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J.M. GRASSE ELEMENTARY SCHOOL
SELLERSVILLE, PENNSYLVANIA

NIOSH INVESTIGATOR:
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SUMMARY

On May 29, 1990, a bargaining unit representing employees of J.M. Grasse Elementary School requested the National Institute for Occupational Safety and Health (NIOSH) to evaluate this school's indoor environmental quality (IEQ) in response to some staff members' reports of upper respiratory problems suspected to be related to working there. NIOSH investigators conducted an environmental survey at the school on February 4 and 5, 1991.

The survey included an inspection of the relevant areas and heating, ventilation, and air conditioning (HVAC) equipment. Also, some of the HVAC systems were evaluated by measuring airborne carbon dioxide (CO_2) levels, which act as secondary indicators of ventilation effectiveness, and some were also evaluated by estimating their air flowrates. Air temperatures and relative humidities were measured to assess thermal comfort. The survey also included air sampling for possible chemical contaminants, and the collection of bulk-material samples for possible microbiological contaminants.

The estimated minimum outside-air-intake rates provided by two of the heating and ventilating units in the older wing of the building were insufficient. However, the units, predominately operating at maximum intake rates due to weather conditions, provided sufficient ventilation to most areas during the survey as indicated by the measured indoor CO_2 levels (which ranged from 425 to 1100 ppm). Also, most indoor relative humidities (which ranged from 18% to 37%) were below recommended ranges at the temperatures measured (which ranged from 68°F to 76°F), although this is not unusual during the heating season in buildings without artificial humidification. Also, an airborne concentration of an aliphatic hydrocarbon mixture (identified as a photocopier solution) greater than usually found in the non-industrial indoor environment was measured in the Main Office, but the concentration was well below recognized limits for occupational exposures. No microorganisms were detected in any of the bulk-material samples, including two of old, stained carpeting. However, one of the teachers had complained of symptoms after using an overhead cabinet where, reportedly, there was much accumulated dust.

Several factors, including insufficient ventilation rates, low relative humidities, airborne vapors of an aliphatic hydrocarbon mixture (identified as a photocopier solution), and accumulated dust in some storage locations, may impact upon the IEQ in this school building. However, the findings of this evaluation cannot substantiate any of these factors as causative in relation to the teachers' complaints and reported symptoms.

Keywords: SIC 8211 (elementary and secondary schools), indoor environmental quality (IEQ), ventilation rates, relative humidity, aliphatic hydrocarbons.

INTRODUCTION AND BACKGROUND

On May 29, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) of J.M. Grasse Elementary School from the Pennridge Education Association, which represents employees of this school. Association representatives requested NIOSH to evaluate the indoor environmental quality (IEQ) at the school in response to some staff members' reports of upper respiratory problems which they suspected to be related to working in the school building. An environmental survey was conducted at the school by NIOSH investigators on February 4 and 5, 1991.

The Pennridge School District had previously hired a consulting firm to investigate the environmental conditions at this school in response to the staff members' complaints. In 1989, this consulting firm conducted extensive air monitoring for a variety of possible chemical contaminants and for bioaerosols, evaluated ventilation effectiveness and the possibility of re-entrainment of boiler exhaust-stack emissions, conducted a medical and epidemiological evaluation of staff members, and investigated the possibility of contaminant substances reaching the school from nearby locations via such mechanisms as subsurface transport. They concluded that "based on the analytical data, known health effects information, examination of aerial photographs, investigations of the bedrock structure and type and prior land use, and (our) experience in conducting investigatory Indoor Air Quality Surveys (IAQS), it appears that the physiological expression of alleged symptoms experienced by the teachers is not related to any contaminants in Grasse. In summary, no cause-effect relationship could be identified."

FACILITY DESCRIPTION

The school building houses 23 classrooms, an auditorium, a library, a kitchen, a few offices, and a few other rooms used for ancillary and support functions. Each classroom's average occupancy is about 25 students and one teacher.

Most of the school building was built in 1963, except for a newer wing added in 1969. Most of the newer wing is carpeted including the large, eight-classroom, open-style area at the south end of the wing. The carpeting in this area was installed when the wing was built, and has not been replaced since then. Room 22, located at the north end of the newer wing where it connects to the original structure, has newer carpeting.

