUTION AND AVAILABILITY

Copies of this report have been sent to:

1. Principal, Mifflin Alternative Middle School
3. Employee Requestor

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.