HETA 91-188-2205
APRIL, 1992
BETHLEHEM-CENTER ELEMENTARY SCHOOL
FREDERICKTOWN, PENNSYLVANIA

NIOSH INVESTIGATORS:
Joseph E. Burkhart, CIH
Steven Short, D.O.
Elizabeth Knutti, R.N.

I. SUMMARY

On April 12, 1991, NIOSH was contacted by U.S. Congressman Austin J. Murphy to request our involvement in a health hazard evaluation at the Bethlehem-Center Elementary School, Fredericktown, Pa. This request was made formally on April 16, 1991, by the district superintendent. NIOSH was requested to determine if a health hazard existed for students and staff at the elementary school due to materials used during a roofing project.

Environmental assessments were conducted at the school to determine potential exposures to coal-tar pitch volatiles, volatile organic compounds, carbon monoxide, and formaldehyde. Screening of medical records was also accomplished to evaluate possible acute effects from exposure to coal-tar pitch or other compounds used during the roofing project. Questionnaires were distributed to all elementary school staff for their assessment of health problems experienced during the roofing project.

On April 18, 1991, six samples were collected for qualitative analysis of hydrocarbons. Results indicated that only trace amounts of carbon tetrachloride, <0.03 ppm, was detected on one of the samples. That sample was collected near the administrative offices in D-Wing. Carbon tetrachloride was not identified in any of the other samples, nor was it detected in the analysis of the bulk roof material.

On June 26, 1991, samples were collected and submitted for analysis of organic volatile compounds and polynuclear aromatic hydrocarbons. Results showed low levels of xylene, toluene and styrene were detected in B-wing of the school. Those results were expected since painting of ceiling tiles was being performed during the sampling survey. The highest levels found for xylene, toluene and styrene were 9.76 parts per million (ppm), 0.36 ppm and 17.1 ppm, respectively.

Of the 17 PNAs analyzed, only 4 were detected above the limit of quantitation. Trace levels of PNAs ranged from 0.001 to 0.055 milligrams per cubic meter (mg/m^3) benzene soluble fraction, with naphthalene comprising the majority of the sample. Naphthalene levels ranged from 0.001 to 0.046 mg/m^3.

No carbon monoxide or formaldehyde was detected at any of the locations sampled inside or outside the elementary school. Carbon monoxide and formaldehyde concentrations were determined using direct reading monitors.

Direct reading carbon dioxide monitors were placed in each of the three classroom wings (Wing A, Wing B, and Wing D) of the school. The monitors were placed in classrooms located in the center and to the rear of the wings. Results with school students present ranged from 600 - 2000 ppm CO_2, with the higher levels measured late in the afternoon. Information relating to occupant load per classroom wing was used to determine that Wing A was providing 6.5 cfm of fresh outside air per person; Wing B - 4.3 cfm per person; and Wing D - 6.3 cfm per person. These values are far below the ASHRAE recommended criterion of 15 cfm per person for adequate fresh outside air.

A total of ninety-four questionnaires were mailed to employees at the elementary school. Sixty questionnaires (64%) were completed and returned. The major health complaints, as reported, were headaches (76%), red burning eyes (44%), respiratory irritation or sore throat (32%), and nausea (26%).

NIOSH requested medical records on students effected by the odors at the elementary school. Those records were reviewed to determine if reported health symptoms are consistent with acute exposure to coal tar products.

Of the records reviewed, two students and one teacher with histories of pre-existing asthma documented exacerbation of their symptoms after exposure to the roofing odors.

The levels of carboxyhemoglobin (CO-Hb) reported in eight students after being away from the school from 1 to 14 days, are not consistent with the biological half-life elimination process of CO-Hb.

Other tests performed on the students, when corrected for age, were within normal limits.

Efforts taken by the school district to identify and resolve problems associated with the roofing project are commendable. In future, the impact on students and staff should be the number one consideration when planning renovations. Any future renovation work of that magnitude should be accomplished after the end of the school term.

NIOSH opinion is that the roofing project was the agent which focused attention on a facility suffering from pre-existing indoor air quality problems. Based on the information collected, our investigation has found nothing within the elementary school which would constitute a health hazard for either staff or students. However, the lack of sufficient quantities of outside air and poor air distribution within the school may be the cause of the past and present health related complaints reported at the Bethlehem-Center Elementary School.

Keywords: SIC 8211 (Educational facilities, Elementary and Secondary), indoor air quality, coal-tar pitch volatiles, polynuclear aromatic hydrocarbons, volatile organic compounds, roofing tar, carbon monoxide, formaldehyde, carboxyhemoglobin.

II. CHRONOLOGY OF EVENTS

On April 16, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a Health Hazard Evaluation request from the Superintendent of the Bethlehem-Center School District. NIOSH was requested to determine if a health hazard existed for students and staff at the Beth-Center Elementary School due to materials used during a roofing project.

In October 1990, the District's Board of Education let a contract to have the roof of the elementary school repaired and resaturated with a material used to restore/rejuvenate existing tar buildup roofs. According to the architects specifications, the resaturant (Garland Roof Preservative Tar) was to be applied to the repaired roof mat at a rate of not less than 8 gallons per 100 square feet. Using that application criteria, and the size of the elementary school, it was estimated that approximately 7,680 gallons of the material was applied to the roof. According to the manufacturer's (The Garland Company, Inc. of Cleveland, Ohio) Material Safety Data Sheet (MSDS), the roofing resaturant is comprised of Coal Tar Pitch Volatile (40-70% by weight) and Aromatic Process Oil (10-30% by weight). During mid-November 1990, the roof resaturation project was started and completed. Because of cold weather, the roofing contractor reported that the resaturant was heated to approximately 170°F to reduce the oils viscosity in order to pump it to the roof top. Even as heated, this process is still considered a cold process, (according to an independent roofing contractor contacted by NIOSH).

During that time, numerous children were symptomatic and complaining of headaches, nausea, burning eyes, and respiratory difficulties. On November 19, 1990, thirteen children were sent home and November 20, 30 children were sent home because of varying health complaints associated with the coal tar odor.

Due to the concern for the childrens' welfare, school officials closed the school for 4 days. On November 28, 1990, two days after completion of the roof project, the district contracted a private environmental consultant to determine if a health hazard from the roof resaturant existed at the elementary school. Air samples were collected for coal tar pitch volatiles (polynuclear aromatic hydrocarbons, PNAs), hydrocarbons, carbon monoxide and carbon dioxide. Results reported showed no detectable levels of PNAs, trace levels of hydrocarbons, no carbon monoxide, and 488 - 606 ppm of carbon dioxide. Student illnesses were attributed to the "nuisance odor" of the solvents used in the preparation of the roof material. No long term health effects were expected since classes were cancelled and students were not in direct contact with the material. A recommendation in that report suggested that classes not be held in the building until the odor dissipates. That recommendation was to prevent occupants from becoming nauseous from the offensive odor. Two days later, the elementary school was reopened and classes resumed until early April.

On April 3, 1991, unseasonably warm weather caused another episode of a "tar odor". Again, school children began complaining of the smell, with 12 children being sent home. On April 4, 1991, school officials closed the school. Representatives from the roofing contractor, Garland Company, and the school board toured the facility to assess the problems. As a result of that tour, six foot air intake stacks were added to the air handlers (which are located on the roof) in an attempt to reduce the odors from entering the school. Also, a sprinkler system was installed on the roof to keep the resaturant cool, in an attempt to reduce the off-gassing. Due to concerns about the water run-off into the sanitary sewer, the sprinklers were later dismantled.

On April 5, 1991, the school was reopened. On April 8, odors were again present, which resulted in 25 children being sent home. On April 9, the school district voted to close the school pending a full investigation and evaluation of any possible health hazards associated with the roofing material.

On April 11, 1991, the school district contracted with a second private consultant to conduct air sampling within the school. Results reported were similar to that of the first contractor; no PNAs or volatile organic compounds were detected.

On April 12, 1991, NIOSH was contacted by U.S. Congressman Austin J. Murphy to request our involvement in the hazard evaluation at the school. This request was made formally on April 16, 1991 by the district's Superintendent.

On April 17, 1991, NIOSH representatives made an initial site visit to the school to collect background information and assess current efforts in resolving the odor problem. A return visit was made on April 18 to collect samples for qualitative analysis of hydrocarbons. Qualitative analysis is a screening tool used to identify hydrocarbon peaks. If sufficient hydrocarbon peaks are detected during the qualitative analysis, then the identified peaks are used as references for quantitative analysis by a gas chromatograph. Consequently, if no peaks are detected by GC-FID screening, none would be seen by the mass spectrometer. On April 22, preliminarily laboratory results were received and reported to the school board at a public meeting.

On April 22, 1991, representatives from the Occupational Safety and Health Administration (OSHA) conducted a site visit at the school and collected environmental samples. It was reported that those results also showed no detectable concentrations of volatile organic compounds or carbon monoxide.

Results of the NIOSH samples, along with an outline of NIOSH involvement was presented at a public meeting on April 24, 1991. At that meeting, NIOSH requested parents to sign medical release forms for access to their childrens' medical records. Parents requested that additional samples be collected during hot weather conditions and with the raised intake air stacks removed. NIOSH agreed that follow up sampling would be performed under those conditions.

On May 19, 1991, OSHA made a return visit to the school to collect additional samples (under hot weather conditions). OSHA reported that nothing was detected on any of the samples and they were unable to find the presence of any health hazards.

On May 22, 1991, the second private consultant made a return visit to the school for additional sampling. Results were all nondetectable for PNAs and hydrocarbons.

On June 26, 1991, NIOSH representatives made a third visit to the school to collect additional air samples. Samples were collected under the conditions requested by the parents, that is, hot weather conditions and removal of the raised air intake stacks from the air handlers.

On August 9, 1991 a fourth visit by NIOSH was made to the school to evaluate the heating system. One underlying concern from the parents was that when the heating system was activated, the heat would cause the roofing material to off gas. Additionally, there were some added concerns that a possible source of the carbon monoxide might be the heating system. The heating system was activated, and samples were collected using direct reading instrumentation and indicator tubes for carbon monoxide, carbon dioxide, sulfur dioxide and nitrogen dioxide.

On September 12, 1991, NIOSH made a fifth visit to the school to evaluate the air handling systems by sampling for carbon dioxide. This sampling was conducted during school hours while children were present to serve as a source of carbon dioxide. Also, carbon monoxide measurements were made inside the school while school buses were arriving and departing the school.