HEATING, VENTILATION, AND AIR CONDITIONING DESCRIPTION

Heating, ventilation, and air conditioning (HVAC) of the classrooms and most other rooms in the facility are provided by "univents" located along these rooms' outside walls, under the windows. The windows may be opened to provide supplemental natural ventilation. The univents are small air-handling units (AHUs), each serving a single room. Two types of univents are found in the school. The original portion of the building is fitted with one type, which contains hot-water coils for heating the air; the hot water is supplied from an oil-fired boiler in the equipment room. These units cannot cool the air. The newer wing is equipped with the second univent type, which has electrical-resistance coils to heat the air and electric-powered mechanical refrigeration to cool the air.

Along with the appropriate type of coil(s), each univent has an air mover (fan) which operates continuously, replaceable air filters (which are not high-efficiency types), a set of supply-air (s.a.) diffusers along its top surface, return-air (r.a.) inlets along the floor and outside-air (o.a.) inlets in the outside wall under the windows, and an automatically variable damper to change the ratio of o.a. to r.a. Each unit is controlled by a pneumatically-powered thermostat mounted on the wall of the room it serves. When the thermostat calls for heat (or cooling), the appropriate coil is activated and the o.a./r.a. damper inside the unit moves to its minimum-o.a.-intake position. When the thermostat is "satisfied," the coil is deactivated and the o.a./r.a. damper inside the unit returns to its maximum-o.a.-intake position.

A small number of rooms in the facility (e.g., the restrooms, guidance office, and speech room) are not served by univents. They are served only by exhaust fans.

EVALUATION CRITERIA

NIOSH investigators have completed over 1100 investigations of the occupational indoor environment in a wide variety of non-industrial settings. The majority of these investigations have been conducted since 1979.

The symptoms and health complaints reported to NIOSH by building occupants have been diverse and usually not suggestive of any particular medical diagnosis or readily associated with a causative agent. A typical spectrum of symptoms has included headaches, unusual fatigue, varying degrees of itching or burning eyes, irritations of the skin, nasal congestion, dry or irritated throats and other respiratory irritations. Typically, the workplace environment has been implicated because workers report that their symptoms lessen or resolve when they leave the building.

A number of published studies have reported high prevalences of symptoms among occupants of office buildings.[1,2,3,4,5] Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[6,7] Among these factors are imprecisely defined characteristics of heating, ventilating, and air-conditioning (HVAC) systems, cumulative effects of exposure to low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.[8,9,10,11,12,13] Indoor environmental pollutants can arise from either outdoor sources or indoor sources.[14]

There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related than any measured indoor contaminant or condition to the occurrence of symptoms.[15,16,17] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[17,18,19,20]

Less often, an illness may be found to be specifically related to something in the building environment. Some examples of potentially building-related illnesses are allergic rhinitis, allergic asthma, hypersensitivity pneumonitis, Legionnaires' disease, Pontiac fever, carbon monoxide poisoning, and reaction to boiler corrosion inhibitors. The first three conditions can be caused by various microorganisms or other organic material. Legionnaires' disease and Pontiac fever are caused by *Legionella* bacteria. Sources of carbon monoxide include vehicle-engine exhaust emissions and inadequately ventilated kerosene heaters or other fuel-burning appliances. Exposure to boiler additives can occur if boiler steam is used for humidification or is released by accident.

Problems NIOSH investigators have found in the non-industrial indoor environment mirror those discussed in the preceding three paragraphs, and have included poor air quality due to ventilation system deficiencies, overcrowding, volatile organic chemicals (from building materials and office furnishings, machines, and other contents), tobacco smoke, microbiological contamination (of HVAC systems, old carpeting, ceiling tiles, etc.), and outside air pollutants; comfort problems due to improper temperature and relative humidity conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job-related psychosocial stressors. In most cases, however, these problems could not be directly linked to the reported health effects.

Standards for exposures to chemical substances and other agents specifically for the non-industrial indoor environment do not exist. NIOSH, the Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards or recommended limits for occupational exposures.[21,22,23] With few exceptions, airborne pollutant concentrations observed in the office work environment fall well below these published occupational standards or recommended exposure limits. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended building ventilation design criteria and thermal comfort guidelines.[24,25] The ACGIH has also developed a manual of guidelines for approaching investigations of building-related complaints that might be caused by airborne living organisms or their effluents.[26]

Measurement of indoor environmental contaminants has rarely proved to be helpful in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proved relationship between a contaminant and a building-related illness. The usual low-level concentrations of particles and variable mixtures of organic materials found are troublesome to interpret. However, measuring ventilation and thermal-comfort parameters is often useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems. The bases for the specific measurements made in this investigation are described in the following subsections.

