HETA 98-0235
North View Elementary School
Clarksburg, WV

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Eva Hnizdo, Greg Kullman, and Pengfei Gao, of the Field Studies Branch, Division of Respiratory Disease Studies (DRDS). Field assistance was provided by Steve Berardinelli, Jr., Randy Boylstein, John Tran and Greg Feather. Analytical support was provided by Bill Jones and Peng-fei Gao. Desktop publishing was performed by Terry Rooney.

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Health Hazard Evaluation Report 98-0235
North View Elementary School
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SUMMARY

In May of 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request to conduct a health hazard evaluation (HHE) at the North View Elementary School in Clarksburg, WV. The request, submitted by the West Virginia Education Association (WVEA), cited indoor air quality associated health complaints such as asthma, sinus infections, allergies, respiratory problems and increased absenteeism.

On May 27 and June 6, 1999, NIOSH investigators conducted initial investigations of the environmental conditions and health concerns. The investigation involved interviews with workers, a questionnaire survey, lung function testing, inspection of the building and the air handling unit (AHU), and measurements of temperature, relative humidity, carbon dioxide, and microbial volatile organic compounds in air. On July 22, 1999, NIOSH investigators made a site visit with officials from the Environmental Protection Agency (EPA) to further inspect the school AHU. On August 11 and 12, 1999, during the summer recess, NIOSH investigators took additional environmental measurements to assess the potential for fungal growth and other indoor environmental conditions when the school was unoccupied. Following these surveys, an interim report with recommendations was presented to the school management and employees. On August 14, 1999, further questionnaire survey and lung function testing were done to determine the baseline respiratory health status following a summer recess. On February 11 and 17, 2000, NIOSH investigators conducted additional environmental and medical assessment at the school during the winter season. This survey also evaluated progress made on recommendations provided in the interim report and their impact on employee health. The results of the investigation are summarized below.

At the initial investigation on May 1999, employees who worked in the basement area of the school reported higher occurrence of upper and lower respiratory symptoms than those who worked on the first or second floor of the school. Almost all employees from the basement area (89%) reported wheezing and shortness of breath with wheezing during the last 12 months, and 66% reported taking medication for breathing problems. The employees working on the second floor had the lowest prevalence of respiratory symptoms. The prevalence of nonspecific symptoms (these include a stuffy/runny nose, irritation of the eyes, throat, headache and sinus problems) was also high. There was a noticeable decrease in the prevalence of respiratory symptoms during the summer recess. However, during the winter months the frequency of reported symptoms increased, in particular in the basement and on the first floor. Cross-sectional spirometry testing determined that 8% of the adult school occupants had mild obstructive impairment. Serial lung function tests performed by nine occupants who complained of asthma-like respiratory symptoms did not show visible variability in lung function in response to being in the school environment.

On inspection of the school, we observed water incursions and fungal growth on interior ceiling tiles in basement areas. Bioaerosol concentrations in building air, measured during the school break with the AHU in operation, were below ambient levels for fungi, bacteria, spores, and endotoxin. Some of the fungal and bacterial organisms identified in the building, especially in basement areas, were different from those identified in ambient samples suggesting amplification of these organisms within the building. Five unique microbial volatile organic compounds (MVOCs) were detected in the basement area; none of these compounds were detected on the sample collected on the second floor. The airborne dust concentrations measured in building air were below those measured in ambient air. Samples for carbon dioxide, obtained when school was in session, suggest inadequate outside air intake and distribution. Inspection of the AHU indicated too small a filter surface area and other operational problems that would impact system operation and indoor environmental quality.

The complaints that motivated this HHE request were substantiated by a questionnaire survey documenting an increase in respiratory symptoms among school staff in the basement in comparison with the other staff. Although we did not demonstrate work-related changes in lung function over a short period of time in the few teachers studied, we found environmental conditions that are plausibly associated with lower respiratory symptoms. These include evidence of moisture incursion and mold growth in the basement areas. In addition, we found suboptimal operation of the AHU which may explain some of the upper respiratory, eye irritation, and headache symptoms, which were high throughout the school. Our interim and final recommendations, provided on pages 10 and 11, are directed towards correcting these IEQ problems.

Keywords: Indoor Environmental Quality, Bioareosols, Fungi, Asthma

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INTRODUCTION

In May of 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request to conduct a health hazard evaluation (HHE) at the North View Elementary School in Clarksburg, WV. The request was submitted by the West Virginia Education Association (WVEA). The request cited several indoor air quality related health concerns such as asthma, sinus infections, allergies, respiratory problems, and increased absenteeism.

On May 27 and June 6, 1999, NIOSH investigators conducted initial investigations of the environmental conditions and health concerns. The investigation involved interviews with workers, a questionnaire survey, lung function testing, inspection of the building and the air handling unit (AHU), and measurements of temperature, relative humidity, carbon dioxide, and microbial volatile organic compounds in air. On July 22, 1999, NIOSH investigators made a site visit with officials from the Environmental Protection Agency (EPA) to further inspect the school AHU. On August 11 and 12, 1999, NIOSH investigators took additional environmental measurements to assess the potential for fungal growth and other indoor environmental conditions during the summer when the school was not in session. Following these surveys, an interim report with recommendations was presented to the school management and employees. On August 14, 1999, on return from the school break, further questionnaire survey and lung function testing were done to determine the baseline respiratory health status following a summer recess. On February 11 and 17, 2000, NIOSH investigators conducted additional environmental and medical assessment at the school during the winter season. This survey also evaluated progress made on recommendations provided in the interim report and their impact on employee health.

This report describes the medical and environmental findings from this HHE and provides recommendations for improving indoor environmental quality and reducing employee symptoms.

BACKGROUND

North View Elementary School in Clarksburg, WV, was constructed during the 1920s. Approximately 300 students and 36 teachers and support staff occupy the school. The school is a four-story brick building of approximately forty classrooms, a band room, a cafeteria, a furnace room, a library, several storage areas, and administrative offices. The basement area was expanded and converted from a shop into classrooms for kindergarten children. The building also contains a gymnasium that is accessed from the first floor hallway. The basement areas and part of the ground floor are partially below grade. The school has one elevator that serves all floors.

The heating, ventilation, and air conditioning (HVAC) system consisted of one AHU located on the first floor in a mechanical room. The fresh air intake, located on the side of the building at ground level, had louvered openings which were automatically adjustable according to ambient temperature. Outside air entered the louvered wall opening into the mechanical room and was mixed with recirculated air. The mixed air then flowed through fiberglass filters located in the AHU. The mixed, filtered air passed through the heating coils into the supply duct work and was delivered to the occupied spaces through supply diffusers located in the ceiling. The heating coils were heated via hot water from several natural gas-fired boilers located in the mechanical room. The flue pipe from boilers ran horizontally through the return air plenum, exited the building through an exterior wall, and traveled up to the roof. Return air from the occupied building areas entered return plenums to a common return located
above the dropped ceiling; this air was returned to the mechanical room. Air filters were a medium efficiency fiberglass material and were replaced as needed by visual inspection. The building does not have central air-conditioning.

The building had a flat roof that has been replaced with rubberized membrane roofing within the last five years.

North View Middle School was a smoke-free building, as required by West Virginia State law. Use of all tobacco products is prohibited on school property.

METHODS

A preliminary telephone inquiry with a representative of the school occupants revealed a respiratory illness complaint area to be in the basement where the kindergarten, preschool and speech classes are located. The illness was ascribed to poor indoor air quality and fungal contamination of the wall-to-wall carpet in the basement. In addition, the occupants complained that the indoor air quality in the whole school was worse during the winter months when the heating system was switched on.

Both environmental and medical measurements were collected at the school over a period of several months from May 1999 through February 2000. The objectives were to assess the indoor environmental quality and the respiratory health problems of the school occupants; to identify the environmental factors responsible for the reported health problems; and to make recommendations and assess their effectiveness.