This report focuses on the efforts of NIOSH to determine if a health hazard exists for students and staff at the elementary school. Although environmental sampling was performed at the school by other groups, those results will not be used in this report to formulate or influence findings and recommendations.

III. FACILITY DESCRIPTION

The Beth-Center Elementary School building was built in 1974 to accommodate grades K through 6. There are approximately 990 students enrolled at the school, with an additional 100 teachers and support staff employed. This single-story, 96,000 square foot, building was heated, cooled, and ventilated by eight individual roof-mounted air handling units (AHU) with ducted air supply; the false ceiling space served as the return air duct to the HVAC. The HVAC system was not equipped with a humidification component. Two oil fired boilers are used as supplemental heat sources for water convection heating.

The majority of the classrooms were ventilated by four AHUs (four individual ventilation wings) with airflow controlled through variable air volume (VAV) boxes. The fresh air intake dampers on each AHU are capable of supplying 10% fresh outside air to each wing.

IV. EVALUATION DESIGN/METHODS

A. Environmental

1. Bulk Analysis of Resaturant

Bulk samples of the raw roof tar were extracted with carbon disulfide, diluted to a pale brownish color, and analyzed by GC/FID and GC/MSD using the 30-meter DB-1 column (splitless mode). Also, an XAD-2 sorbent tube was sampled inside the headspace of one of the bulks. The XAD-2 was desorbed using carbon disulfide and analyzed as mentioned above.

2. Volatile Organic Chemicals

On April 18, 1991, area high volume air samples for qualitative analysis of volatile organic chemicals (VOCs) were collected at six randomly selected locations at the Beth-Center Elementary School. In addition, bulk samples of the raw roof resaturant were collected and forwarded for analysis. Volatile organic chemical sampling was conducted using activated charcoal tubes and high volume sampling pump calibrated at 6 liters per minute. Sampling times varied from 60 to 120 minutes. The charcoal tubes were submitted for qualitative analysis of VOCs compounds by gas chromatography/mass spectrometry (GC/MS). The charcoal tubes were desorbed with 2 milliliters (ml) of carbon disulfide and screened by the gas chromatograph with a flame ionization detector (FID), using a 30-meter DB-1 fused silica capillary column (splitless mode). Representative samples were chosen for further analysis by GC/MS to identify contaminants.

On June 26, 1991, a return visit was made to the elementary school in order to collect additional VOC samples. This second set of air samples were collected under the environmental conditions and HVAC operating parameters requested by the parents, namely hot weather greater than 80ºF and the removal of the raised air intake stacks.

Air samples for volatile organic chemicals, polynuclear aromatic hydrocarbons (PNAs), formaldehyde and carbon monoxide were collected at randomly selected classrooms within the Beth-Center Elementary School. In addition, other preselected sampling locations were the library, the cafeteria, the roof top and the outside perimeter of the school.

VOCs were collected and analyzed as previously described, with the exception that the sampling flow rate was 50 cubic centimeters per minute (cc/min) for a duration of 6-8 hours. Analysis was conducted according to NIOSH Analytical Method 1500.[(1)]

3. Polynuclear Aromatic Hydrocarbons

PNA samples were collected and analyzed according to NIOSH Analytical Method 5515.[(1)] Each sample was collected on a pre-weighed 37 millimeter Teflon filter followed by XAD-2 sorbent tube at a flow rate of 2.0 lpm. Sampling times varied from 6-8 hours. Each sample was protected from sunlight by wrapping both the filter and the tube with aluminum foil. After sampling, all samples were placed on ice for transport to the laboratory.

The Teflon filter is used to trap particulate phase PNAs which is typically generated during demolition of existing roof types. Since this was not the case at the elementary school, the laboratory was instructed to analyze only those filters which showed a total collected mass of more that 100 micrograms of material. The XAD-2 tubes are used to trap vapor phase PNAs. Each tube was desorbed with 1 ml of benzene and analyzed using a GC/FID for 17 specific PNAs. The PNA analyses included the following compounds: acenaphthylene (ACL), acenaphthene (ACE), fluorene (FLU), phenanthrene (PHE), anthracene (ANT), fluoranthene (FLE), pyrene (PYR), benzo(c)phenanthrene (BCP), benzo(a)anthracene (BAA), chrysene (CHY), benzo(e)pyrene (BEP), benzo(b)fluoranthene (BBF), benzo(k)fluoranthene (BKF), benzo(a)pyrene (BAP), dibenz(a,h)anthracene (DAH), benzo(g,h,i)perylene (BGP) and indeno(1,2,3-cd)pyrene (INP).

4. Carbon monoxide, Carbon dioxide, Sulfur Dioxide, Nitrogen Dioxide and Formaldehyde

Although not constituents of the roofing preservative, concerns for exposure to the these chemical compounds were expressed by parents. Their concerns stem from the company's MSDS which lists under reactivity data that carbon monoxide is a hazardous decomposition product. Also, it was reported by a local physician who examined a number of children that they were suffering from carbon monoxide poisoning.

Formaldehyde exposure was evaluated since adhesives were used to secure panels to the exterior of the school. Sulfur dioxide and nitrogen dioxide measurements were only conducted during the evaluation of the heating plant.

Carbon monoxide and formaldehyde measurements were made in each classroom where VOCs and PNAs were collected. Measurements were made using Interscan Series 4000 direct reading monitors. Each monitor was calibrated before, and rechecked after the survey using 25 ppm certified span gas for carbon monoxide, and a gas generation system producing 0.5 ppm for formaldehyde. The limit of detection for these meters are 1% of a full scale reading. For formaldehyde, that 1 % of a full scale reading corresponds to a limit of detection of 0.01 ppm; and 1 ppm for carbon monoxide.

Measurements for carbon monoxide, carbon dioxide, sulfur dioxide and nitrogen dioxide were made on August 8, 1991 while the heating system was activated. Those measurements were made in *each* classroom using Interscan, Series 4000 direct reading monitors, also calibrated before and after the survey.

5. Ventilation System Assessment

A visual inspection of the air conditioners, heating system (including boiler room) ductwork, interior rooms, and exterior structure (including roof) of the elementary school was performed. Additionally, direct air velocity measurements through each of the wing air handling units were made using a Alnor velometer. Wing ventilation rates were calculated based upon the volume of air delivered to the wings. Estimates of the amount of fresh outside air delivered to each occupant in the wings was calculated based on the design specifications of the air handling units.

B. Medical

1. Questionnaire Survey

A medical/informational questionnaire was sent all employees of the school. The purpose of the questionnaire was to assess health problems experienced by employees as a result of the roofing project. Specific questions were asked relating to the employees work locations, previous health problems unrelated to the roofing project, and absenteeism rates of staff and students. Finally, each staff member was given the opportunity to address their significant points or health concerns related to the roofing project or other possible exposures.

2. Medical Records Review

Parents were asked at the public meeting, and also in a letter from the School Administration, to provide NIOSH with a signed release for access to their childrens' medical records. Each record received was screened to determine the child's symptoms, laboratory test results, diagnosis, treatment, follow-up action, and any past medical conditions.

V. EVALUATION CRITERIA

As a guide to the evaluation of the hazard posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. 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.

The primary source of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and Recommendations, 2) the American Conference of Governmental Industrial Hygienist's (ACGIH) Threshold Limit Values (TLVs)[2],and 3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Levels (PELs)[3]. Both NIOSH recommendations and ACGIH TLVs usually are based on more recent information than are the OSHA permissible exposure limits (PELs).

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.

1. Volatile Organic Compounds

Volatile organic compounds are monitored in indoor air quality (IAQ) investigations to provide a qualitative understanding of the variety of chemicals which exist in the indoor environment. VOCs found in indoor environments result from the use of cleaning compounds, perfumes, waxes, paints, furnishings, and various occupant activities.

Many components of the roof resaturant are volatile organic compounds, Compounds such as xylene, toluene, styrene and many other light and heavy molecular weight hydrocarbons are constituents of Aromatic Process Oils, as identified on the Material Safety Data Sheet. Not all hydrocarbons exhibit the same toxicological effects; therefore, exposure criteria is dependant on the particular hydrocarbon and toxic effect.

2. Polynuclear Aromatic Hydrocarbons

Polynuclear aromatic hydrocarbons (PNAS) are the constituents of concern in petroleum asphalt and coal tar pitch products. These large molecules (Figure 1) contain numerous 6 carbon rings and have been shown to be carcinogenic as a group with certain individual PNAs exhibiting increased carcinogenic capability. There are potentially thousands of different PNAs in pitch. PNAs can be separated out of particulate samples using solvents like benzene or cyclohexane. By limiting exposure to the soluble materials of pitch, the cancer risk is believed to be reduced.[4-7]

Older hot roofing systems used either coal tar pitch or petroleum asphalt materials. (Petroleum asphalt is the residue from the fractional distillation of petroleum products.) Generally, coal tar pitch is believed to be more toxic than petroleum asphalt due to higher quantities of soluble PNAs.

Several PNAs including benzo(a)pyrene and benzanthracene have been shown to be carcinogenic in animals. From the epidemiologic and experimental toxicologic evidence on coal tar products, NIOSH has concluded that these are carcinogens and can increase the risk for lung cancer and skin neoplasms (benign and malignant).[4] An epidemiologic mortality study of members of the United Slate, Tile and Composition Roofers, Damp and Waterproof Worker's Association found elevated death rates from lung cancer and cancer of several other sites.[7] These roofers had worked with both CTP and petroleum asphalt. This study found an elevated standardized mortality ratio for skin cancer (excluding melanoma) of 4.00.

Investigators have documented carcinogenic activity in laboratory animals exposed to either petroleum asphalt or coal tar pitch fumes.[8] NIOSH investigators also found carcinogenic activity for both petroleum asphalt and coal tar pitch fumes and that carcinogenic activity increased when the pitch roofing materials were heated to 316ºC as opposed to heating the materials to 232ºC.[9]

Excess risks of lung cancer, oral cancer, and skin neoplasms (benign and malignant) have been found in working populations handling coal-tar products, which NIOSH has defined to include coal-tar, coal-tar pitch, and creosote.[4,5]

The acute toxic effects of exposure to coal-tar pitch include skin and mucous membrane irritation mediated directly and, more noticeably, through photosensitivity reactions. These reactions involve an interaction between the photosensitizing agent (PNAs) and ultraviolet (UV) radiation, a component of sunlight. The mechanism involves the absorption of this radiant energy by the skin and by the PNAs on the skin, which can then result in cell damage.[6] As expected, these reactions affect outdoor workers who handle these materials and receive exposure to sunlight. Thus, these reactions are more frequent and severe in the summer and during mid-day.