VENTILATION RATES

ASHRAE™ Standard 62–1989, "Ventilation for Acceptable Indoor Air Quality," generally specifies an outside-air (o.a.) intake rate of 15 ft^3/min (cubic feet per minute, or cfm) per person for classrooms.[24] This standard also specifies that, for HVAC systems which have variable air flowrates, provision must be made to supply o.a. at a rate adequate to maintain acceptable indoor air quality in the occupied spaces. For systems such as those at J.M. Grasse Elementary which have automatically variable o.a.-intake rates, the most certain way to fulfill this requirement is to ensure that the minimum o.a.-intake rate meets or exceeds the ASHRAE specification of 15 cfm/person.

Carbon dioxide (CO_2) is a normal constituent of exhaled breath; measurement of CO_2 concentrations can be used as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. Indoor-air CO_2 concentrations are normally higher than the generally constant ambient-air CO_2 concentration, which ranges from 300 to 350 parts per million (ppm). When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected.[24] Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased.

TEMPERATURE AND RELATIVE HUMIDITY

The perception of comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures. Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. ANSI/ASHRAE Standard 55–1981 (see Figure) specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[25] ASHRAE further recommends maintaining relative humidities between 30% and 60% "to minimize the growth of allergenic or pathogenic organisms."[24]

EVALUATION METHODS

The environmental survey included an inspection of the relevant areas of the facility and the HVAC systems serving those areas, discussions with the school's custodian about these items, and measurements of some of these HVAC systems' airflows. The ventilation effectiveness of these HVAC systems was also evaluated by measuring airborne CO_2 concentrations, which act as a secondary indicator of that parameter. Air temperatures and relative humidities were measured to assess thermal comfort. The survey also included air sampling for possible chemical contaminants, and the collection of bulk-material samples for possible microbiological contaminants.

Bulk-material samples were collected from four locations in the school building that staff members had alleged to be the sites of water-stained, or otherwise suspect, materials. These were analyzed for microorganisms, by culturing followed by microscopic examination.

EVALUATION OF HVAC SYSTEMS

Volumetric airflow rates were estimated using an Alnor thermo-anemometer to measure face air velocities at representative numbers of locations across the s.a.-diffuser, o.a.-intake, and r.a.-inlet openings, and by measuring the dimensions of the openings.

The ventilation effectiveness of several HVAC systems was also evaluated by measuring, as a secondary indicator, airborne CO_2 concentrations using an electronic, direct-reading GasTech RI411A CO_2 Meter with infrared detection; simultaneous measurements were also made occasionally with the Dräger detector-tube system (specifically, a hand-held bellows pump and colorimetric, length-of-stain 0.01%/a CO_2 detector tubes were used). Temperatures and relative humidities were measured using an Environmental Tectonics Corporation Psychro-Dyne automatic psychrometer with two mercury-containing glass thermometers (one wet and one dry bulb).

AIR SAMPLING FOR CHEMICAL CONTAMINANTS

A total of 13 general-area air samples were collected and analyzed for possible chemical contaminants using several methods, the details of which are provided in Appendix A. Each sample was collected by using a battery-powered "low-flow" air-sampling pump to draw air, at a measured rate and for a measured period of time, through a collection medium appropriate for the specific method.

Samples were collected at four locations: (1) Classroom #22, since the requestors focussed some of their complaints on this room; (2) the Main Office, since the consultants had measured higher levels of hydrocarbons there than in other areas (including an unidentified hydrocarbon at the highest concentration of any compound that they quantified at the school); (3) Classroom #7, considered an "indoor background" location since complaints were not focussed on this room; and, (4) an "outdoor background" location east of the building near the playground. Background samples are important when evaluating potentially "trace" concentrations of contaminants, because they may illustrate differences in trace contaminants between the areas being investigated and the ambient background.

Sampling durations were approximately 7½ hours (hr), with sample collection during the entire school day on February 5, 1991, for all samples except one; for that sample, since it was collected and analyzed with the highly sensitive "thermal desorption" method (see Appendix A), a shorter collection duration (98 minutes) was used. It was collected in the Main Office during the morning of that day.