ENVIRONMENTAL

To assess indoor air quality in the North View Elementary School, measurements included air samples for total dust, endotoxins, culturable bacteria and fungi, microbial volatile organic compounds (MVOCs), fungal spores, and carbon dioxide. Measurements of temperature and relative humidity were also taken. A sample of dust from the school's AHU filter was cultured for bacteria and fungi; this sample was also qualitatively analyzed for particulates by polarized light microscopy and scanning electron microscopy. The school ventilation system was inspected. The school building was also inspected for any sources of moisture incursion and subsequent microbiological growth. Samples of a water damaged ceiling tile from a basement room were cultured for bacteria and fungi. Table 1 provides detail on the environmental sampling methods used during this survey. [1-10]

MEDICAL

The medical evaluation offered to all adult occupants of the school was designed: (1) to compare the prevalence of respiratory symptoms in the complaint area, i.e., in the basement, with those in other areas of the school; (2) to identify environmental factors associated with the reported health problems; (3) to determine the effect of longer recess from the school environment during the summer vacation on the prevalence of asthma-like respiratory symptoms; and (4) to determine the effect of remediation measures, based on recommendations made in the interim report, on the prevalence of upper and lower respiratory symptoms.

The medical evaluation consisted of three questionnaire surveys and two kinds of lung function testing. The respiratory symptoms questionnaire surveys were conducted on May 27, 1999, i.e., before the school closure for summer vacation, on August 11, 1999, i.e., immediately on return from school vacation, and on February 17, 2000, i.e., during the winter months after the heating system was on for several months. A modified European Community Respiratory Health Survey Questionnaire was used for the assessment of respiratory symptoms. [11,12] The effect of remediation measures, based on recommendations made after the August 1999 visit, was evaluated in the February 2000 survey.

Lung function testing done on May 27 to June 3, 1999 involved serial lung function testing, using belt spirometers, on nine employees who complained of asthma-like symptoms during the survey. The objective was to determine if employees who reported symptoms of cough, wheezing, shortness of breath and chest tightness showed variability in lung function in response to being in the school environment. The employees were instructed to perform lung function tests five times during the day (on waking up, at ten o'clock, at midday, on leaving the school in the afternoon, and before going to bed at night). Three best blows at a time were considered for the analysis. The tests were done from May 27 to June 3: seven weekdays and two weekends (four days). Lung function testing done on August 11, 1999, during a work day, involved spirometry tests on all adult occupants of the school. The objective was to determine the baseline lung function after the summer school recess and the prevalence of chronic airflow impairment. Appendix I describes the spirometry methods and criteria for identification of an obstructive or restrictive breathing pattern.

RESULTS

ENVIRONMENTAL EVALUATION

Water Incursions

Evidence of water incursion was observed in the basement area in most of the classrooms (the speech, kindergarten, and pre-school rooms). The water incursions occurred at ceiling level, as evidenced by stained tile. The leaks appeared at locations where there was an interface between brick and a newer external fascia. We also noticed some unsealed cracks in the exterior brick walls. Also, in the basement speech room, a metal exhaust air vent exits the building near a source of water incursion; this is likely a source of water leaks or condensation.

The ceiling tile in the basement speech room appeared to contain surface mold growth. To establish the type of fungal contamination, this tile was removed from the building and a portion submitted for microbiological analysis. Table 2 presents the results from this sample analysis. Cultures of the tile grew both fungi and bacteria. The fungal concentrations from this sample were 13,900,000 colony-forming units per gram of ceiling tile (CFU/g) using cornmeal agar and 13,000,000 using malt extract agar. *Phoma* was the predominant fungal genus identified in the both agar cultures. *Cladosporium*, *Penicillium*, and *Rhodotorula* were also identified in these samples. Fungal cultures from a new, unused sample of ceiling tile were below detectable limits, approximately 154 CFU/g. Mesophilic bacteria (25° centigrade incubation) were detected in the ceiling tile sample at a concentration of 16,900,000 CFU/g. Several bacterial genera were identified in the sample as noted in Table 2. The ceiling tile sample cultured for thermophilic bacteria (55° centigrade incubation) did not grow bacteria. Neither did the new, unused sample of ceiling tile.

In addition to the water incursions in the ceiling areas, school management/teachers also reported that the carpet in the basement area became moldy in areas during the summer months when the school was closed and the ventilation system was not operating. The wall-to-wall carpet in the basement was old and dirty, although we did not observe moisture or fungal growth during inspections in the summer of 1999. The school was not closed during this summer, as in past seasons, and the ventilation system was operated during this summer. Evidence of water incursions into building spaces was observed in the bottom of the elevator shaft following a day of rainy weather.

Air Handling Unit (AHU)

During two of the inspections, the system filters were heavily loaded with particulate greatly reducing air flow (and outside air supply) to building occupants. The mixing room on the ground floor was used to store furniture and building supplies; it was visibly dirty with trash and cigarettes on the floor in the supply air side of the filter bank. The mechanical room for the basement booster fan was also used as a storage room and contained items such as paints, fuel, cleaning chemicals, and other school furniture and supplies.

The supply and return ducts for the school building rooms were located in the ceiling or at ceiling level in many of the rooms. In some rooms, the supply and return ducts were located in close proximity and presented the potential for supply air reentrainment into the return air system and poor air distribution.

Table 2 provides the results from microbiological analysis of AHU filter material. Particulate adhered to the filter was cultured for fungi and bacteria. Mesophilic fungi were present at concentrations of

186,000 and 95,800 CFU/g respectively on CMA and MEA agars. The most abundant fungi were *Aspergillus niger, Paecilomyces variotii*, and *Penicillium* species. Both mesophilic and thermophilic bacteria were cultured from the filter at concentrations of 112,000 CFU/g (mesophilic) and 9,000 CFU/g (thermophilic). Light and electron microscopy analysis of particulate extracted from the filters indicated the presence of a wide variety of particle types from both indoor and outdoor sources. These include skin cells, fabric fibers (indoor sources), trichomes and pollens (outdoor sources), fungal spores and hyphae, insect parts, starch grains, animal hair, feather fragments, and others.

Air Sampling Results

Table 3 provides sampling results for total dust and total endotoxin in air. Samples were time-weighted over a two-day (12 to 13 hour) period and collected during the summer with the AHU operating; school was not in session during sampling. Total dust concentrations ranged from 0.01 milligrams per cubic meter of air (mg/m^3) to a high of 0.08 mg/m^3. The highest concentration was measured in the ambient (outdoor) sample. Endotoxin concentrations in air ranged from 0.3 endotoxin units per cubic meter of air (EU/m^3) to a high of 8.0 EU/m^3. Again, the highest endotoxin concentrations were measured outdoors in the ambient sample collected by the outside air intake; one sample from the basement area had a concentration of 7.8 EU/m^3. (See Appendix I)

Table 4 provides the sampling results for total fungal spores in air. Airborne spore concentrations ranged from 840 spores per cubic meter of air ($spores/m^3$) to a high of 33,400 $spores/m^3$. The highest concentrations were measured in the ambient sample. Culturable fungi are presented in Table 5. Concentrations ranged from 132 CFU/m^3 to greater than 30,900 CFU/m^3. The highest concentrations were measured in the ambient samples and all of these samples were overloaded. Table 6 presents the mean of airborne fungi as a percentage of total CFU/m^3 according to sampling location. Shown are the different culturable airborne fungi identified in the ambient air, the basement, and the first and second floors of the school. *Cladosporium cladosporioides* was the predominant fungus identified in both the ambient and indoor air samples. Several fungi were identified exclusively in the indoor samples although they were not the predominant fungal organisms in these samples; these include *Aspergillus orharaceus, Aspergillus niger, Aspergillus versicolor, Trichoderma harzianum, Fusarium graminerum*, and *Syncephalastrum racemosum*. In comparison to the ambient air samples, the basement samples had lower CFU/m^3 and lower percentage of *Cladosporium cladosporioides*, but higher percentage of *Basidomycetes*. Several species of *Aspergillus* were identified only in the basement. The first floor and second floor classrooms combined also had lower values of CFU/m^3 and lower percentage of *Cladosporium cladosporioides*, but higher percentage of *Penicillium.*

