BUILDING FACTORS ASSOCIATED WITH SCHOOL INDOOR AIR QUALITY PROBLEMS: A PERSPECTIVE

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ABSTRACT

National Institute for Occupational Safety and Health (NIOSH) Health Hazard Evaluation Reports (HHER) involving schools provide a perspective on the building-related factors associated with indoor air quality complaints. Generally, the school HHERs reflected multiple building factors associated with the complaints. The most common building factors cited by NIOSH investigators were: insufficient outside air supplied to occupied spaces; water leaks in the building shell; inadequate source exhaust; poor air distribution or balance; and poor heating, ventilation, and air conditioning (HVAC) system maintenance.

INTRODUCTION

NIOSH has conducted thousands of field investigations of possible health hazards in the workplace. The field investigations are summarized in HHERs. About 98 HHERs address investigations about indoor air quality in educational facilities. The HHERs range from very brief reports in the form of correspondence, especially in earlier years, to extensive documentation of investigations.

In a forthcoming report, we present the relatively standardized structure and methodology of the NIOSH HHER as a framework to assess and compare the school indoor air quality papers found in the peer-reviewed literature as well as California school investigative reports. The school HHERs provide a somewhat more national perspective of indoor air quality complaints and issues across 31 states although half of the 77 of the HHERs reviewed for this report were from three states: Pennsylvania, Ohio, and West Virginia. The HHERs reviewed in this paper were conducted from 1981 to 1994.

METHODS

A total of 88 NIOSH HHER involving educational facilities were identified and obtained. Ten additional NIOSH school HHERs identified through the literature and data base searches were not obtained in time to be included in this report. The 88 NIOSH school HHERs included 11 that involved buildings that did not have kindergarten though twelfth grade (K - 12) classrooms (e.g., kitchen facility, administrative center, University hospital) and thus, these 11 HHERs were not included in this review.

RESULTS

Ideally, every building investigation would identify a specific pollutant or physical agent causing the indoor environmental complaints or occupant health symptoms. Often, however, building investigations identify certain building characteristics that are likely to be associated

with the complaints or symptoms. These generally fall into three major categories, which are not mutually exclusive: 1) ventilation system-related problems; 2) pollutant source-related problems; and 3) building or HVAC renovation-related problems.

Forty-nine of 77 school HHERs listed one or more building characteristics associated with the symptoms reported by occupants in complaint schools. The 28 remaining HHERs either listed no building factor or only listed a specific pollutant such as formaldehyde or PCBs which was investigated. Figure 1 presents a graphical representation of the percentages of the NIOSH HHERs in which various building factors were cited.

Ventilation System-Related Building Problems

Insufficient Outside Air to Occupied Spaces As reflected in Figure 1, the most common building factors associated with indoor environmental complaints were related to the ventilation system, with insufficient outdoor air (OA) being supplied to the occupied space the most commonly cited problem (84%). Examples of ventilation system problems in which insufficient OA to occupied spaces was identified as a problems include a school in which carbon dioxide (CO_2) was as high as 4375 ppm; a speech room and counselor's office that depended on transfer air from adjacent rooms via the hall; a school building under negative pressure, with no OA supplies and consequent mold damage; a building with a ventilation system that would shut off OA if thermostats were mis-set; variable air volume system fans operating at their maximum settings; and a building with HVAC controls that allowed OA delivery only from 7:30 AM to 2:30 PM. Other HVAC system control problems identified included broken thermostats and air intake dampers in a closed position.