OBSERVATIONS AND FINDINGS

At the time of the survey, six of eight teachers working in the newer wing of the building reportedly believed they had been afflicted with too many upper-respiratory infections. One of the teachers had complained of symptoms after using an overhead cabinet which was reportedly quite dusty.

At the request of some of the teachers, the area above the ceiling in the newer wing was visually examined during the facility inspection. No potential problems were observed there. The interiors of the univents that were inspected were found to be acceptably clean and dry. Overall, the visual inspection of the facility revealed no potential health hazards, nor any apparent basis for the reported symptoms and complaints beyond what has been described here.

MICROBIOLOGICAL ANALYSES OF BULK-MATERIAL SAMPLES

No fungi (or bacteria) were detected in any of the four bulk-material samples collected in the school. These samples were small portions of the following materials: (1) an accumulation of material on a ceiling trap door, outside the mechanical equipment room (near the location of a reported former roof leak); (2) carpeting, which appeared stained from water or some other liquid, from outside the girls restroom in the newer wing; (3) water-stained carpeting from Room 15 near the univent (the condensate drain in this univent had reportedly clogged in the past, causing the condensate tray under the cooling coil to overflow and soak the carpeting near the unit; reportedly, this problem has occurred in the past in other rooms as well); and, (4) "new" ceiling material from the hallway outside the auditorium (near the location of a reported former roof leak). The analytical limits of detection for these samples ranged from 200 to 500 colony-forming units per gram of material (CFU/g). Although no microbials were detected in the bulk samples of carpeting, significant relationships have been reported in past studies between the presence of relatively old wall-to-wall carpeting in schools and reported IEQ complaints and symptoms.[27] Causative factors for this observed relationship, such as microbial contamination or other factors, were not identified.

VENTILATION RATES

Airflows were estimated for three univents, in Classrooms #22, #7, and #4, and for two exhaust-air inlets, in the Speech Room and the Guidance Counselor Office. For the heating and cooling unit in Classroom #22, with the outside-air/return-air (o.a./r.a) damper in the minimum-o.a. position, the following flowrates were estimated: o.a.-intake, 469 cfm; r.a., 448 cfm; s.a., 917 cfm. For the heating unit in Classroom #7, with the o.a./r.a damper in the minimum-o.a. position, the o.a.-intake rate was estimated to be 146 cfm. For the heating unit in Classroom #4, with the o.a./r.a damper in the minimum-o.a. position, the following flowrates were estimated: o.a.-intake, 154 cfm; r.a., 476 cfm; s.a., 630 cfm. Under ASHRAE™ Standard 62–1989, for 25 students and a teacher, the recommended o.a.-delivery rate is 390 cfm. These results suggest that the combination heating and cooling units provide o.a. at sufficient rates even during minimum-o.a.-intake operating conditions. However, the minimum rates provided by the older heating units are apparently less than half the recommended rate.

Since the o.a.-intake rates on the older heating units are at their minimums only during heating cycles, it is possible that these units chronically (on the average throughout a given day) deliver o.a. at insufficient rates during extremely cold weather when heating-cycle time periods are more frequent and longer. Some rooms alleged by teachers to have poor IEQ were served by the older units, but others were served by the newer combination units.

The exhaust-air flowrate from the Speech Room was estimated to be 500 cfm, and that from the Guidance Counselor Office was estimated to be 600 cfm. Since these rooms are not served by mechanical supply-air systems, the operation of their exhaust systems causes "transfer air" from nearby rooms to be drawn into these rooms via the hallway. Each of these rooms typically is occupied by two or fewer people, so o.a. should be delivered to each at an effective rate of 30 cfm. However, the proportion of the transfer air entering these rooms that can be considered as effectively "fresh" o.a. will vary depending upon how much excess o.a. (above minimum requirements) is being provided by the univents to the nearby rooms. This, in turn, varies due to the cycling of those univents. If most of the nearby rooms are not provided o.a. at sufficient rates during extreme cold weather, then these two rooms will not receive o.a. at sufficient "effective" rates.