Table 7 provides concentrations of culturable, mesophilic bacteria in air. Concentrations ranged from 230 CFU/m^3 to greater than 30,900 CFU/m^3. The highest concentrations were measured in the ambient samples. Table 8 lists the mean of airborne fungi as a percentage of total CFU/m^3 according to sampling location. *Micrococcus lutenus, Streptomyces sp*, and *Coryneform bacteria* were the predominant bacteria identified in both the ambient and indoor samples. There were some differences in the pattern of bacterial species among the three locations. The outside air had higher representation of *Brevibacillus brevis*, *Corynebacterium aquaticum*, and *Microbacterium sp*; these species were absent in the indoor air. The indoor air had higher representation of *Micrococcus luteus* both for the basement and upper floors. Some bacterial species were identified only in the indoor air including *Staphylococcus coafulase, Oerskovia sp., Agrobacterium radiobacter, Pseudomonas stutzeri, Nocardiopsis, Micrococcus roseus*, and *Enterobacteria agglomerans.*

Table 9 provides microbial volatile organic compounds (MVOCs) from air samples. The MVOCs help in understanding the level and type of microbial contamination. The concentrations of the unique MVOCs are provided for each sampling location. Five unique MVOCs were detected inside the school. Unique MVOCs were not detected in the ambient sample. The MVOC concentration was highest in the classroom on the ground floor and the lowest in Classroom 308 on the second floor. Although the total MVOC level in the Pre-school was not significantly higher than that in Classroom 308, it is evident that different MVOCs were determined in the Pre-school and the other basement rooms. This may imply that some fungi or bacteria that grew in the basement did not grow (or were present at much lower levels) in Classroom 308. In the basement, four or five unique MVOCs were determined, and the concentration was the highest in the Speech Room.

Table 10 provides the short-term, carbon dioxide samples collected when school was in session (June 1999). Concentrations are reported in parts per million parts air by volume (ppm) by floor and grade. Table 11 provides the mean short term, carbon dioxide (CO_2) concentrations by floor. Concentrations are reported in ppm for samples collected with the school in session (June 1999) and out of session (August 1999). With school in session (and the building occupied), the lowest CO_2 concentrations (average 433 ppm) were measured in the ambient samples. The highest average concentration was measured in the basement areas with a mean of 1020 ppm. CO_2 concentrations were higher on all floors with school in session. Table 12 provides the CO_2 sampling results from the long term, time-weighted samples collected with school in session. Three of the five samples collected within the school exceeded 1000 ppm. Temperatures in the school during summer operating conditions ranged from 72 ^{0}F to 82 ^{0}F (Table 10); relative humidity ranged from 42 to 57 percent.

During the February 2000 site visit, we observed that progress had been made on some of the interim recommendations provided in August of 1999. The carpet in the basement area had been removed and replaced with tile flooring. The school engineering / maintenance was working to promptly identify and correct sources of water incursion into the building. During the site visit, school management completed the recommendation to remove the blockage from the return air grill for the basement AHU booster fan system. Efforts to replace the AHU filters on a more regular basis had also been undertaken.

MEDICAL EVALUATIONS

Questionnaire surveys

Ninety-two percent of the employees participated in the May 27, 1999 questionnaire survey. Overall, about half (53%) of all participants reported wheezing in the last 12 months or shortness of breath (46%), while about one-third (33%) reported chest tightness in the last 12 months or were taking medication for breathing problems (30%) (see Table 13). Employees who worked in the basement reported higher occurrence of upper and lower respiratory symptoms than employees who worked on the first or second floor of the school. Of the nine employees who worked in the basement, eight reported wheezing in the last 12 months and shortness of breath, and six reported taking medication for breathing problems. These rates were about twice as high as those for the ten second floor employees, who had the fewest symptoms (three with wheezing in the last 12 months, one with shortness of breath, and three taking medication). The prevalence of other nonspecific symptoms (stuffy/runny nose, irritation of the eyes, throat, headache, dizziness, and sinus problems) did not show major differences across the three areas, but the overall prevalence of these symptoms was high. There were six employees, 18%, who reported asthma diagnosed by a doctor. Of these, four worked in the basement where the prevalence was 44%. Smoking could have contributed to the increased prevalence of respiratory symptoms observed in the basement, as more employees who worked in the basement smoked by comparison to those who worked on the first or second floor.

Results from the questionnaire survey done on August 11, 1999, i.e., after two months recess, show a substantial decrease in the prevalence of respiratory symptoms that employees experienced during the last two months (i.e., while on school vacation). Table 14 shows that of the nine employees who worked in the basement area, only one employee reported wheezing and two reported taking medication for breathing problems. The number of employees taking medication for breathing dropped specifically in the basement area, but remained the same on the first and second floor (see Table 14). Overall, 8% reported an attack of wheezing and 8% reported an attack of chest tightness during the last two months, and 24% reported taking medication for breathing problems. Three employees, 12%, reported having asthma.

By comparison with the August survey, the results from the February 2000 survey show an increase in the prevalence of respiratory symptoms experienced during the last two months (see Table 15). The increase was particularly noticeable in the basement and on the first floor, but not on the second floor of the school. Overall, there was a noticeable increase in the prevalence of difficulty in breathing (22%) and in chest tightness (19%). The prevalence of nonspecific symptoms continued to be high.

The observed prevalence of respiratory symptoms was highest in the basement area for both the May 1999 and the February 2000 surveys. The prevalence was highest in May 1999, decreased substantially after the school vacation, and increased again in February 2000. However, the periods over which the symptoms were ascertained in the three questionnaire surveys were comparable only for the last two surveys. The results indicate that the prevalence of asthma-like respiratory symptoms declined during the summer school vacation and increased during the winter period.

In the February 2000 survey, a large percentage of employees reported that the school was still very dusty. Employees complained that the AHU blew out a large amount of black soot which contributed to the high amount of settled dust and that there was inadequate and irregular cleaning of dust in the school. Inadequate air distribution was reported by the employees to be accountable for poor air quality, in particularly in the basement classrooms. Through interviews, the employees who worked in the basement reported that they no longer felt as sick as they were in May 1999 and that the replacement of the basement carpet with tiles helped. However, the prevalence of reported symptoms was still highest in the basement.

Serial Lung Function Testing

Serial lung function testing using belt spirometers done from May 27 to June 3, 1999 on nine employees who complained of asthma-like symptoms during the survey was designed to determine if these employees show variability in lung function in response to being in the school environment. The lung function curves produced from the individual blows of the participants indicated a normal pattern and good effort for seven of the participants. One participant withdrew from the testing, and one person with doctor's diagnosed asthma had an abnormal lung function pattern, but no work-related pattern could be discerned. On visual inspection, the serial lung function pattern appeared to be normal for the seven participants who produced good effort.

There were no significant differences between the average weekday's and weekend's lung function values (FEV_1, and PEFR) observed upon waking up, at midmorning, after lunch, in early evening, and late evening. Table 16 shows the mean within-person differences and the probability levels testing those differences. There were, however, factors that could have obscured the effect tested. Firstly, most employees with asthma-like respiratory symptoms were taking medication for breathing. Secondly, when the serial lung function testing was done, many classrooms had natural ventilation through open windows and thus the indoor air contamination might have been diluted and would have differed from the winter months when the heating system was in use. Individual results were reported to the teachers.

Cross-sectional spirometry

Lung function testing during a working day on August 11, 1999, involved all adult occupants of the school. The objective was to determine the baseline lung function after the summer school recess and the prevalence of chronic airflow impairment. There were 25 adult school occupants who participated in the spirometry lung function testing on August 11, 1999. The average sex, age and height adjusted percent predicted forced vital capacity (FVC) was 103.9 (Standard deviation, s.d., 13.1), the average percent predicted forced expiratory volume in one second (FEV_1) was 99.0 (s.d., 14.9) and the average ratio of FEV_1/FVC was 78.8% (s.d., 6.9). There were two employees whose ratio was in the mild obstructive range. The prevalence of mild obstructive impairment was thus 2/25= 8%. These two employees did not participate in the serial lung function testing.