A TWA exposure of 0.2 ug/m^3 was recommended by the coke oven advisory committee for benzo(a)pyrene under OSHA 29 CFR 1910.1029 coke oven emission standard, but was not adopted. A special NIOSH hazard review of chrysene recommended that it be controlled as an occupational carcinogen.[10] Also, ACGIH includes chrysene and benzo(a)pyrene in its list of industrial substances of confirmed human carcinogens, and is recognized to have co-carcinogenic potential. [2,11]

Current occupational exposure criteria for coal tar products is 0.2 mg/m^3 for OSHA and ACGIH (benzene solubles). [3] NIOSH's recommended exposure limit is 0.1 mg/m^3 (cyclohexane extractables).[4]

Naphthalene, or moth balls, is technically not considered a true PNA because it has only two fused benzene rings (a true PNA has three or more).[12] Because naphthalene is analyzed as a PNA, it will be reported with PNA compounds. Naphthalene has its own separate industrial exposure criterion of 50 mg/m^3.

3. 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, to name a few, are poorly vented heating systems, automobile exhaust, and cigarette smoke. The combination of incomplete combustion and inadequate venting often results in overexposure.[13]

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.[14] Symptoms exhibited are related to the level of CO-Hb in the blood, as shown in Table I.

Intermittent exposures are not cumulative in effect and, in general, symptoms occur more acutely with higher concentrations of CO. [14] The OSHA PEL and the NIOSH REL for exposure to CO is 35 ppm averaged over an 8-hour work shift, 40 hours per week, with a ceiling level of 200 ppm. The ACGIH TLV is 50 ppm and 400 ppm ceiling limit. ACGIH has also proposed a biological exposure index (BEI) of $<8\%$ CO-Hb in blood at the end of a work shift. [2]

Few other compounds are known to act in a manner similar to CO and increase the CO-Hb level in blood. Methylene chloride is most notable example of these compounds; it is a widely used solvent.

4. 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. Irritation 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 elderly, those with pre-existing allergies or respiratory diseases, and persons who have become allergy 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.[15]

Formaldehyde vapor has been found to cause a rare form of nasal cancer in Fisher 244 rats exposed to a 15 ppm concentration for 6 hours per day, 5 days per week, for 24 months. Whether these results can be extrapolated to human exposure is the subject of considerable speculation in the scientific literature. Conclusions cannot be drawn with sufficient confidence from published mortality studies of occupationally exposed adults as to whether or not formaldehyde is a carcinogen. Studies of long-term human occupational exposures to formaldehyde have not detected an increase in nasal cancers.

Nevertheless, the animal results have prompted NIOSH to recommend that formaldehyde be handled as a potential occupational carcinogen. An estimate of the cancer risk to workers exposed to formaldehyde levels at or below 3 ppm has not yet been determined. NIOSH recommends that workplace exposures be reduced to the lowest feasible limit.[16] OSHA has recently reduced its occupational exposure limit for formaldehyde to 1.0 ppm.[3]

The fact that formaldehyde is found in so many home products, appliances, furnishings, and construction materials has prompted several agencies to set standards or guidelines for residential formaldehyde exposure. The American Society of Heating Refrigeration and Air Conditioning Engineers (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.[17] An indoor air formaldehyde concentration of less than 0.05 ppm is of limited or no concern according to the World Health Organization (WHO).[18]

5. 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.

The OSHA PEL for CO_2 is 10,000 ppm for an 8-hour TWA exposure. The NIOSH REL and ACGIH TLV is 5000 ppm for an 8-hour TWA exposure. These industrial limits, however, are not relevant, considering CO_2 levels encountered in office buildings.

6. Ventilation System

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE), Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, specifies that indoor carbon dioxide levels be less than 1000 ppm.[19] This level is based mainly on a correlation with odor perception and comfort and is far below the ACGIH threshold limit value (5000 ppm for industrial environments) and the levels at which adverse health effects would be expected. ASHRAE Standard 62-1989 also recommends ventilation rates of 15 and 20 cubic feet per minute (cfm) per person of outside air for classrooms and libraries, and offices, respectively. These values are based on a specified number of occupants per 1000 ft^2 of occupied space.

By ventilating the building with the proper amount of outside air, ASHRAE believes that CO_2 levels can be kept to less than 1000 ppm and that other contaminants, except for unusual sources, will be kept at acceptable levels. This standard further specifies that the outside air meet applicable Environmental Protection Agency (EPA) standards for outdoor air. Applicable EPA standards for outdoor air for certain contaminants are listed in the ASHRAE 62-1989.

In evaluating the contaminants found at the Bethlehem-Center Elementary School, it should be noted, that there are no specified exposure criteria for such non-industrial settings. Therefore, results will be referenced to those occupational standards only as a bench mark for comparison purposes.

VI. RESULTS

A. Environmental

1. Volatile Organic Compounds

On April 18, 1991, six samples were collected for qualitative analysis of hydrocarbons. Analysis of four samples showed only trace hydrocarbon peaks, generally not of sufficient quantity to warrant further analysis by GC/MS. Two air samples were held back for quantitative analysis of peaks determined from the screening analysis. Those samples were analyzed by the GS/MS even though concentrations of contaminants were very low. Those samples were analyzed for hexane, benzene, carbon tetrachloride, toluene and xylene. Results, shown in Table II, indicated that only a trace amount of carbon tetrachloride, <0.03 ppm, was detected on one of the samples. That sample was collected near the administrative offices in D-Wing. Carbon tetrachloride was not identified in any of the other samples, nor was it detected in the analysis of the bulk roof material.

Figure 2 shows the reconstructed ion chromatograph of the bulk roof resaturant. This figure illustrates the convoluted matrix of components comprising coal tar pitch products. In all, 33 compounds were identified from the bulk material of the roof tar.

On June 26, 1991, forty-five charcoal tube area samples were collected and submitted for hydrocarbon analysis. Analyses were performed for six specific hydrocarbons per sample, for a total of 270 separate analyses. The selection of the six specific hydrocarbons was based on information provided from the results of our first sampling effort conducted in April 1991. Results, shown in Table III, indicated that low levels of xylene, toluene and styrene were detected in B-wing of the school. Those results were expected since painting of ceiling tiles was being performed during the sampling survey. The highest levels found for xylene, toluene and styrene were 9.76 parts per million (ppm), 0.36 ppm and 17.1 ppm, respectively. No carbon tetrachloride was detected on any of the samples collected.

2. Polynuclear Aromatic Hydrocarbons

PNA sampling results are shown in Table IV. Twenty-four samples were collected and submitted for PNA analysis. Analyses were performed for 17 separate PNAs per sample, for a total of 408 analyses. The LOD and LOQ for all PNAs analyzed was 0.001 and 0.0019 mg/m3 per sample.

Of the 17 separate PNAs analyzed, only 4 were detected above the limit of quantitation. Those PNAs quantitated were the low molecular weight PNAs, which would be expected to off-gas easily from coal tar pitch. PNAs detected were acenaphthylene, acenaphthene, fluorene and phenanthrene. In addition, naphthalene was also detected. Trace PNA levels ranged from 0.001 to 0.055 milligrams per cubic meter (mg/m3) benzene soluble fraction, with naphthalene comprising the majority of the PNA on each sample. Naphthalene levels ranged from 0.001 to 0.046 mg/m3.

3. Carbon monoxide, Sulfur dioxide, Formaldehyde, and Nitrogen dioxide

No carbon monoxide or formaldehyde was detected at any of the locations sampled inside or outside the elementary school. Neither carbon monoxide or formaldehyde are constituents of the roofing material; therefore, the results were expected.

In addition, samples collected on August 8, 1991 with the heating system activated showed no carbon monoxide, sulfur dioxide or nitrogen dioxide. Direct reading instrumentation was used to sample *every* classroom within the elementary school. This sampling was conducted while inside temperatures ranged from 82ºF to 90ºF, and a outside temperature of 74ºF.

4. Carbon Dioxide

Prior to the discussion of carbon dioxide results, it is important to again stress that measurements were made in an effort to determine the effectiveness of the ventilation systems for providing fresh 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.

During the firing of the boilers (August 8, 1991), carbon dioxide concentrations within the elementary school ranged from 400 - 800 ppm, with 1000 ppm being measured in the boiler room. Outside concentrations were measured at 400 ppm. Those measurements were made while only a few staff and maintenance employees were working inside the school, with no students present.

On September 12, 1991, direct reading carbon dioxide monitors were placed in each of the three classroom wings (Wing A, Wing B, and Wing D) of the school. The monitors were placed in classrooms located in the center and to the rear of the wings. Those areas were located on the downstream end of the air handling units. The possibility does exist that some other classrooms may have had higher or lower levels, but since the intent was to determine the effectiveness of the system, it was felt the selected locations would be representative of levels within the wing.

Results with school students present ranged from 600 - 2000 ppm, with the higher levels measured late in the afternoon. Figure 3 shows one of the recordings made of CO_2 concentration measured in one classroom during the morning hours. This recording was stopped about 12:30 pm due to problems encountered with the recording device. However, it does show the classic CO_2 concentration rise and stabilization over time. It would be expected that recording would have remained stable at levels between 1600 and 1800 ppm throughout the remainder of the school day. Other measurements were made in classrooms using indicator tubes specific for carbon dioxide, with results ranging from 800 - 1500 ppm.

5. Ventilation System

The ventilation system serving each wing was evaluated on the basis of providing adequate fresh outside air per wing and occupant load. The systems were found to be sufficiently sized to provide adequate outside air, however, distributing that air to each classroom may be a problem. The air handlers are designed to limit the amount of outside air, which mixes with the recirculated air, by adjusting the air inlet (damper stop) to approximately 10%. Typically, this is done in an effort to avoid cooling or heating the fresh air entering the system, which depending on the season is either hotter or colder than the recirculated air. However, in many instances, this commonly used practice does not allow for adequate fresh outside air to enter a facility, thereby increasing health and comfort complaints.

Measurements of the quantity of fresh air entering the system indicated that 11-12% outside air was being brought into the school. Calculations were made to determine, based on the air handlers rated capacity, in cfm, and occupant load, if sufficient air was being brought into the elementary school. Results of those calculations are shown in Table V. It should be noted that not every air handling system operates at 100% of its rated capacity, therefore, in making these calculations, each system was evaluated at an 85% operating capacity.