Measured airborne CO_2 concentrations in the classrooms and Main Office during the NIOSH visit did not exceed 800 ppm (see Table), so levels were not considered elevated on the day of the survey. In fact, the levels fell during the day in some rooms. These findings are consistent with the above discussion regarding airflow rates, considering the measured outdoor temperatures on the day of the survey (see Table). Heating-cycle time periods may have been rather infrequent and short on that day, and likely became even less frequent as the outdoor temperatures rose during the day. Therefore, elevated CO_2 levels would not be expected, and declining levels would be expected.

Airborne CO_2 concentrations in the auditorium reached 1100 ppm following an assembly there. This level is considered slightly elevated, and inadequate o.a. exchange may be indicated.

TEMPERATURE AND RELATIVE HUMIDITY

All measured air temperatures but one (at 68°F) were within recommended ranges, while all measured relative humidities but two were below recommended ranges (see Table). It is unclear why the one measured temperature in Classroom #22 at the end of the school day was below the recommended range, although as outdoor temperatures rose through the day under partly sunny skies, the thermostat may have been lowered or the windows opened. The failure to meet relative humidity guidelines was caused, at least in part, by the dry outdoor conditions during much of the day of the survey. However, low indoor relative humidities are not unusual during the heating season in buildings without artificial humidification, such as this school, even when outdoor relative humidities are moderate. When cool outdoor air of a given humidity level is introduced to a warm indoor space, its relative humidity (percent of saturation) falls as its temperature rises (warm air can hold more moisture before becoming saturated). However, the moisture in exhaled breath and the evaporation of water used in the building introduce additional moisture, which helps to offset this effect. Although chronically low humidities may be a factor in the IEQ complaints at this school, there may be no practical solution available. Retrofitting a humidification system to an existing building may lead to problems with moisture condensation if the building's "envelope" and many of its other features were not designed or selected for a humidified structure. Condensation inside building materials (and elsewhere) may cause structural damage and microbial growth problems. Additionally, some types of humidification systems themselves can suffer from microbial growth problems.

AIRBORNE CHEMICAL CONTAMINANTS

Only one noteworthy finding resulted from the general-area air sampling for volatile organic compounds and aldehydes. This was the measurement of branched aliphatic hydrocarbons (primarily C_{10} to C_{12}) in the Main Office air at a concentration of 60 mg/m^3. While this level is well below even the most stringent industrial exposure criteria (which is the NIOSH Recommended Exposure Limit of 350 mg/m^3 for hydrocarbon mixtures of this type), it exceeds levels typically measured in the non-industrial indoor environment, such as those measured in Classrooms 22 and 7 (0.50 and 0.77 mg/m^3, respectively). The level outside the school was determined to be less than 0.08 mg/m^3.

The composition of the hydrocarbon mixture detected in the Main Office was very similar to certain photocopier toner solutions. A photocopier was located within several feet of the area air-sampling location in the Main Office during the NIOSH visit. These findings help to clarify some of the data generated by the consultants who had previously evaluated the indoor environment at the school. They measured higher levels of hydrocarbons in the Main Office than in other areas, including an unidentified hydrocarbon at a higher concentration than any of the other compounds that they quantified. If complaints about indoor air quality in the Main Office occur, it is possible that they are related to the presence of the hydrocarbon mixture detected. However, other areas of the building will not be affected.

The remaining results of the general-area air samples, which are briefly summarized in Appendix B, do not indicate the presence of any unusual chemical compounds in the air of the building. As is typical for indoor environments, traces of a number of compounds were detected qualitatively, in addition to the C_{10} to C_{12} aliphatic-hydrocarbon mixture. Quantitative analyses were performed for five of these. None of the measured concentrations are unusual for an indoor environment and, as is typically the case, they are well below all industrial evaluation criteria.

CONCLUSIONS

Several factors which may impact upon the IEQ in this school building have been identified in the previous section, and they are addressed with recommendations below. However, the findings of this evaluation cannot substantiate any of these factors as causative in relation to the teachers' complaints and reported symptoms.

RECOMMENDATIONS

1. Clean the accumulated dust in all overhead cabinets and other such locations.

2. Since significant relationships have been reported in past studies between the presence of relatively old wall-to-wall carpeting in schools and reported IEQ complaints and symptoms, removal of all old carpeting in this facility represents good practice despite the "negative" bulk sampling results. This type of sampling may miss contamination located near, but not within, the sampling location selected.

3. Periodically, the condensate drains of all univents with cooling coils (air conditioning) should be cleaned to prevent clogging.