DISCUSSION

The Health Hazard Evaluation in the North View Elementary School was conducted to assess the indoor environmental quality and respiratory health problems of school occupants, and to identify any environmental factors potentially responsible for the reported health problems. The respiratory symptom questionnaire survey conducted on May 27, 1999 identified a complaint area to be in the basement of the school. The occupants of the basement reported higher prevalence of asthma-like respiratory symptoms (cough, wheezing, shortness of breath, chest tightness) by comparison with the other areas of the school. The nonspecific symptoms, such as a stuffy nose, irritation of the eyes, irritation of the throat, headache, dizziness, and mental confusion, though slightly higher in the basement, were high on all floors. There was a noticeable decrease in the prevalence of respiratory symptoms during the summer recess. However, during the winter months the frequency of reported symptoms increased, in particular in the basement and on the first floor. Serial lung function tests taken on nine occupants who complained of asthma-like respiratory symptoms did not show visible variability in response to being in the school environment. The prevalence of mild obstructive lung function impairment among 25 employees was 8%. The questionnaire results substantiate the complaints that motivated this HHE request documenting an increase in respiratory symptoms among school staff in the basement in comparison with the other staff. Although we did not demonstrate work-related changes in lung function over a short period of time in the few teachers studied, we found environmental conditions that are plausibly associated with higher respiratory symptoms.

The environmental investigation revealed visible signs of moisture incursion in the basement and significant microbial growth on a water damaged ceiling tile taken from the speech room in the basement. The wall-to-wall carpet in the basement was old and dirty, and though no visible signs of moisture or fungal growth were seen, there was potential for fungal growth during the summer recess when the carpet was washed. Measurements of MVOC showed higher representation of unusual types of MVOC in the basement area, by comparison to other areas in the school. The culturable airborne fungal concentrations were significantly lower in the school indoor air by comparison to ambient concentrations. However, the fungal and bacterial profile differed between the basement samples, the samples taken from the first and second floor of the school, and ambient air samples. The basement area had an increased representation of *Basidomycetes* and *Aspergillus* species. The first and second floors had significantly increased *Penicillium* by comparison with the ambient air and the basement. A dust sample extracted from the AHU filter showed predominant species to be *Aspergillus niger*, *Paecilomyces variotii* and *Penicillium*, in addition to other less frequently represented species. This indicates that the HVAC system filters have retained organisms different from those expressed in the air samples at the time of our survey. The basement samples also had higher representation of bacterial species not found in the ambient or first and second floor air samples. This pattern is consistent with reports of building related problems associated with water incursion and related fungal or bacterial growth. The deviation in the fungal and bacterial profiles from the ambient air profile in the North View Elementary School suggests that the indoor environment in the school is potentially conducive to fungal growth, although the absolute numbers of fungi in air (in CFU/m^3) observed for the individual fungal species were low. Though only a limited number of viable samples were collected in the school, the combined findings of visible water incursions, surface mold contamination, and airborne fungal profiles all consistently suggest potential IEQ problems from bioaerosols in the basement areas of the school.

In general, moisture incursion and related fungal growth in buildings are recognized sources of indoor air quality related health problems.[13] Residential characteristics identified to be associated with undesirable fungal contamination include flooding, home dampness, old wall-to-wall carpet, number of surfaces with visible mold, low frequency of vacuuming, and contaminated HVAC. Health problems reported in the literature to be associated with fungal contamination of the air include allergic reactions such as rhinitis, asthma and hypersensitivity pneumonitis, and other reactions to mycotoxins produced by fungi that can lead to general sickness.[14] Although fungi and bacteria are universal components of the ambient air, it is suggested that when the interior fungal growth is different from that of the ambient air that this is a marker for indoor environmental quality problems that can lead to various health problems, including respiratory and other nonspecific symptoms.[13,15-17]

There were no clear differences in the measurements of total airborne endotoxin and dust between the complaint and non-complaint areas, and the concentration of both of these analytes was higher in the ambient samples. Endotoxin concentrations were below the threshold levels that have been associated with symptoms among individuals sensitized to cotton dust.[18,19]. While there were occupant complaints about the dustiness in the school, these complaints may reflect concerns regarding visible surface dirt or dust and general housekeeping issues.

The basement areas had high concentrations of CO_2, when occupants were present in the classes, as did other areas of the school building, indicating inadequate outside air intake or distribution. The old ventilation system at North View Elementary School had several design problems, including a reduced filtration surface area and poor AHU air supply and return design in some rooms. Combined, these would result in suboptimal AHU performance. The high prevalence of nonspecific symptoms found among the school occupants is commonly reported in buildings with inadequate ventilation; this is often coincident with high indoor CO_2 concentrations which serve as a marker for inadequate outside air intake and distribution. The primary source of CO_2 in an office or school building is human respiration and this contaminant serves as an indicator of the adequacy of outside air intake and distribution within the building.[20] The American Society for Heating Refrigeration and Air-Conditioning (ASHRAE) Standard 62-1999, Ventilation for Acceptable Indoor Air Quality, recommends 1000 ppm as an upper limit for CO_2 concentrations.[21] When school was in session, some of the CO_2 measured throughout the school exceeded this level indicating inadequate ventilation. Additionally, some of the indoor dry bulb temperatures exceeded 79 ^{0}F, the upper limit recommended by ASHRAE during summer operating conditions.[22]

Progress on the implementation of the NIOSH recommendations provided in the August interim report included the replacement of the basement carpet with tiles, improvements in maintenance practices regarding more frequent replacement of AHU filters, and prompt repair of the sources of water incursions into the school. From the questionnaire survey done on February 2000, and through interviews, we found that employees who worked in the basement no longer felt as sick as they reported in May 1999 and the replacement of basement carpet with tiles, as recommended, helped. However, employees continued to complain of inadequate fresh air distribution, and the prevalence of symptoms continued to be highest in the basement. A large percentage of employees reported that the school was still very dusty and that the AHU blew out a large amount of black soot which resulted in high amount of settled dust. The cleaning of this dust in the school was reported to be inadequate. The school air distribution was still reported to be inadequate and accountable for poor air quality, particularly in the basement classrooms. These results suggest the need for additional remediation efforts targeting improvement in ventilation practices and housekeeping/cleaning of the AHU.

CONCLUSIONS

1) Building occupants/staff working in the basement at North View Elementary School reported an increase in respiratory symptoms in comparison with the other staff. Employees who worked in the basement area of the school reported higher occurrence of upper and lower respiratory symptoms than employees who worked on the first or second floor of the school. Almost all employees from the basement area reported wheezing and shortness of breath with wheezing during the last 12 months. Serial lung function tests taken over a short period of time on nine occupants who complained of asthma-like respiratory symptoms did not show visible variability in lung function in response to being in the school environment.

2) Environmental conditions that are plausibly associated with lower respiratory symptoms were identified at the school including evidence of moisture incursion in basement areas, old / stained carpets, fungal growth on basement surfaces, and airborne fungal profiles suggestive of possible amplification of these organisms by conditions within the building.

3) The prevalence of nonspecific symptoms (a stuffy/runny nose, irritation of the eyes, throat, headache and sinus problems) was high and did not show as large differences across building floors. Some aspects of the AHU operation at North View Elementary were suboptimal affecting all floors. This may explain some of the upper respiratory symptoms, eye irritation, and headache, which were high throughout the school. The high CO_2 concentrations measured in many of the rooms during a school session suggest the need for additional outside air intake and distribution when school is in session. Additionally, the temperatures measured in some school rooms were too high by comparison to ASHRAE standards.

4) The control steps taken in response to the interim NIOSH recommendations helped to some extent, as employees who worked in the basement no longer felt as sick as they were in May 1999. However, the reporting of respiratory symptoms continued to be highest in the basement. A large percentage of employees reported that the school was still dusty, that the AHU blew out a large amount of black particulates, and that air distribution was still inadequate in the basement. Thus the remediation measures involving ventilation system operation and cleaning of the AHU were still not sufficient.

RECOMMENDATIONS

Following HHE surveys at the school, interim recommendations were provided to the school in August of 1999. These recommendations included:

1. Stop all sources of water leaks and incursions into building areas promptly. Replace all porous building materials (including ceiling tiles) with evidence of water damage or mold growth. *(Completed)* Disinfect all nonporous, building structural components with a mild bleach solution.