Information was supplied relating to occupant (only students) load per school wing. In using that information, it was determined that Wing A was only providing 6.5 cfm per person; Wing B - 4.3 cfm per person; and Wing D - 6.3 cfm per person. These values are far below the ASHRAE recommended criterion of 15 cfm per person for adequate outside air. Using that ASHRAE criteria and the current fresh air quantities per wing, the maximum number of students per wing was calculated to be: Wing A - 113, Wing B - 96, and Wing C - 113. (It should be noted that the calculated occupancy load per wing is based on the assumption that the fresh air is being evenly distributed per wing.) However, another problem discovered was poor air distribution within the elementary school.

Even if the proper amounts of fresh outside air were entering the system, the distribution of that air to the classrooms may be impeded. Air enters each room through a variable air volume (VAV) box. One VAV box may channel air to two or more rooms at a time. By design, VAV boxes vary the amount of air which can pass through and is dependent on its own internal damper which is adjusted by an individual room thermostat control. In simpler terms, if in the summer time a room feels too cold and the teacher adjusts the thermostat higher to reduce the cold air, then the airflow to that room is shut off. Airflow to individual rooms is completely controlled through the thermostat adjustment. Therefore, if a number of thermostats are adjusted past a specific point, outside air, or even recirculated air is shut off.

Many of the room thermostats checked were set to a point which did not allow air to enter the room. Also, some thermostats were not working properly, which in turn would not open the VAV box damper to allow air to enter a room. And a few thermostats were observed to work in reverse order, raising to cool, lowering to heat. To complicate this problem even more, a number of classrooms have doors which were closed during our visit. When one of those rooms (A13) was checked, the thermostat was found to be shut off and no fresh or recirculated air was entering the room. The room was fully occupied by students and was found to be stuffy, hot and had a carbon dioxide concentration of 1500 ppm.

As a demonstration to two of the school board members and one parent, one room was picked to show the effects of the thermostat problems. In that room, it was observed that the thermostat was closed, and carbon dioxide levels were approximately 900 ppm. After opening the thermostat and allowing air to enter the room, measurements taken approximately one hour later showed carbon dioxide levels at or near background of 400 ppm.

B. Medical

1. Questionnaire Results

A total of ninety-four questionnaires were mailed to employees at the elementary school. Sixty questionnaires (64%) were completed and returned. Of those responding, 55 or 92% were aware of the problems at the elementary school. Some of those responding, 16 (29%) felt that there were previous problems at the school, prior to the roofing project. However, the majority, 71%, felt that there were no prior problems at the school.

The demographic distribution within the elementary school and general assessment of respondents to problems resulting from the roofing project are shown in Table VI. The respondents were almost equally divided as to whether or not they were personally affected by the roof odor; 34 (54%) were affected and 26 (46%) were not affected.

The health complaints reported from those personally affected are shown in Table VII. The major symptoms, as reported, were headaches (76%), red burning eyes (44%), respiratory irritation or sore throat (32%) and nausea (26%). Also shown are other health complaints reported at lower frequencies.

2. School Nurse Records and Logs

Log records of students reporting to the school nurse due to an illness/injury were requested and provided by the school. Information on illnesses were tabulated for the current school year and compared to information collected the previous school year. Each input to the log was classified according to illness type as either headaches, nausea, or stomach aches. Figures 4 - 6 shows the results of that comparison.

For the months of November (when the resaturant was applied) and April (when the second episode of odors occurred), an increase in the number of students reporting headaches (Figure 4) were seen. Students reporting headaches were generally higher in the 1990-1991 school year as compared to the 1989-1990 school year. When considering the school population (approximating 1000 individuals), those reporting headaches in November 1990-1991 were only 3% higher than those reporting in 1989-1990, and only 1% higher in April.

Students reporting symptoms of nausea (Figure 5) have generally decreased for the school year 1990-1991, as compared to 1989-1990. Stomach problems (Figure 6) were generally consistent between school years. Only a slight increase was seen in December through February, the cold and flu season.

3. Medical Records Review

NIOSH received medical record release forms for 37 students at the elementary school. Medical records for the 37 students were reviewed to determine if reported health symptoms were consistent with acute exposure to coal tar products.

In screening the records, it was observed that various diagnostic tests were performed on a small population of students, with the dependant factor being of the physician ordering the tests. Some tests performed on the elementary school children included electrocardiographs (EKGs), CAT scans, chest x-rays, arterial blood gases for carboxyhemoglobin (CO-Hb), liver function enzymes, and pulmonary function tests.

It was also evident from the records that many of the students were seen by their physicians simply because they were students at Bethlehem Center Elementary School, not because of a specific health problem. Documentation within the records stated that some parents felt that their children "were exposed to toxic fumes at the school and wanted them tested". Of the records reviewed, two students and one teacher have documentation of asthmatic symptoms subsequent to the roofing episode.

It appears that a misinterpretation by a number of individuals of the MSDS on the roof resaturant has caused an unwarranted concern for exposure to carbon monoxide. As previously mentioned, the MSDS states under reactivity data that carbon monoxide is a hazardous decomposition product. As currently found on the roof, the resaturant is not generating carbon monoxide.

However, eight students had arterial blood gases drawn which showed low levels of carboxyhemoglobin (CO-Hb); thus, establishing the link between the roofing project and carbon monoxide for some parents and school board members. That link apparently escalated into fears of long term health affects, demands for replacing the roof, to the extreme of razing the building.

The results of the carboxyhemoglobin tests ranged from less than 1.0% to 3.2%. Figure 7 shows the results of each of the CO-Hb tests and the time and date the test was performed relevant to the closing date of school. In order to protect the identity of the students, their names have been removed and substituted with a code.

Carbon monoxide is not a cumulative poison, once removed from the exposure, the level of CO-Hb in the body starts to reduce. That amount of reduction is based on the oxygen intake into the body. CO-Hb has a biological half-life of 1-5 hours (depending on the amount of oxygen)[14]. For example, if a person has a biological exposure index of 10% CO-Hb, in 5 hours that level would be expected to be 5%; and, in an additional 5 hours, 2.5%, and so on until the CO-Hb is eliminated.

The levels of CO-Hb measured in the eight students at the Beth-Center Elementary School, after being away from the school from 1 to 14 days, is not consistent with the biological half-life elimination process of CO-Hb. Therefore if those tests were accurate, then the exposure to carbon monoxide is occurring away from the school. No source of carbon monoxide was found at the elementary school. It is possible that the blood levels of CO-Hb reported in the students may be attributed to other exposure sources. Other sources, as previously mentioned, could include but not limited to, exposure to sidestream tobacco smoke and auto exhaust.

Information on the accuracy range for CO-Hb, or standard deviation, of the testing facilities' procedures are unknown. Since the levels found in the students were low (<5%), many of the results reported could fall below the confidence level for accurately determining the CO-Hb levels. This is not uncommon, and has been observed in another NIOSH investigation. [20]

Based on the information collected on the CO-Hb levels found in the students, the time lapse for testing, and the lack of a carbon monoxide source vindicates the roof resaturant as the source of carbon monoxide exposure.

Other tests performed on the students, when corrected for age, were within normal limits for ages 2 - 15 years. Records show that all EKG reports evaluated by a local Cardiologist, in consultation to the ordering physician, were normal. Laboratory reports of liver function studies were also reported to be elevated, in particular alkaline phosphatase, lactic dehydrogenase (LDH), phosphorus, and aspartate transaminase (AST) levels. It appears that the reported values were based on normal adult ranges and were not corrected for age.

Alkaline phosphatase levels vary with age and are generally elevated in children during periods of accelerated bone growth. In the first four weeks of life, it rises rapidly to 5 or 6 times above normal adult levels. It then decreases slowly until puberty, when there is another increase, followed by a decrease to adult levels at 16 to 20 years of age. Levels can be as high as 3 times the normal adult level (20-100 units/liter (U/L) for 20 to 60 years of age). When corrected, alkaline phosphatase levels were within the normal range for children (100 - 350 U/L for age 2 to 10 years).[21]

Also, other liver function tests were not corrected for age. AST ranges in children ages 2 - 8 years old can be as high as 40 - 50 U/L. Levels reported in the tested children ranged from 20 - 48 U/L. LDH levels in children ages 3 - 17 years old can be as high as 2 times that of a normal adult level (100 - 190 U/L).[21]

The normal phosphorus electrolyte level in children is 4.0 - 7.0 milligrams per deciliter (mg/dl)[20]. All laboratory reports were within that range.

VII. CONCLUSIONS

There are no specific exposure criteria for schools or other non-industrial environments; however, it is our opinion that the levels of organic volatile compounds and PNAs found in the school should not cause adverse health affects. Results showed that low levels of xylene, toluene and styrene were detected in B-wing of the school. This was expected since painting of ceiling tiles was being performed during the sampling survey. It is expected that the levels of organic volatile compounds detected will dissipate once painting is completed, which should be before school opens.

In putting the results in perspective, an acute episode of exposure to a very pungent smelling odor occurred at the Bethlehem-Center Elementary School. Due to that pungent odor, some students and teachers with preexisting health conditions, such as asthma and allergies may have been affected to the extent of triggering a reaction.

It is our opinion that the roofing project was the tool which focused attention on a facility suffering from pre-existing indoor air quality problems. This is evident from the nurses records which showed only a slight increase in the number of health complaints for the 90-91 school year as compared to the 89-90 year.

NIOSH has responded to over 1000 complaints of indoor air quality problems in a wide variety of settings. The majority of these investigations have been conducted since 1979, paralleling the "energy efficiency" concerns of building operators and architects.

Commonly, the symptoms and health complaints reported by building occupants have been diverse and not suggestive of any particular medical diagnosis or readily associated with a causative agent. A typical spectrum of symptoms has included headaches, varying degrees of itching or burning eyes, irritation of the skin, sinus problems, dry and irritated throats, and other respiratory irritations. The workplace environment typically has been implicated because symptoms reportedly disappear when the worker is away from the office environment.