4. Upgrade the replaceable air filters in the univents to higher-efficiency types if compatible higher-efficiency replacements are available. ASHRAE recommends that filter efficiency (not "arrestance") be at least 35 to 60%, and 85% is often specified in modern buildings. A knowledgeable supplier should be consulted to assure that replacement filters are selected which are compatible with the existing hardware so that airflow rates are not adversely affected. The supplier's and/or manufacturer's recommendation for frequency of filter changes should be strictly followed. This improvement will not only help provide cleaner air to the occupied spaces, it will help vital parts of the AHUs, particularly the cooling coils, stay cleaner in the future, reducing periodic cleaning needs.

5. A mechanical firm with engineering capability should be retained to: (1) confirm the o.a.-intake-rate estimates reported above for both types of univents, using a flow-measuring instrument such as a "flowhood;" and, assuming the conclusions about the adequacy of the o.a.-intake rates do not change based upon the new measurements, (2) subsequently recommend appropriate modifications for the older classroom univent AHUs (and, if necessary to assure continued adequate heating capabilities, for the school's boiler) to increase their minimum o.a.-intake rates to 390 cfm in accordance with ASHRAE™ Standard 62-1989. This firm should also evaluate the auditorium's HVAC system to determine if it is adequate in regard to the provision of o.a., and make recommendations on how to upgrade the ventilation in the Speech Room and Guidance Counselor Office to provide appropriate o.a. delivery. In the interim, the doors into these rooms should have ventilation grilles or louvers to allow free air exchange with the hallway.

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2. Pennridge Education Association, Sellersville, Pennsylvania
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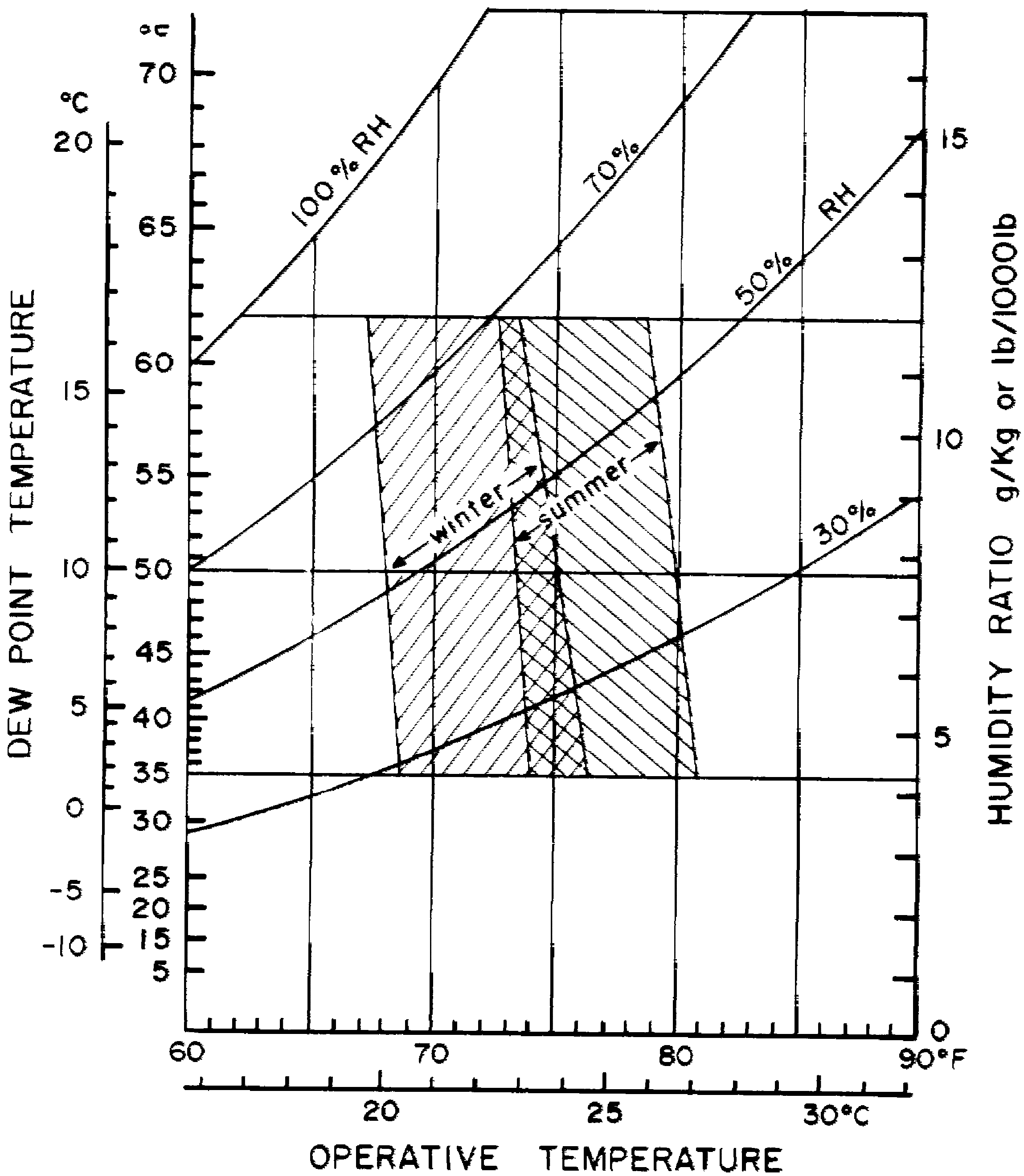
For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