2. Control temperature and relative humidity in the basement, and other building areas, to promote good indoor environmental quality. The ASHRAE recommends the following ranges of temperature and relative humidity for summer and winter months:

Winter:	Temperature: 68 to 74 degrees Fahrenheit (^{o} F) Relative Humidity: 30 to 70 (%)
Summer:	Temperature: 73 to 79 degrees

Fahrenheit (° F)
Relative Humidity: 30 to 70 (%)

It is important to ensure that the basement areas are adequately ventilated to control relative humidity during the summer months, when the area is unoccupied, to help prevent the growth of microorganisms.

3. The school should consider replacing the carpet in the basement areas with tile or other nonporous flooring to help reduce the potential for microorganism growth and dissemination in these areas. If carpets are used in the basement, additional preventive maintenance is needed to help ensure that the basement carpets are kept dry, clean, and adequately maintained to prevent the growth of microorganisms. *(Completed)*

4. Clean the debris from supply air plenum, ground floor, and refrain from using this area for furniture storage.

5. Clean the construction debris from the return air plenum, basement level, and keep this area clean and dry.

6. Remove the paints, fuel, and cleaning chemicals from the basement mechanical room and store these agents outside the building or in another storage area, separate from the ventilation system, with dedicated exhaust to the outdoors.

7. The return air grill for the basement AHU booster fan system is blocked with wood; this blockage should be removed to improve air supply/distribution in the basement rooms. *(Completed)*

8) Replace the AHU filters on a more frequent schedule to prevent particulate buildup and reduced air flow/distribution. (Filter loading can be assessed visually and filters may need to be changed every 3 weeks to 1 month to prevent overloading). *(Completed)*

9. Open the windows in the more crowded school classrooms, as ambient conditions allow, for natural ventilation to help ensure adequate outside air intake for building occupants.

10. Regular preventive maintenance on the window air-conditioners is recommended. The filters should be cleaned or replaced several times throughout the year and the cooling coils inspected and cleaned as needed. Some of the window units had outside air intake capacity and these units should be operated with the outside air intake open.

The progress on these recommendations was evaluated during follow-back evaluations in February of 2000. The carpet in the basement area has been removed and replaced with tile flooring. The school engineering/maintenance was working to promptly identify and correct sources of water incursion into the building. During the site visit, school management completed recommendation #7 and removed the blockage from the return air grill for the basement AHU booster fan system. Efforts to replace the AHU filters on a more regular basis had also been undertaken.

The recommendations provided in the interim report, and not addressed to date, should be completed. In addition, the following are provided as additional recommendations based on subsequent site visits and the total findings from this HHE:

11. Increase the effective AHU filter surface area by relocating and enlarging the bank of filters to increase air flow and distribution.

12. In rooms where the AHU supply and return grills are in close proximity, install a baffle on the supply air grill to direct supply air flow towards building occupants and away from the return air grill.

13. Improve housekeeping efforts directed at the removal of any large, visible particulates released from the AHU or other sources in the basement and other school areas. Consider vacuum cleaning the AHU supply ducts.

14. Prevent the accumulation of water at the base of the elevator shaft. Additional drainage or sump

pumps may be required to prevent accumulation of water in the shaft.

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Table 1
Environmental Sampling Methods

Analytes	Media/Sampler	Flow Rate (LPM)	Analytical Methods
Total Dust and Endotoxin in air	37 millimeter (mm) Polyvinyl Chloride Filter in a closed-face Filter Cassette	3	1) Gravimetric analysis [(1)] 2) Kinetic chromogenic Limulus amebocyte lysate test [(2)]
Spores in Total Airborne Dust	25 mm polycarbonate Filter in an open-face, graphite-filled polystyrene filter cassette with extended cowls	2	Spore count by light microscopy under bright-field illumination [(3)]
Culturable Bacteria & Fungi in Air	Andersen, Viable Sampler (single stage) using tryptic soy agar with 0.01 % cycloheximide for bacteria and malt extract for fungi	28.3	Incubation and enumeration of bacteria & fungi [(4,5)]
Microbial Volatile Organic Compounds (MVOCs)	Sorbent tube with 100 milligrams of Tenax TA	0.1	Gas chromatography with mass spectrometer detection [(6,7)]
Carbon Dioxide	Indicator tubes - short term, direct reading tubes and direct reading survey meter	--	Direct reading [(8)]
Carbon Monoxide	Indicator tubes - short term, direct reading tubes	--	Direct reading [(8)]
Culturable Bacteria & Fungi on Ceiling Tile and AHU Filters	Ceiling tile collected in large plastic bag.		Direct observation and culturing, incubation, and enumeration of bacteria & fungi [(4,5)]
Particulates on AHU Filters	Bulk Sample	–	Polarized light microscopy and scanning electron microscopy [(9)]
Temperature and rh	Electronic Psychrometer	--	Direct measure [(10)]

Table 2
Culturable Bacteria and Fungi from Bulk Material Samples
July 1999

Location	Material	Agar / Incubation	Microorganisms	Percent of Sample	Concentration (CFU/g)
Fungi					
Basement - Speech Room	Ceiling Tile	Cornmeal Agar (CMA) / 25 ^{0}C	*Cladosporium*	< 1	13,900,000
			Phoma	98	
			Rhodotorula glutini	1	
Basement - Speech Room	Ceiling Tile	Malt Extract Agar (MEA) / 25 ^{0}C	*Cladosporium*	1	13,000,000
			Penicillium	< 1	
			Phoma	96	
			Rhodotorula glutini	2	
Blank Sample	Ceiling Tile	CMA & MEA / 25 ^{0}C	No Growth	--	No Growth (< 154)
AHU Room	Dust Extracted from AHU Filter	CMA / 25 ^{0}C	*Alternaria alternata*	2	186,000
			Aspergillus niger	42	
			Aspergillus sydowii	< 1	
			Aspergillus ustus	2	
			Chaetomium globosum	< 1	
			Paecilomyces variotii	30	
			Penicillium	19	
			Rhizopus stolonifer	1	
			Rhodotorula glutinis	3	
Bacteria					
AHU Room	Dust Extracted from AHU Filter	MEA / 25 ^{0}C	*Alternaria alternata*	< 1	95,800
			Aspergillus niger	53	
			Cladosporium	< 1	
			Paecilomyces variotii	26	
			Penicillium	16	
			Rhizopus stolonifer	2	
			Rhodotorula glutinis	2	

Table 2 (continued)
Culturable Bacteria and Fungi from Bulk Material Samples
July 1999

Location	Material	Agar / Incubation	Microorganisms	Percent of Sample	Concentration (CFU/g)
Bacteria					
Basement - Speech Room	Ceiling Tile	Tryptic Soy Agar (TSA) / 25 ^{0}C	*Brevundimonas vesicularis*	75	16,900,000
			Coryneform bacteria	25	
Basement - Speech Room	Ceiling Tile	Tryptic Soy Agar (TSA) / 55 ^{0}C	No Growth	--	No Growth (< 169)
Blank Sample	Ceiling Tile	TSA / 25 ^{0}C & 55 ^{0}C	No Growth	--	No Growth (< 154)
AHU Room	Dust Extracted from AHU Filter	TSA / 25 ^{0}C	*Bacillus*	100	112,000
AHU Room	Dust Extracted from AHU Filter	TSA / 55 ^{0}C	*Thermoactinomyces candidus*	81	9,000
			Thermoactinomyces bacillus	19	

Table 3
Airborne Total Dust and Endotoxin
August 1999

Sample	Floor	Location	Volume (m^3)	Dust[1] (mg/m^3)	Endotoxin[2] (EU/m^3)
7884	–	Ambient	2.2	0.08	8.0
7880	B	Preschool	2.3	0.01	0.3
7877	B	Speech Room	2.3	0.02	0.7
7883	B	Kindergarten	2.2	0.01	7.8
7881	B	Kindergarten	2.3	0.01	0.3
7871	G	First Grade	2.3	0.01	0.6
7875	2	Fifth Grade	2.2	0.02	0.6

[1] Total dust concentrations in milligrams (mg) per cubic meter (m^3);
[2]Endotoxin concentrations in endotoxin units (EU) per m^3.
Total dust and endotoxin concentrations time-weighted over a 2-day sampling period.