The causes of comfort and health problems related to indoor air quality are typically multifactorial, which makes determination difficult. The investigations NIOSH has conducted have been classified by the primary type of problem found: inadequate ventilation (which Beth-Center Elementary suffers), contamination from inside the building, contamination from outside the building, microbiological contamination, contamination from building materials, and "unknown". The predominant problems identified in the NIOSH indoor air environment investigations can be placed into the following three categories listed in order of decreasing frequency: inadequate ventilation, chemical contamination, and microbiological contamination. Inadequate ventilation, a category which includes shortage of outside air, poor air distribution, and short circuiting of supply air, is reported most commonly in the NIOSH building investigations (greater than 50% of cases). These ventilation problems make it difficult to control heating and cooling, and allow the accumulation of contaminants in the occupied space. The resulting conditions may cause occupants to become uncomfortable or experience adverse health effects.

Efforts taken by the school district to identify and resolve problems associated with the roofing project are commendable. In future, the impact on students and staff should be the number one consideration when planning renovations. Any future renovation work of that magnitude should be accomplished after the end of the school term.

And finally, anxiety of the parents, school administration, and some local officials has played a major role in escalating the fears that a health hazard exists at the elementary school. Since the health of small children was at issue, most all parties involved fell victim to that anxiety. NIOSH has attempted to alleviate this anxiety by maintaining open communications with all parties such as attending public meetings, conducting extensive environmental sampling well beyond the scope of the roofing project, and presenting objective results and recommendations based on its scientific investigation.
Based on the information collected, our investigation has found nothing within the elementary school which would constitute a health hazard for either staff or students. However, the lack of sufficient quantities of outside air and poor air distribution within the school may be the cause of the health related complaints reported at the Bethlehem-Center Elementary School.

VIII. RECOMMENDATIONS

The following recommendations are made in order of priority. They are presented to assist with, first, getting the current situation under control and, second, correcting obvious problems and then progressing on to more creative solutions.

1. The ventilation deficiencies identified during this investigation should be corrected by a firm specializing in system tuning and balancing. This would include, but not be limited to recalibrating and repairing the room thermostats and VAV boxes to assure proper operation. Also adequate outside air needs to be brought into the elementary school. This could be accomplished by opening the dampeners on the air handlers. Rough calculations indicate that in order to provide the necessary air, the dampers should be opened to 35%.

However, this does not necessarily mean that the air will be evenly distributed through the VAV systems. Therefore, it is recommended that each classroom be sized according to the amount of fresh air entering the room. For example, using the 15 cfm outside air per person recommended by ASHRAE, a class size of 25 students would require 375 cfm of outside air entering the room. If no outside air is entering the room, then no students should occupy that room. Once the air handling systems are tuned, thermostats should be locked in order to prevent any unauthorized adjustments.

2. Smoking by staff should be banned from within the elementary school. If smoking is to be allowed in the building, a separate smoking room should be provided. This room should be provided with 60 cfm fresh air per person, in accordance with ASHRAE standard 62-1989. Room air should be exhausted directly to the outside, with no recirculation of room air into other occupied areas.

3. Maintain open and honest communication between all effected parties. Open communication and trust are very important while solving indoor environmental problems. One means of facilitating communication would be the formation of a working committee composed of representatives from all of the interested parties. This committee could be the center of all information exchange so that persons seeking the latest, most accurate information will have a contact point. This committee could also be charged with receiving information about trial solutions and their results, and planning for the next solution.

4. Designate one person to receive complaints about the building. This person should be a neutral party who does not have reprimand power over the teaching staff. Files should be kept on complaints according to air handler and room occupied by the complainant or the complainant's child. All complaints should be acted upon and, once the problem is resolved, the action taken should be reported back to the complainant.

IX. REFEREMCES

1. National Institute for Occupational Safety and Health. NIOSH manual of analytical methods. Vol 1-2, 3rd ed. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1984. (DHHS (NIOSH) publication no. 84-100).

2. American Conference of Governmental Industrial Hygienists. Threshold limit values and biological exposure indices with intended changes for 1990-1991. Cincinnati, Ohio: ACGIH, 1987.

3. Occupational Safety and Health Administration. OSHA safety and health standards. 29 CFR 1910.1000. Occupational Safety and Health Administration, revised 1989.

4. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to coal tar products. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1978. (DHHS publication no. (NIOSH) 78-107).

5. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to asphalt fumes. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1978. (DHHS publication no. (NIOSH) 78-106).

6. Harrison's Principles of Internal Medicine. Ninth Edition. New York, McGraw-Hill Book Company, 1980. pp 255-262.

7. Hammond EC, Selifkoff IJ, Lawther PL, and Seidman H. Inhalation of benzpyrene and cancer in man. Ann NY Acad Sci 1976; 271:116-124.

8. Bingham E, Trosset RP, Warshawski D. Carcinogenic potential of petroleum hydrocarbons. J Environ Path Toxicol 1980, 3:483-563.

9. Niemeier RW, Thayer PS, Menziens KT, VonThuna P, Moss GE, Burg J. A comparison of the skin carcinogenicity of condensed roofing asphalt and coal tar pitch fumes. Proceedings of the 3rd NCI/EPA/NIOSH collaborative workshop: Program on Joint Environmental and Occupational Cancer Studies. March 1984.

10. National Institute for Occupational Safety and Health. Special occupational hazard review and control recommendations - chrysene. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1978. (DHEW publication no. (NIOSH) 78-163.

11. American Conferences of Governmental Industrial Hygienist. Documentation of threshold limit values. 5th ed. Cincinnati, Ohio: ACGIH, 1986.

12. Rom W, et.al. Environmental and Occupational Medicine. 2nd ed., Little, Brown and Company, Boston, 1983.

13. Proctor NH, Huges JP. Chemical hazards in the workplace. J.B. Lippencott Company, Philadelphia. 1978.

14. Lindgren GO. "Carbon monoxide" in the encyclopedia of occupational health and safety. International Labour Office, Geneva, 1971.

15. National Research Council. Formaldehyde and other aldehydes. National Academy Press. Washington, DC, 1981

16. National Institute for Occupational Safety and Health. Current intelligence bulletin 34--Formaldehyde: Evidence of carcinogenicity. Cincinnati, Ohio: National Institute of Occupational Safety and Health, 1981. (DHHS (NIOSH) publication No. 81-111).

17. Gammage RB, Hawthorne AR, "Current status of measurement techniques and concentrations of formaldehyde in residences." Turoski V. Formaldehyde: analytical chemistry and toxicology. "Developed from a symposium sponsored by the Division of Environmental Chemistry at the 87th Meeting of the Chemical Society, St. Louis, Missouri, April 8-13, 1984."

18. World Health Organization Regional Office for Europe. Indoor air pollutants: exposure and health effects. WHO-EURO Reports and Studies-78. World Health Organization, Copenhagen, Denmark, 1983.

19. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). Ventilation for acceptable indoor air quality. ASHRAE Standard 62-1989. Atlanta, GA. 1989.

20. Kerndt, PR, Sinks TH, Wallingford KM. Health hazard evaluation report HETA 86-206. Cincinnati, Ohio. National Institute for Occupational Safety and Health. 1986.

21. Wallach J. Interpretation of diagnostic tests: A synopsis of laboratory medicine. 4th ed. Little, Brown and Company, Boston, 1986.

X. AUTHORSHIP AND ACKNOWLEDGMENTS

Project Officers:	Joseph E. Burkhart, CIH Steven Short, D.O. Elizabeth Knutti, R.N.
Report Prepared by:	Joseph E. Burkhart, CIH
Laboratory Analysis:	DATACHEM Salt Lake City, UT
Originating Office:	Respiratory Disease Hazard Evaluation and Technical Assistance Program Clinical Investigations Branch Division of Respiratory Disease Studies Morgantown, West Virginia

XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report may be freely reproduced and are not copyrighted. Single copies of this report will be available for a period of 90 days from the NIOSH Publications Office, 4676 Columbia Parkway, Cincinnati, Ohio 45226. To expedite your request, include a self-addressed mailing label along with your written request. After this time, copies may be purchased from the National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

Copies of this report have been sent to:

1. Bethlehem Center School Superintendent
2. OSHA, Pittsburgh Area Office
3. U.S. Congressman Austin J. Murphy
4. PA State Health Department

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.

Figure 1.

Bethlehem-Center Elementary School

Name, Chemical Formula, and Structure of PNAs
Evaluated for in Samples

NAME	ACRONYM (as used in report)	MOLECULAR WEIGHT	STRUCTURE	NAME	ACRONYM (as used in report)	MOLECULAR WEIGHT	STRUCTURE
Acenaphthylene	ACL	152.21		Chrysene	CHR	228.30	
Acenaphthene	ACE	154.21		Benzo(b)fluoranthene	BBF	252.23	
Fluorene	FLU	166.23		Benzo(k)fluoranthene	BKF	252.32	
Phenanthrene	PHE	178.24		Benzo(e)pyrene	BEP	252.32	
Anthracene	ANT	178.24		Benzo(a)pyrene	BAP	252.32	
Fluoranthene	FLE	202.26		Indeno(123-cd)pyrene	INP	276.34	
Pyrene	PYR	202.26		Dibenz(a,h,)anthracene	DAH	276.34	
Benzo(c)phenanthrene	BCP	228.30		Benzo(ghi)perylene	BGP	278.36	
Benzo(a)anthracene	BAA	228.30					

Table I.

Bethlehem-Center Elementary School

Principal Symptoms Correlating with Exposure to Carbon Monoxide

Atmospheric carbon monoxide concentration (ppm)	Carboxyhemoglobin concentration (%)	Principle symptoms
50	7	Slight Headache
100	12	Moderate headache and dizziness
250	25	Severe headache and dizziness
500	45	Nausea, vomiting, collapse possible
1000	60	Coma
10000	95	Death

Table II.

Bethlehem-Center Elementary School

Report of Hydrocarbon Analysis (ppm)
(April 18, 1991)

SAMP.	AREA	HEXANE	BENZENE	CARBON TET.	TOLUENE	XYLENE
7227-1	D-wing by Administrative office	(*)	(*)	0.03	(*)	(*)
7227-2	B-Wing, doorway of Rm. B6	ND	ND	ND	ND	ND
7227-3	A-Wing, doorway of Rm. A7	ND	ND	ND	ND	ND
7227-4	Center of library	ND	ND	ND	ND	ND
7227-5	Center of cafeteria	ND	ND	ND	ND	ND
7227-6	Outside, Near back of D-Wing	ND	ND	ND	ND	ND
	Limit of Detection (ppm)	0.001	0.001	0.006	0.0009	0.001
	Limit of Quantitation (ppm)	0.003	0.003	0.017	0.003	0.005

ND = Not Detected
(*) = Values reported were between the LOD and LOQ.