HETA 90-287
John M. Grasse Elementary School
Sellersville, Pennsylvania

Figure. Thermal-comfort criteria, from ANSI/ASHRAE Standard 55–1981.



Acceptable ranges for persons, at light activity levels, wearing typical summer and winter clothing.

HETA 90-287
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Sellersville, Pennsylvania

5 February 1991

Table. Measured air temperatures, relative humidities, and carbon dioxide (CO_2) concentrations

Location	Time (military)	CO_2 Concentration (ppm)	Temperature (°F)	Relative Humidity (% Saturation)	Dew Point (°F)
Classroom #22	0900	800 (dt*: 800)	73	18%†#	28†#
	1210	--	74.3	22%†#	33†#
	1535	600	68‡	37%	41.6
Classroom #7	1020**	350	73	18%†#	28†#
	1135	425	73.6	18%†#	28†#
Auditorium	1000***	1100	74	23%†#	34†#
Main office	0845	725 (dt*: 700)	75	22%†#	33.7†#
	1110	600 (dt*: 650)	74.6	19%†#	30.4†#
	1415	525 (dt*: 800)	76	28%#	41.6#
Outdoor ambient	0910	375	57.0	23%	21
	1200	--	63	26%	28
	1530	325 (dt*: 250)	67	36%	39.4

* Reported CO_2 concentrations measured with GasTech meter, except for those labelled with "dt," which were measured with Dräger detector tubes.

** Before measurements collected, room was unoccupied for enough time to affect results.

*** Measurements collected immediately following a crowded assembly.

† Humidity below range specified in ASHRAE thermal-comfort criteria (specified minimum absolute humidity corresponds to 35°F dew point; see Figure).

Relative humidity below ASHRAE-recommended range of 30% to 60% intended "to minimize the growth of allergenic or pathogenic organisms."

‡ Temperature below winter range specified in ASHRAE thermal-comfort criteria (see Figure).

APPENDIX A

DETAILS OF AIR SAMPLING AND ANALYTICAL METHODS FOR POSSIBLE CHEMICAL CONTAMINANTS

Each air sample was collected for use with one of two complementary analytical purposes: (1) qualitative analysis to identify any organic compounds which may have been present in the air sampled; or, (2) subsequent quantitative determination of the airborne concentrations of any compounds qualitatively identified. To achieve these analytical purposes for a wide variety of organic compounds, including aldehydes, three types of collection media were used: (1) tubes packed with activated-charcoal adsorbent ("charcoal tubes") were used to collect samples for the qualitative and quantitative analyses of general volatile organic compounds (VOCs); (2) special adsorbent-containing tubes called thermal-desorption tubes (TD tubes) were used to collect samples for the qualitative identification (only) of general organic compounds; and, (3) special reagent-containing tubes were used to collect samples for qualitative and quantitative analyses of aldehydes.