Table 4
Total Airborne Fungal Spores
August 1999

Sample	Floor	Location	Spores/m^3
2	–	Ambient	33,400
3	B	Pre-School	1,740
4	B	Speech room	5,690
7	B	Kindergarten	840
5	B	Kindergarten	872
1	G	First Grade	4,650
6	2	Fifth Grade	1,320

Spores/m^3 = spores per cubic meter of air.

Table 5
Culturable Airborne Fungi
August 1999

Sample	Date	Floor	Location	CFU/m^3	Fungi (Percent of Sample)	Average CFU/m^3
8	Aug. 11	--	Ambient	> 30900	*Cladosporium cladosporioides (95), Epicoccum migrum (2), Fusarium (1), Alternaria alternata (< 1), Paecilomyces variotti (< 1), Paecilomyces chatarumvariotti (< 1)*	
13	Aug. 11	--	Ambient	> 30900	*Cladosporium cladosporioides (Predominant), Epicoccum migrum, Fusarium, Alternaria alternata, Paecilomyces variotti, Paecilomyces chatarumvariotti, Penicillium, Beauveria brongniartii, Basidomycetes*	
18	Aug. 12	--	Ambient	> 30900	*Cladosporium cladosporioides (Predominant), Epicoccum migrum, Pithomyces chartarum, steril fungi,*	
22	Aug. 12	--	Ambient	> 30900	*Cladosporium (Predominant), Epicoccum migrum, Pithomyces chartarum*	> 30900
4	Aug. 11	B	Pre-school	292	*Cladosporium cladosporioides (48), Cladosporium sphaerospermum (15), Basidomycetes (15), Paecilomyces variotti (11), Penicillium (4), steril fungi (4), Aspergillus orharaceus (4)*	
11	Aug. 11	B	Pre-school	279	*Cladosporium cladosporioides (78), Alternaria alternata (11), Trichoderma harzianum (6), steril fungi (6),*	286
2	Aug. 11	B	Speech Room	536	*Cladosporium cladosporioides (57), Basidomycetes (14), Alternaria alternata (7), Epicoccum nigrum (5), Aspergillus versicolor (5), Penicillium (5), Aspergillus niger (2), Paecilomyces variotti (2), Syncephalastrum racemosum (2)*	

Table 5 (Continued)
Culturable Airborne Fungi
August 1999

Sample	Date	Floor	Location	CFU/m^3	Fungi (Percent of Sample)	Average CFU/m^3
10	Aug. 11	B	Speech Room	670	*Cladosporium cladosporioides (71), Pithomyces chartarum (9), Basidomycetes (6), Alternaria alternata (6), Epicoccum nigrum (3), Penicillium (3), steril fungi (3)*	603
14	Aug. 12	B	Kindergarten	132	*Cladosporium cladosporioides (67), Basidomycetes (27), Yeasts (7)*	
20	Aug. 12	B	Kindergarten	168	*Cladosporium (85), Pithomyces chartarum (8), Cuvularia (8)*	150
6	Aug. 11	G	First Grade	431	*Cladosporium cladosporioides (44), Cladosporium sphaerospermum (25), Penicillium (16), Aspergillus niger (6), Paecilomyces variotti (6), steril fungi (3)*	
12	Aug. 11	G	First Grade	1090	*Cladosporium cladosporioides (78), Penicillium (7), Alternaria alternata (4), Paecilomyces variotti (4), steril fungi (4), Aspergillus niger (2), Cuvularia (2)*	760
16	Aug. 12	2	Fifth Grade	317	*Cladosporium cladosporioides (60), Cladosporium sphaerospermum (12), Penicillium (12), Basidomycetes (8), Epicoccum nigrum (4), Paecilomyces variotti (4)*	
21	Aug. 12	2	Fifth Grade	254	*Cladosporium(70), Epicoccum nigrum (10), Penicillium (10), Fusarium graminerum (10)*	286

CFU/m^3 - Colony forming units per cubic meter of air.
Using the Positive-Hole Correction Table to adjust colony counts from a 400-holes impactor for the possibility of collecting multiple particles through a hole.

Table 6
Culturable airborne fungi, as percentage of total CFU, according to the location in the school
August 1999

Fungus name	Location in the school and ambient air (Number of samples)					
	Ambient air (n=4)		Ground and 2nd floor (n=4)		Basement (n=6)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Count of all species (CFU/m^3)	>30900		524	387	346	86.8
By species (%)						
Cladosporium cladosporium	95.0	0	63.0	14.7	67.7	13.6
Cladosporium sphaerosperum	1.5	1.0	9.3	11.9	2.5	6.1
Epicoccum migrum	1.8	0.5	3.5	4.8	1.3	2.2
Fusarium	0.5	0.6	2.5	5.0	0	0
Alternaria Alternata	0.005	0.01	1.0	2.0	4.0	4.7
Paecilomyces variotti	0.005	0.01	3.5	2.5	2.2	4.4
Paecilomyces Chatarumvariotti	0.005	0.01	0	0	0	0
Penicillium	0.003	0.01	11.2	3.8	2.0	2.3
Beauveria brongniartii	0.003	0.01	0	0	0	0
Basidomycetes	0.003	0.01	2.0	4.0	10.3	10.4
Pithomyces chartarum	0.5	0.6	0	0	2.8	4.4
Aspergillus orharaceus	0	0	0	0	0.7	1.6
Aspergillus versicolor	0	0	0	0	0.8	2.0
Aspergillus niger	0	0	2.0	2.8	0.3	0.8
Trichoderma harzianum	0	0	0	0	1.0	2.5
Syncephalastrum racemosum	0	0	0	0	0.3	0.8
Yeast	0	0	0	0	1.2	3.3
Cucularia	0	0	0.5	0.5	1.3	3.3

S.D.= Standard Deviation of the mean.
CFU/m^3 = Colony formng units per cubic meter of air.

Table 7
Culturable Airborne Bacteria
August 1999

Sample	Date	Floor	Location	CFU/m³	Bacteria (Percent of Sample)	Average CFU/m³
8	Aug. 11	--	Ambient	> 30900	*Brevibacillus brevis (39), Corynebacterium aquaticum (25), Microbacterium sp. (17), Streptomyces sp. (8), Micrococcus luteus (3), Alcaligenes faecalis (3), Bacillus (3), Micrococcus (3)*	
13	Aug. 11	--	Ambient	> 30900	*Pseudomonas pseudoalcaligenes (47), Streptomyces sp. (26), Corynebacterium aquaticum (16), Microbacterium sp. (17), Bacillus (11)*	> 30900
18	Aug. 12	--	Ambient	3200	*Micrococcus luteus (59), Corynebacterium aquaticum (19), Brevibacillus brevis (7), Coryneform bacteria (6), Brevundimonas vesicularis (4), Brevundimonas diminuta (3), Streptomyces sp. (1),*	
22	Aug. 12	--	Ambient	2710	*Brevibacillus brevis (31) Corynebacterium aquaticum (29), Burkholderia cepcia (17), Streptomyces sp. (12), Bacillus (7), Coryneform bacteria (5),*	2950
4	Aug. 11	B	Pre-school	418	*Micrococcus luteus (44), Streptomyces sp. (25), Coryneform bacteria (13), Staphylococcus coafulase negative (13), Bacillus (6)*	
11	Aug. 11	B	Pre-school	418	*Micrococcus luteus (63), Coryneform bacteria (26), Bacillus (4), Oerskovia Sp. (4), Micrococcus (4)*	418
1	Aug. 11	B	Speech Room	780	*Micrococcus luteus (53), Oerskovia Sp. (26), Bacillus subtilis (11), Burkholderia cepcia (5), Agrobacterium radiobacter (5)*	
10	Aug. 11	B	Speech Room	892	*Micrococcus luteus (50), Micrococcus (12), Burkholderia cepcia (12), Staphylococcus coafulase negative (9), Pseudomonas stutzeri (6), Bacillus (6), Coryneform bacteria (3), Nocardiopsis sp. (3)*	836