Table III.

Bethlehem-Center Elementary School

Results of Hydrocarbon Analysis (ppm)
(June 26, 1991)

SAMP	VOL	LOCATION	CT	MLC	BEN	STY	TOL	XYL
		AREA = "A" WING						
H38	63.5	A2	ND	ND	ND	ND	ND	ND
H44	63.1	A4	ND	ND	ND	(*)	ND	ND
H5	62.9	A5	ND	ND	ND	ND	ND	ND
H42	62.7	A6	ND	ND	ND	(*)	ND	ND
H24	62.4	A7	ND	ND	ND	ND	ND	ND
H48	62.3	A9	ND	ND	ND	ND	ND	ND
H46	62.1	A10	ND	ND	ND	ND	ND	ND
H26	63.6	A12	ND	ND	ND	ND	ND	ND
H33	62.4	A15	ND	ND	ND	ND	ND	ND
		AREA = "B" WING						
H32	65.2	B2	(*)	(*)	(*)	6.76	0.18	3.59
H31	65.6	B4	0.16	0.01	0.02	17.1	0.36	9.76
H13	65.9	B6	(*)	(*)	(*)	5.97	0.18	3.28
H37	63.8	B8	0.03	0.06	0.01	5.17	0.18	3.00
H35	63.1	B9	0.03	0.06	0.01	5.98	0.18	3.36
H19	63.8	B10	ND	ND	ND	3.18	(*)	1.71
H47	62.9	B11	ND	(*)	0.02	5.57	0.18	3.16
H20	63.3	B12	ND	(*)	ND	3.78	(*)	2.11
H14	63.6	ALCOVE	ND	(*)	0.01	3.98	(*)	2.23
H17	63.2	STORE. RM	(*)	(*)	ND	5.57	0.18	2.81
		AREA = "C" WING						
H9	63.0	VOCAL RM	ND	ND	ND	(*)	ND	ND
H22	60.6	CAFETERIA	ND	ND	ND	(*)	ND	ND
H41	60.5	CAFETERIA	ND	ND	ND	ND	ND	ND
H1	58.5	MULTI-P RM.	ND	ND	ND	ND	ND	(*)
H12	56.4	LOCKER RM.	ND	ND	ND	0.24	ND	ND
H11	54.3	MUSIC RM.	ND	ND	ND	(*)	ND	ND
H36	54.0	BOILER RM.	ND	ND	ND	ND	ND	0.20
H6	54.0	BACK DOOR	ND	ND	ND	0.12	ND	0.08

Table III (continued)

Bethlehem-Center Elementary School

Report of Hydrocarbon Analysis (ppm)
(June 26, 1991)

SAMP	VOL	LOCATION	CT	MLC	BEN	STY	TOL	XYL
		AREA = "D" WING						
H2	63.1	D1	ND	ND	ND	ND	ND	ND
H43	64.5	D2	ND	ND	ND	ND	ND	ND
H40	65.9	D5	ND	ND	ND	ND	ND	ND
H30	65.1	D6	ND	ND	ND	ND	ND	ND
H3	65.0	D7	ND	ND	ND	ND	ND	ND
H10	66.2	D10	ND	ND	ND	ND	ND	ND
H45	65.7	D13	ND	ND	ND	ND	ND	ND
H8	64.8	ADMIN. OFF.	ND	ND	ND	ND	ND	ND
H16	64.8	CONF. RM.	ND	ND	ND	ND	ND	ND
		AREA = CENTER HUB						
H28	64.5	LIBRARY	ND	ND	ND	ND	ND	ND
H15	63.6	HEALTH OFF.	ND	ND	ND	ND	ND	ND
H18	57.3	HALLWAY	ND	ND	ND	0.64	ND	0.31
H21	54.5	PAY PHONE	ND	ND	ND	0.64	ND	0.31
H7	54.3	GEN OFF.	ND	ND	ND	ND	ND	(*)
H23	54.3	GEN OFF.	ND	ND	ND	ND	ND	ND
		AREA = OTHER LOCATIONS						
H50	61.2	OUTSIDE NE	ND	ND	ND	ND	ND	ND
N34	59.3	OUTSIDE SW	ND	ND	ND	ND	ND	ND
H4	57.5	ROOFTOP	ND	ND	ND	ND	ND	ND
	Limit of Detection (ppm)	0.03	0.03	0.006	0.04	0.05	0.04	
	Limit of Quantitation (ppm)		0.08	0.10	0.02	0.13	0.15	0.13

CT = Carbon Tetrachloride, MLC = Methyl Chloroform, BEN = Benzene, STY = Styrene, TOL = Toluene, XYL = Xylene,
ND = Not Detected.
(*) = Value reported was between the LOD and LOQ

Table IV.
Bethlehem-Center Elementary School

PNA-Benzene Soluble Air Sampling Results (mg/m3)

SAMP	AREA	NAP	ACL	ACE	FLU	PHE	ANT	FLE	PY	BAA	CHR	BBF	BK	BE	BAP	IN	DAH	BGP	TOTAL
P1	D13	.035	.	.003	(*)	(*)	.	.	.	.	.	.	.	.	.	.	.	.	0.038
P2	D7	.019	.	.004	.002	(*)	.	.	.	.	.	.	.	.	.	.	.	.	0.025
P3	D2	.026	.	.004	(*)	.	.	.	.	.	.	.	.	.	.	.	.	.	0.030
P4	D10	.041	.	.004	.002	.001	.	.	.	.	.	.	.	.	.	.	.	.	0.048
P11	LIBRARY	.031	(*)	.005	.004	.003	.	.	.	.	.	.	.	.	.	.	.	.	0.016
P12	A7	.016	.	(*)	(*)	.	.	.	.	.	.	.	.	.	.	.	.	.	0.016
P13	A5	.030	.	.002	(*)	.	.	.	.	.	.	.	.	.	.	.	.	.	0.032
P14	A15	.025	.	.002	(*)	(*)	.	.	.	.	.	.	.	.	.	.	.	.	0.027
P15	A10	.029	.	.004	.002	(*)	.	.	.	.	.	.	.	.	.	.	.	.	0.035
P16	OUTSIDE SW	(*)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
P17	OUTSIDE NE	.021	(*)	.005	.005	.007	(*)	(*)	.	.	.	.	.	.	.	.	.	.	0.038
P18	B4	.014	(*)	.003	(*)	(*)	.	.	.	.	.	.	.	.	.	.	.	.	0.017
P19	B2	.016	ND	.003	(*)	(*)	.	.	.	.	.	.	.	.	.	.	.	.	0.019
P20	B6	.014	.005	.003	(*)	(*)	.	.	.	.	.	.	.	.	.	.	.	.	0.022
P21	B10	.015	(*)	.004	.002	(*)	.	.	.	.	.	.	.	.	.	.	.	.	0.021
P22	B8	.011	.	(*)	(*)	.	.	.	.	.	.	.	.	.	.	.	.	.	0.011
P23	ROOF	.015	.	(*)	(*)	(*)	.	.	.	.	.	.	.	.	.	.	.	.	0.015
P24	CAFETERIA	.042	.	.004	.006	.003	.	.	.	.	.	.	.	.	.	.	.	.	0.055
P25	HALL PHONE	.018	.	.003	.002	(*)	.	.	.	.	.	.	.	.	.	.	.	.	0.023
P26	BOYS LOCKER	.013	.	(*)	(*)	.	.	.	.	.	.	.	.	.	.	.	.	.	0.013
P27	MAIN HALL	.016	.	.004	.004	(*)	(*)	.	.	.	.	.	.	.	.	.	.	.	0.024
P28	MUSIC RM.	.033	.	.005	.003	.002	.	.	.	.	.	.	.	.	.	.	.	.	0.043
P29	MULTI-P RM.	.032	.	.003	.002	(*)	.	.	.	.	.	.	.	.	.	.	.	.	0.037
P30	D5	.042	.	.004	(*)	(*)	.	.	.	.	.	.	.	.	.	.	.	.	0.046

The "." in the table indicates a Non-Detectable level. LOD = 0.001 mg/m3, LOQ = 0.0019 mg/m3
Levels reported between the LOD and the LOQ are shown by (*).

Table V.
Bethlehem-Center Elementary School

Determination of Air Flow Quantity by Design Specificiations and Occupant Load by Classroom Wings

Criteria	Wing A	Wing B	Wing D
System design specification or rated capacity	20,000 cfm	17,000 cfm	20,000 cfm
Design capacity less 15% (as described in report)	17,000 cfm	14,450 cfm	17,000 cfm
Amount of fresh *outside air* entering system (10% design capacity)	1,700 cfm	1,445 cfm	1,700 cfm
Current occupant load (students and teachers)	260	337	268
Current quantity of fresh outside air (per person) being supplied	6.5 cfm	4.3 cfm	6.3 cfm
Percent below ASHRAE standard	57%	71%	58%
Quanity of fresh air needed to meet *current* occupant load	3,900 cfm	5,055 cfm	4,020 cfm
Position of damper required to provide necessary fresh *outside air*	23%	35%	24%
Allowable occupant load based on *current* air intake	113	96	113

Contribution of teachers was estimated at 12 per classrom wing.

Table VI.

Bethlehem-Center Elementary School

School Demographic Distribution of Respondents Effected and Not Effected by the Roofing Project.

LOCATION	PERSONALLY EFFECTED	NOT PERSONALLY EFFECTED	TOTALS
A - WING	5 (8%)	9 (15%)	14
B - WING	9 (15%)	1 (2%)	10
C - WING	2 (3%)	0 (0%)	2
D - WING	7 (12%)	4 (7%)	11
OTHER*	11 (18%)	12 (22%)	23
TOTALS	34 (56%)	26 (46%)	60

* = Other areas including cafeteria, library, maintenance, and administrative offices.

Table VII.
Bethlehem-Center Elementary School

Reported Health Complaints by School Staff
Personally Effected by the Roofing Project.

HEALTH COMPLAINT/SYMPTOM	FREQUENCY
HEADACHES	76%
SHORTNESS OF BREATH	14%
RED BURNING EYES	44%
NAUSEA	26%
CONGESTION	3%
SORE THROAT	32%
FATIGUE	3%
JOINT PAIN	3%
COUGH	9%
INSOMNIA	3%
PNEUMONIA/FLU	3%
SKIN IRRITATION	3%

Figure 2.