CHARCOAL-TUBE samples for VOCs, whether for qualitative or quantitative analyses, were collected using an air-flow rate of 200 milliliters per minute (mL/min). The analyses of both types of these samples includes desorption with carbon disulfide followed by some type of gas chromatography (GC). The qualitative analysis requires GC with mass-spectrometry detection (MSD), while the quantitative determination may be accomplished, depending on the compound being measured, by GC with flame-ionization detection (FID), similar to NIOSH Methods 1500, 1501, and 1550,[1] by GC with nitrogen-phosphorus detection (NPD) or other appropriate detecti system.

TD TUBES called Carbotrap™ 300 Multi-bed Thermal Desorption Tubes were used, with an air-flow rate of 20 mL/min, to collect samples for the qualitative identification of general organic compounds. The analysis of these samples includes desorption by heating in a special oven, with the effluent fed directly to GC with MSD. This method is much more sensitive than the charcoal-tube method described above, and may be able to identify more substances. However, it is not quantitative, and only the quantitative charcoal-tube method is available for determination of the airborne concentrations of the compounds identified.

THE SPECIAL REAGENT TUBES used to collect samples for aldehydes, whether for qualitative or quantitative analyses, contain XAD-2 resin coated with (2-hydroxymethyl)piperidine (2-HMP). For both types of sample, an air-flow rate of 80 mL/min is used. Each variety of aldehyde present reacts with th 2-HMP to form its oxazolidine derivative. The qualitative aldehyde samples were collected and analyzed in accordance with NIOSH Method 2539.[1] A variet of sampling and analytical methods are available for the quantitative determination of aldehydes, depending upon which of these compounds are detected with the qualitative sampling. Two of these, NIOSH Methods 2538 and 2541, for acetaldehyde and formaldehyde, respectively, were used for th

HHE. For all three methods mentioned here, analysis includes desorption of the oxazolidine derivatives with toluene followed by GC with FID. For the qualitative analyses only, initial identification of any oxazolidine derivatives present is made by GC-FID, and this is followed by GC-MSD to confirm these initial identifications.

SAMPLING LOCATIONS BY SAMPLE TYPE were as follows:

- Classroom #22: Two charcoal-tube samples (one for qualitative and one for quantitative analysis) and two aldehyde reagent-tube samples (for similar purposes).

- Main Office: Same as for Classroom #22. Additionally, one TD-tube sample.

- Indoor background location (Classroom #7): One charcoal-tube sample an one aldehyde reagent-tube sample, for the quantitative analysis of any compounds qualitatively identified in the above two locations.

- Outdoor background location: Same as for the indoor background locatio

REFERENCE

1. Eller PM, ed. [1984-90]. NIOSH manual of analytical methods, Third edition with supplements. Cincinnati, OH: U.S. Department of Healt and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 84-100.

APPENDIX B

SUMMARY OF RESULTS -- AIR SAMPLING FOR CHEMICAL CONTAMINANTS

Only one noteworthy finding resulted from the general-area air sampling for volatile organic compounds and aldehydes. This was the measurement of branched aliphatic hydrocarbons (primarily C_{10} to C_{12}) in the Main Office air which was discussed fully in the text.

The remaining results of the general-area air samples do not indicate the presence of any unusual chemical compounds in the air of the building. As typical for indoor environments, traces of a number of compounds were detec qualitatively, in addition to the C_{10} to C_{12} aliphatic-hydrocarbon mixture. Specifically, formaldehyde, acetaldehyde, acetone, ethanol, isopropanol, hexane and heptane isomers, 1,1,1–trichloroethane, benzene, acetic acid, trichloroethylene, toluene, xylene isomers, and a siloxane compound were al identified in the school's air.

Quantitative analyses were performed for five compounds, in addition to the aliphatic-hydrocarbon mixture, selected from among the relatively more prominent of the detected compounds. These compounds were 1,1,1–trichloroethane, trichloroethylene, toluene, acetaldehyde, and formaldehyde. Airborne concentrations of the first four of these were too to be quantified (less than 0.002 parts per million [ppm] for the first thr less than 0.003 ppm for acetaldehyde) in all locations except the Main Offi there, levels of 1,1,1–trichloroethane and trichloroethylene were high enou to be quantified (at 0.0099 ppm and 0.015 ppm, respectively). The highest level of formaldehyde was found in the outdoor background location; the highest indoor level was estimated to be 0.005 ppm, in Classroom #22. None these measured concentrations are unusual for an indoor environment and, as typically the case, they are well below all industrial evaluation criteria.

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