Table 7 (continued)
Culturable Airborne Bacteria
August 1999

Sample	Date	Floor	Location	CFU/m^3	Bacteria (Percent of Sample)	Average CFU/m^3
14	Aug. 12	B	Kindergarten	241	*Micrococcus luteus (75), Micrococcus roseus (6), Brevibacillus diminuta (6), Streptomyces sp. (6), Staphylococcus coafulase negative (6)*	
20	Aug. 12	B	Kindergarten	562	*Micrococcus luteus (55), Staphylococcus coafulase negative (14), Coryneform bacteria (9), Micrococcus roseus (9), Bacillus (5), Streptomyces sp. (5), Nocardiopsis sp. (5),*	402
6	Aug. 11	G	First Grade	710	*Micrococcus luteus (42), Oerskovia sp. (29), Coryneform bacteria (13), Bacillus (8), Streptomyces sp. (4), Micrococcus (4)*	
12	Aug. 11	G	First Grade	643	*Micrococcus luteus (70), Coryneform bacteria (13), Bacillus (9), Staphylococcus coafulase negative (4), Enterobacter agglomerans (4)*	677
16	Aug. 12	2	Fifth Grade	342	*Micrococcus luteus (69), Streptomyces sp. (23), Coryneform bacteria (8)*	
21	Aug. 12	2	Fifth Grade	230	*Micrococcus luteus (50), Coryneform bacteria (13), Bacillus (13), Micrococcus (13), Staphylococcus coafulase negative (6), Nocardiopsis sp. (6)*	286

CFU/m^3 - Colony forming units per cubic meter of air.
Using the Positive-Hole Correction Table to adjust colony counts from a 400-holes impactor for the possibility of collecting multiple particles through a hole.

Table 8
Culturable airborne bacteria, as percentage of total CFU, according to the location in the school
August 1999

Bacterial species	Location in the school and ambient air (Number of samples)					
	Ambient air (n=4)		Ground and 2nd floor (n=4)		Basement (n=6)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Count of all species (CFU/m^3)	>16700	NA	552	245	481	86.8
By species (%)						
Brevibacillus brevis	19.3	18.7	0	0	0	0
Corynebacterium aquaticum	22.3	5.9	0	0	0	0
Microbacterium sp	8.5	9.8	0	0	0	0
Streptomyces sp	11.8	10.5	6.0	9.7	6.8	11.0
Micrococcus luteus	15.5	29.0	56.7	10.9	57.8	14.0
Alcaligenes faecalis	0.8	1.5	0	0	0	0
Bacillus	5.3	4.8	3.5	2.8	7.5	5.5
Micrococcus	0.8	1.5	2.7	4.8	4.3	6.1
Pseud. pseudoalcaligenesis	11.8	23.5	0	0	0	0
Coryneform bacteria	2.8	3.2	8.5	10.0	11.8	2.5
Brevundimonas vesicularis	1.0	2.0	0	0	0	0
Brevundimonas diminuta	0.8	1.5	1.0	2.5	0	0
Burkholderia cepcia	4.3	8.5	2.8	4.9	0	0
Staphylococcus coafulase	0	0	7.0	6.1	2.5	3.0
Oerskovia sp	0	0	5.0	10.4	7.3	14.5
Bacillus subtilis	0	0	1.8	4.5	0	0
Agrobacterium radiobacter	0	0	0.8	2.0	0	0
Pseudomonas stutzeri	0	0	1.0	2.5	0	0
Nocardiopsis	0	0	1.3	2.2	1.5	3.0
Micrococcus roseus	0	0	2.5	4.0	0	0
Enterobacteria agglomerans	0	0	0	0	1.0	2.0

S.D.= Standard Deviation of the mean. NA=not availlable.
CFU/m^3 = Colony forming units per cubic meter of air.

Table 9
Microbial Volatile Organic Compounds[1]
August 1999

Location	3-methyl-1-butanol	2-hexanone	2-heptanone	1-octan-3-ol	3-octanol	Total
Ambient	ND	ND	ND	ND	ND	ND
Fifth Grade, 2nd Floor	ND	198	526	ND	ND	724
First Grade, Ground Floor	ND	648	1228	ND	ND	1,876
Pre-School, Basement	123	174	350	56	97	799
Kindergarten, Basement	177	178	417	56	215	1,041
Speech Room, Basement	ND	334	575	84	145	1,138

ND - non detectable.
[1]ng/m^3 - nanograms per cubic meter of air

Table 10
Carbon Dioxide Concentrations from
Short Term Air Samples
June 1999

Location	Concentration (ppm)	Temperature (^{0}F)	Relative Humidity (%)	Room Occupants	Average CO_2 Concentration (ppm)
AMBIENT					
Outside Air Intake	450	80	58	0	
Outside Speech Room	450	75	70	0	
Outside Kitchen	400	80	63	0	433
BASEMENT					
Speech Room	750	74	57	1	
Preschool	1150	73	51	3	
Kindergarten	1200	76	53	49	
Kindergarten	900	77	50	0	
Kindergarten	1000	76	49	1	
Storage Room	1100	76	49	0	1020
GROUND					
Gym	800	78	50	17	
First Grade	1350	75	44	0*	
First Grade	1000	77	49	15	
Cateteria	950	81	51	81	
Kitchen	700	82	51	3 - Exhaust fans on	
First Grade	700	78	48	0	
Hall - by Cafeteria	950	78	51	0	921
FIRST					
Library	750	82	42	5	
Teachers Break Room	850	75	43	3	

Table 10 (continued)
Carbon Dioxide Concentrations from
Short Term Air Samples
June 1999

Location	Concentration (ppm)	Temperature (^0F)	Relative Humidity (%)	Room Occupants	Average CO_2 Concentration (ppm)
FIRST (Continued)					
Hallway by Office	850	78	48	0	
Office	650	75	43	1	
Second Grade	850	77	52	0	
Third Grade	1150	78	52	16	
Third Grade	1300	77	51	21	
Photocopy Room	650	74	44	1	
Music Room	1200	77	49	22	
Second Grade	1050	75	48	20	
Second Grade	900	78	48	1	
Second Grade	1200	78	48	20	
Nurses Station	750	78	50	0	934
SECOND					
Hallway	850	76	51	0	
Stairwell	950	77	56	0	
Fourth Grade	850	80	53	16	
Fourth Grade	850	80	51	8	
Special Services	800	75	55	6	
Special Services	950	76	44	6	
Math	850	73	48	2	
fifth Grade	700	79	56	16	
Reading room	950	75	48	0	
Fifth Grade	1100	77	42	18	
Fourth Grade	800	74	40	0	
Reading Room	800	72	45	0	871

*Students left for lunch just prior to sampling; a count was not obtained
ppm - Parts per million parts air by volume
School in session

Table 11
Mean Carbon Dioxide Concentrations from Short Term Air Samples

Location	N	Mean CO_2 (ppm)	S.D.
BASEMENT			
School in Session	6	1020	169
School out Session	9	511	70
GROUND			
School in Session	7	921	225
School out Session	6	475	27
FIRST			
School in Session	13	935	221
School out Session	0	-	-
SECOND			
School in Session	12	871	103
School out Session	3	483	104
AMBIENT			
School in Session	3	433	29
School out Session	3	383	29

N - Number of Samples, ppm - parts per million parts air, S.D. - Standard deviation
School in session samples collected in June 1999 and school out session samples collected in August 1999

Table 12
Time-Weighted Carbon Dioxide Concentrations
Long Term Samples - School in Session
June 1999

Location	Date	Sampling Time (hr)	CO_2 (ppm)
AMBIENT			
By Outside Air Intake	06-02-99	4	440
BASEMENT			
Preschool	06-02-99	4.3	1210
Speech Room	06-02-99	4.3	930
GROUND FLOOR			
First Grade	06-02-99	4.3	1040
FIRST FLOOR			
Library	06-02-99	4.4	940
SECOND FLOOR			
Fifth Grade	06-02-99	4.0	1110

ppm - parts per mission parts air by volume.