Bethlehem-Center Elementary School

Total Ion Chromatogram for Bulk Sample of Roof Tar

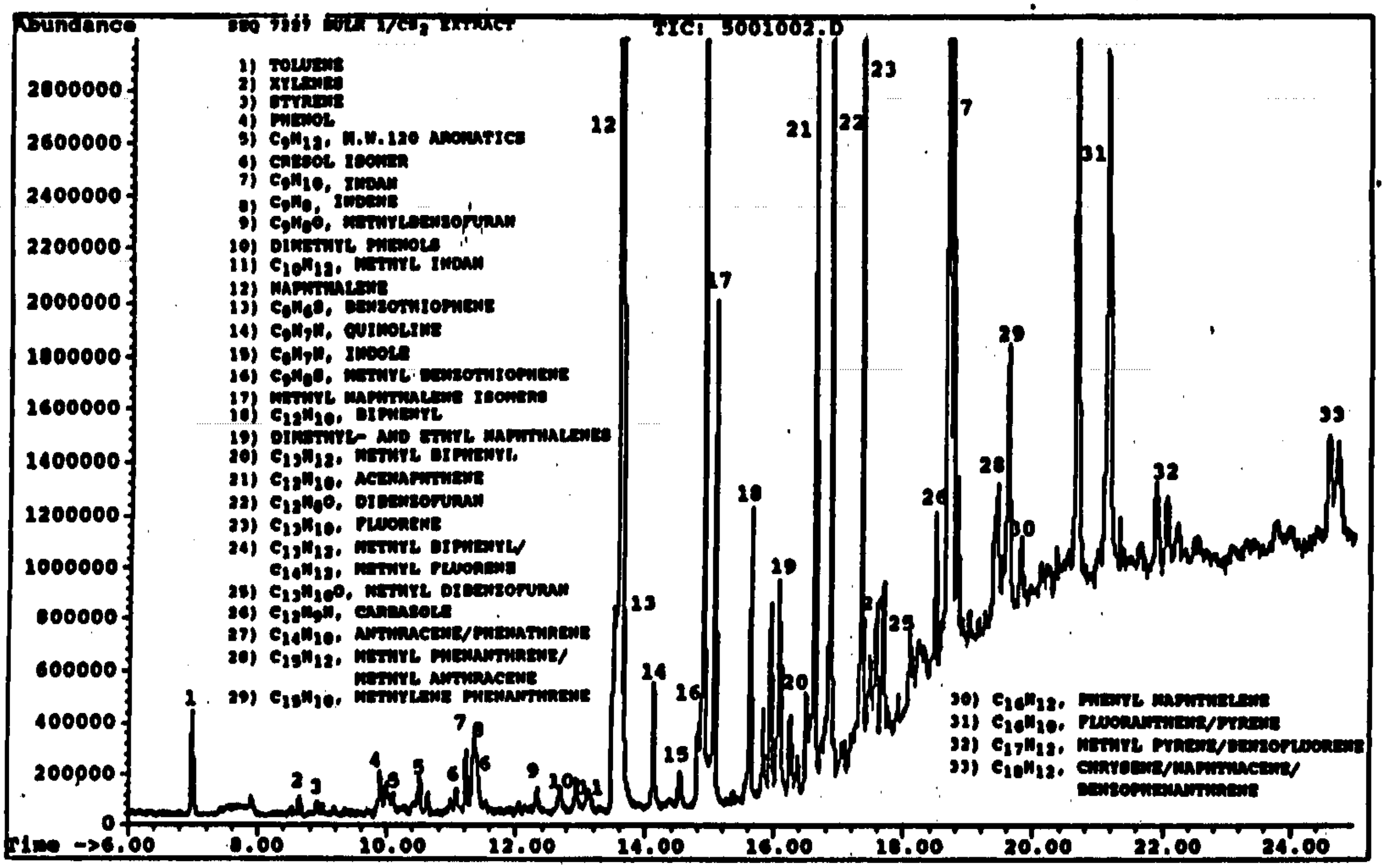


Figure 3.

Bethlehem-Center Elementary School

Real-time Carbon Dioxide Measurements

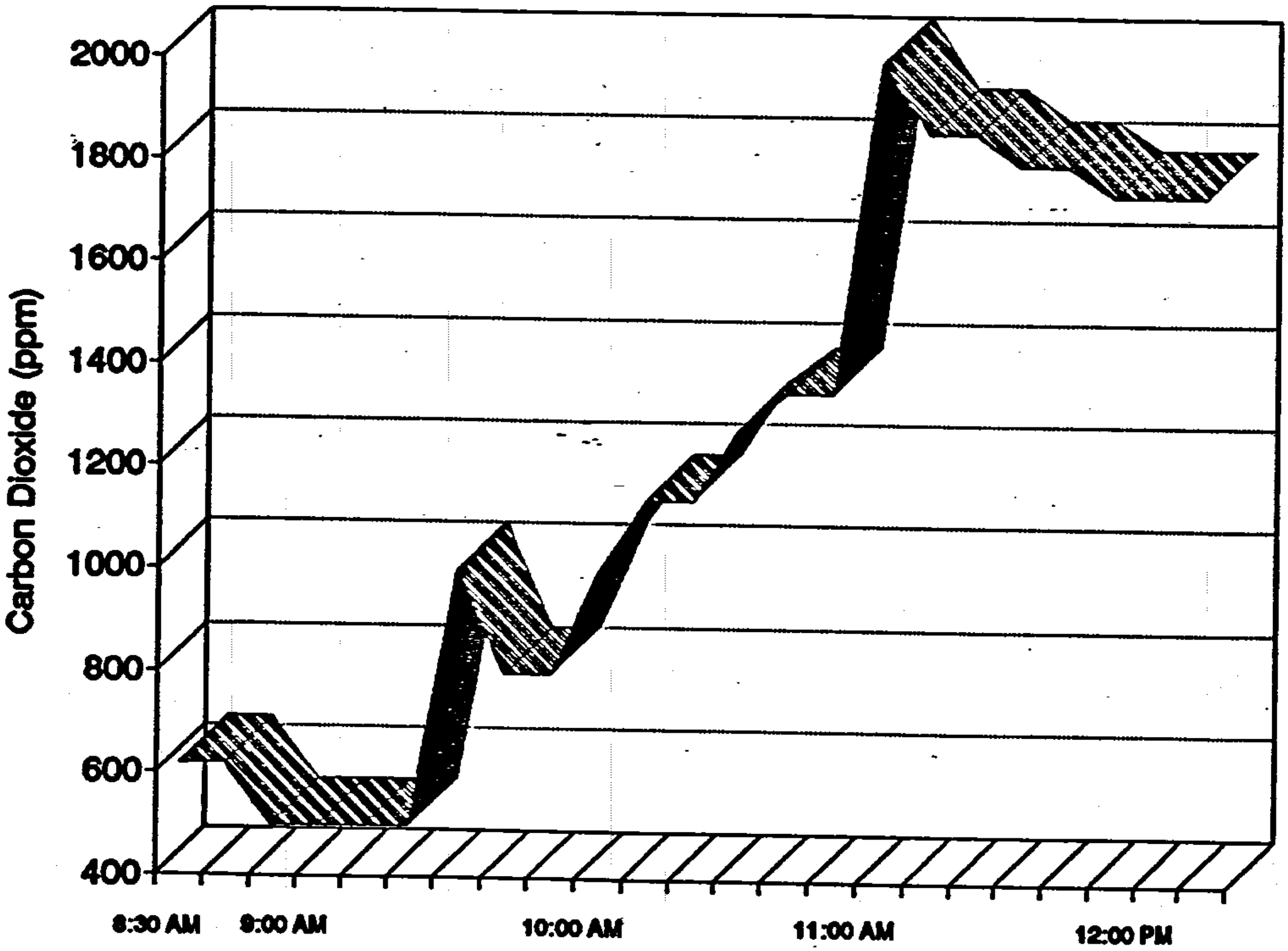
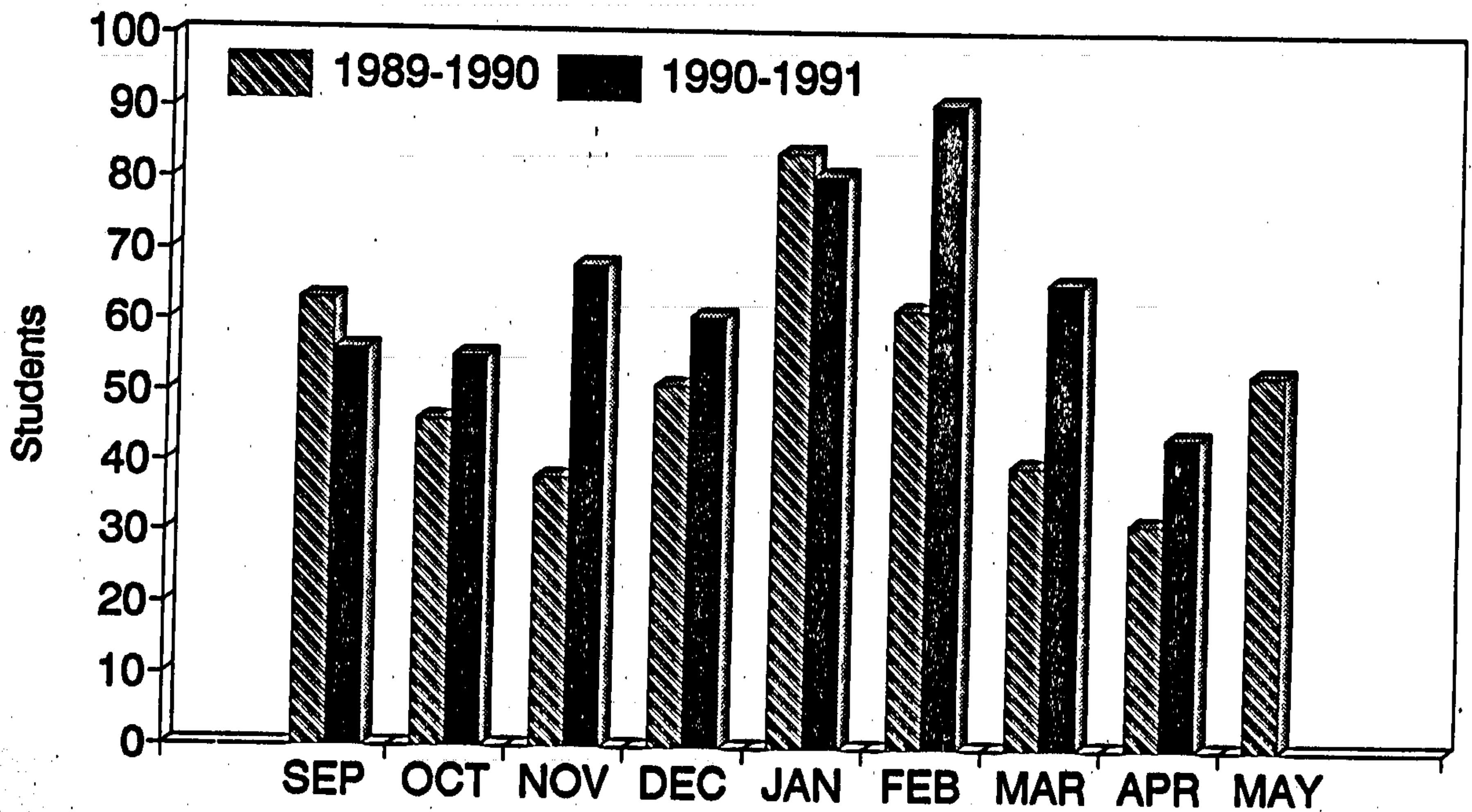


Figure 4.

Bethlehem-Center Elementary School

Comparison of Students Reporting Headaches for School Years 1989-1990 and 1990-1991

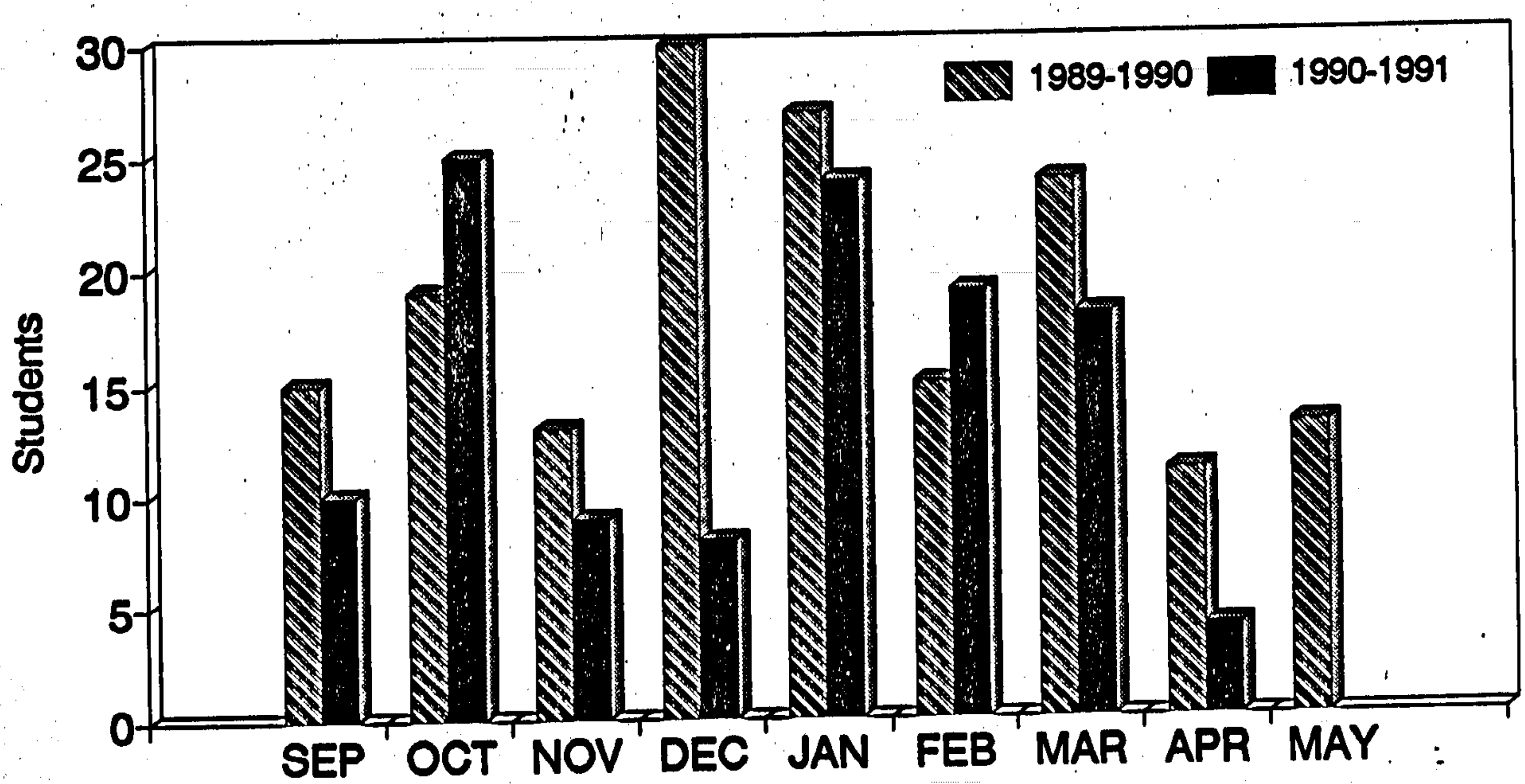


Source: School Nurse's Log

Figure 5.

Bethlehem-Center Elementary School

Comparison of Students Reporting Nausea for School Years 1989-1990 and 1990-1991.

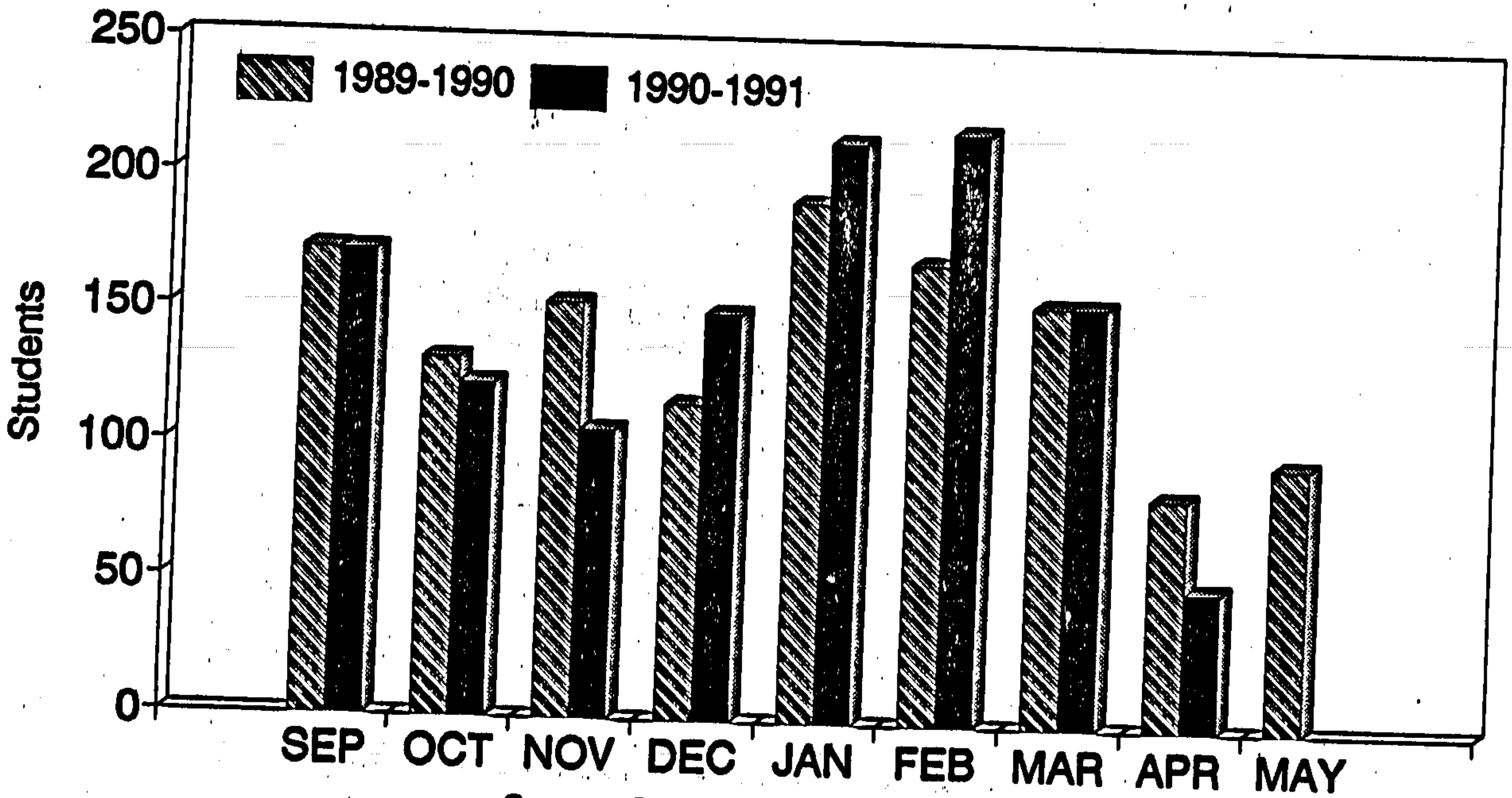


Source: School Nurse's Log

Figure 6.

Bethlehem-Center Elementary School

Comparison of Students Reporting Stomachaches
for School Years 1989-1990 and 1990-1991.



Source: School Nurse's Log

Figure 7.

Bethlehem-Center Elementary School

Reported Carboxyhemoglobin Levels

Relevant to School Closing.

April 1991

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
	1	2	3	4 Beth Center Elementary Closed Last day of school for 7227-S1	5 Beth Center Elementary Reopened	6
7	8 7227-S4 CO-Hb = 3.2% @ 15:27	9 Beth Center Elementary closed for remainder of year 7227-S6 CO-Hb = <1.0% @ 12:00	10	11 7227-S1 CO-Hb = 2.4% @ 15:15 7227-S10 CO-Hb = 2.6% @ 15:15	12 7227-S12 CO-Hb = 2.0% @ 13:00 7227-S8 CO-Hb = <1.0% @ 08:25	13
14	15	16 7227-S15 CO-Hb = 1.8% @ 11:32	17 7227-S20 CO-Hb = 2.5% @ 10:57 NIOSH Visit and Walkthrough	18 NIOSH return visit for sampling	19	20
21	22	23	24 Public Meeting	25	26	27
28	29	30				