Table 13

Prevalence (%) of symptoms, according to school area. Data from a survey done in May 1999 (N=33)

Respiratory Symptom	**Basement**		**1st Floor**		**2nd Floor**		**Total**	
	%	Cases[a] /Total[b]	%	Cases/Total	%	Cases/Total	%	Cases/Total
Cough	44	(4/9)	35.7	(5/14)	20.0	(2/10)	33.3	11/33
Phlegm	33	(3/9)	21.4	(3/14)	10.0	(1/10)	21.2	7/33
Wheezing last 12 months	89	(8/9)	46.2	(6/13)	30.0	(3/10)	53.1	17/32
Shortness of breath	89	(8/9)	42.9	(6/14)	10.0	(1/10)	45.5	15/33
Chest tightness in last 12 months	33	(3/9)	42.9	(6/14)	20.0	(2/10)	33.3	11/33
Medication for breathing problem	67	(6/9)	7.1	(1/14)	30.0	(3/10)	30.3	10/33
At school - stuffy/ runny nose	67	(6/9)	50.0	(7/14)	60.0	(6/10)	57.6	19/33
At school - irritation of eyes	67	(6/9)	50.0	(7/14)	44.4	(4/9)	51.5	17/33
At school - irritation of throat	71	(5/7)	76.9	(10/13)	50.0	(5/10)	66.7	20/30
At school - headache	78	(7/9)	64.3	(9/14)	60.0	(6/10)	66.7	22/33
At school - dizziness	71	(5/7)	35.7	(5/14)	33.3	(3/9)	43.3	13/30
At school - mental confusion	37	(3/8)	7.1	(1/14)	25.0	(2/8)	20.0	6/30
Since at school - Attacks of bronchitis	78	(7/9)	64.3	(9/14)	50.0	(5/10)	63.6	21/33
Since at school - Hay fever, allergies	67	(6/9)	57.1	(8/14)	70.0	(7/10)	63.6	21/33
Since at school - Sinus trouble	78	(7/9)	78.6	(11/14)	80.0	(8/10)	78.8	26/33
Smoking Current	22	(2/9)	7.1	(1/14)	0.0	(0/10)	9.1	3/33
Former	33	(3/9)	7.1	(1/14)	0.0	(0/10)	12.1	4/33
Never	44	(4/9)	85.7	(12/14)	100.0	(10/10)	78.8	26/33
Asthma	44	(4/9)	7.1	(1/14)	10.0	(1/10)	18.2	6/33

[a] Cases= subjects who complained of the symptoms.
[b] Total = the total number of subjects who answered the question.

Table 14
Prevalence (%) of asthma-like respiratory symptoms, according to school area. Data from a survey done in August 1999 (N=25)

Respiratory Symptom	Basement (n=9)		1st Floor (n=9)		2nd Floor (n=7)		Total (n=25)	
	%	N	%	N	%	N	%	N
Cough	0	0	0	0	0	0	0	0
Phlegm	0	0	0	0	14.3	1	4.0	1
Wheezing	11.1	1	11.1	1	0	0	8.0	2
Difficulty breathing	0	0	11.1	1	0	0	4.0	1
Chest tightness	0	0	22.2	2	0	0	8.0	2
Medication for breathing	22.2	2	11.1	1	42.9	3	24.0	6
Asthma	11.1	1	11.1	1	14.3	1	12.0	3

Table 15
Prevalence (%) of symptoms, according to school area. Data from a survey done in February 2000

Respiratory Symptom	Basement		1st Floor		2nd Floor		Total	
	%	Cases[a] /Total[b]	%	Cases/Total	%	Cases/Total	%	Cases/Total
Cough	40.0	4/10	8.3	1/12	0	0/10	15.6	5/32
Phlegm	25.0	2/8	8.3	1/12	0	0/10	10.0	3/30
Wheezing	20.0	2/10	8.3	1/12	0	0/10	9.4	3/32
Difficulty breathing	30.0	3/10	33.3	4/12	0	0/10	21.9	7/32
Chest tightness	20.0	2/10	33.3	4/12	0	0/10	18.8	6/32
Medication for breathing	33.3	3/9	8.3	1/12	10.0	1/10	16.1	5/31
At school - stuffy/runny nose	66.7	6/9	33.3	4/12	50.0	5/10	48.4	15/31
At school - irritation of eyes	33.3	3/9	50.0	6/12	22.2	2/9	36.7	11/30
At school - irritation of throat	50.0	5/10	33.3	4/12	33.3	3/9	38.7	12/31
Asthma	10.0	1/10	8.3	1/12	10.0	1/10	9.4	3/32

[a] Cases= subjects who complained of the symptoms.
[b] Total = the total number of subjects who answered the question.

Table 16

Results from serial lung function testing of FEV_1 and PEFR done on eight employees who reported asthma-like respiratory symptoms. Means for 7 weekdays and 4 weekend days are shown for five testing times during the day. Pairwise t-test compares mean differences across all individuals between weekdays and weekends. No statistically significant differences were found. Data from serial lung function testing done from May 27th to June 6th, 1999.

Lung function tests	Period when tests done	Time period during the day (N=8), mean (Standard Error)				
		Upon waking	Mid-morning	After lunch	Early evening	Late evening
FEV_1	Weekdays (7days)	2.34 (0.14)	2.43 (0.13)	2.43 (0.14)	2.39 (0.14)	2.41 (0.15)
	Weekends (4 days)	2.36 (0.14)	2.37 (0.15)	2.43 (0.14)	2.42 (0.15)	2.39 (0.16)
	Pairwise T-test comparison (N=8)	Diff[a] =-0.02 P[b] = 0.28	Diff=0.01 P= 0.61	Diff=0.001 P= 0.91	Diff=-0.03 P= 0.16	Diff=-0.04 P= 0.41
PEFR	Weekdays (7 days)	5.56 (0.28)	5.85 (0.28)	5.85 (0.29)	5.86 (0.30)	5.77 (0.29)
	Weekends (4 days)	5.50 (0.29)	5.29 (0.38)	5.73 (0.29)	5.80 (0.35)	5.62 (0.30)
	Pairwise T-test comparison (N=8)	Diff=0.05 P= 0.22	Diff=0.40 P=0.08	Diff=0.12 P=0.12	Diff=0.06 P=0.58	Diff=-0.05 P=0.73

[a] Diff= Pairwise t-test compares mean differences across all individuals between weekdays and weekends lung function values.
[b] P= probability value for the difference being equal to zero.

APPENDIX I - EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the 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, however, important to note that not all workers will be protected from adverse health effects even though 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 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 sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs), (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®), and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs). [NIOSH 1992, ACGIH 2001, CFR 2001]. NIOSH encourages employers to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard.

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 (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

MICROBIAL CONTAMINANTS

There are no occupational exposure criteria for airborne fungi, bacteria, or endotoxin. However, a recommended endotoxin exposure limit of 50 endotoxin units (EU)/m^3 based on inhalable dust sampling has recently been adopted in the Netherlands. This limit was established as about half of the 90 EU/m^3 level that induces measurable airways obstruction [Dutch Expert Committee 1998]. Insufficient health data exist to recommend specific limits for fungi, bacteria, or endotoxin concentrations in school building air [ACGIH 1999].

MEDICAL CRITERIA

Because the adult school occupants reported asthma-like respiratory symptoms in the telephone interview and on the HHE request, the medical examination included a questionnaire which was designed to establish the frequency of asthma-like symptoms. The serial peak flow testing was done to establish whether the symptoms were associated with lung function variation that could be related to the school indoor air environment exposure.

Spirometry was performed using a dry rolling-seal spirometer interfaced to a dedicated computer. All values were corrected to BTPS (body temperature, ambient pressure saturated with water vapor). The largest forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were selected for the analysis. Testing procedures conformed to the American Thoracic Society (ATS, 1995) recommendations. Predicted values were calculated using the Knudson et al. (1983) reference equations. To identify employees with abnormal spirometry pattern, the 95^{th} percentile lower limit of normal (LLN) values were used as cutoff points (ATS, 1991).

Obstructive pattern is diagnosed when the observed ratio of FEV_1/FVC% is below the LLN.

Restriction is diagnosed when the observed FVC is below the LLN; and FEV_1/FVC% is above the LLN.

Criteria for the interpretation of the level of severity for obstruction and restriction, as assessed by spirometry, are based on the NIOSH classification scheme as follows:

Mild obstruction is diagnosed when FEV_1/FVC x 100 is within the range 60-80%.
Moderate obstruction is diagnosed when FEV_1/FVC x 100 is within the range 50 - 65%.
Severe obstruction is diagnosed when FEV_1/FVC x 100 is less than 50%.

References:

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