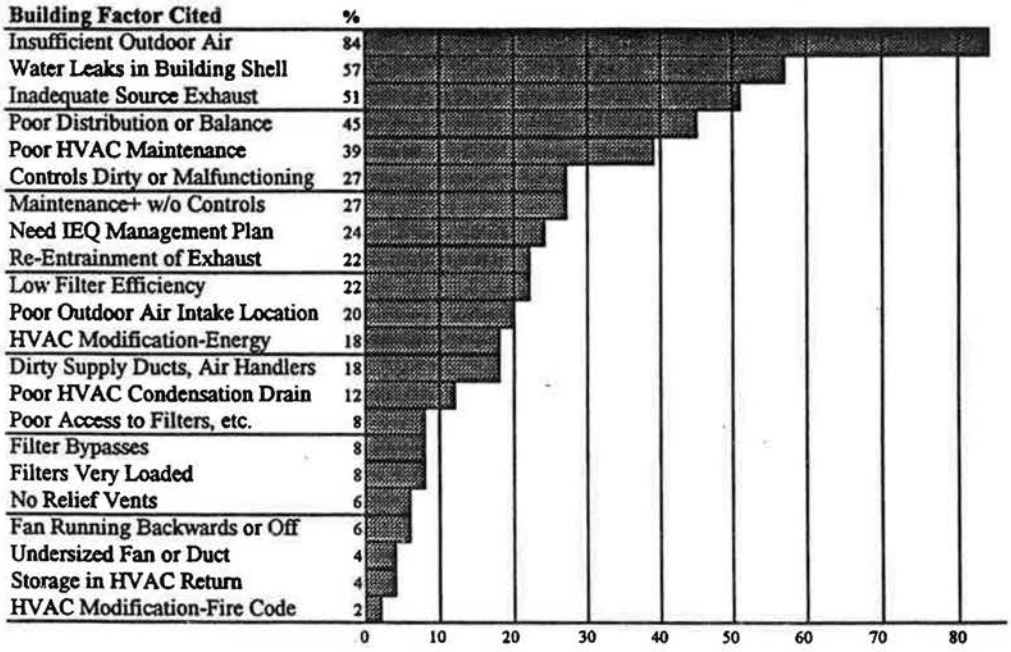

Figure 1 Building Factors Associated with IAQ Problem in Percent, 49 NIOSH School Health Hazard Evaluation Reports, 1981 - 1994

Poor Air Distribution or Balance Problems due to poor distribution of ventilation air were also identified. These included a school in which one classroom was found to have a CO_2 concentration of 2000 while the others classrooms had levels below 1000 ppm; a school originally built with open instructional areas that was altered with the installation of doors which resulted in poor air distribution; and a school with controls that were improperly set with minimum supply air flows that varied among classrooms.

In the NIOSH HHERs, problems due to poor design of HVAC systems were frequently cited. These included systems in which outside air dampers were not accessible and indicators that did not clearly show damper positions; insulation on the outside of a main air handling unit that blocked access to the coil, heat exchangers that were accessible only by leaning across pipes, access to filters blocked by pipes and ducts, and heat exchangers accessible for servicing only through removal of the entire fan assemblies.

In some cases, the building and its HVAC system may be operated in a way that results in a ventilation problem although the system was properly designed and installed. For example, NIOSH investigator Donovan (1) reported that a school's HVAC system was operated in the off mode for 10 minutes every half hour in order to save energy and thus, occupied classrooms and offices were denied any outside air one-third of the time. Kiefer, *et al.* (2) reported a case in which the HVAC system was cycled off between 4:00 PM and 7:00 AM for energy conservation purposes in a windowless Florida elementary school which resulted in extensive mold growth. Static pressure relief dampers were clamped shut or heavily weighted shut, perhaps to save energy, in a school with formaldehyde concerns.

Three NIOSH school HHERs also revealed ventilation problems associated with fans running backwards or not operating at all. Burr, *et al.* (3) found that a fan running backwards inside a heat pump that served a group of classrooms. This resulted in classroom CO_2 concentrations in excess of 2500 ppm. This problem was also reported for a New Mexico high school that was the subject of teacher complaints about inadequate ventilation. In an elementary school that had been the subject of five previous comprehensive environmental and ventilation assessments, Kaiser (4) found that motors in three of 13 roof-top air handlers were burnt out.

Pollutant Source-Related Problems

Poor HVAC System Maintenance In a substantial number of problem schools, poor HVAC maintenance led to contamination of the system and the HVAC system became a source of air pollution. Nineteen of the 49 (39%) of the NIOSH school HHERs cited poor maintenance of the heating, ventilation and air condition system as a factor in indoor air quality problems. In one school, 15 years of no HVAC maintenance that resulted in dirty coils and microbial growth in all inspected air handling units in a windowless school. Filters on outside air intakes that were changed infrequently, maintenance staff not trained on the proper operation of mechanical systems, and inadequate manpower to maintain and repair over one hundred heat pumps were also cited in various HHERs as problems that led to the HVAC system becoming a source of pollutants.

In nine of the 49 (18%) NIOSH school HHERs, dirty supply ductwork or air handlers were cited as building-related factors associated with indoor air quality problems. Supply ducts in a West Virginia elementary school were found to be to be heavily loaded with dust and other debris. In a junior high school, the inside of air handlers were dusty, insect screens were in

need of cleaning, and the insulated duct liners were dirty. In addition, rain and snow had been sucked into the outdoor air intakes and damaged the fiberglass duct lining to such an extent that in-line heating coils had been nearly blocked on at least two occasions.

The NIOSH school HHERs reported a number of cases of indoor air quality problems that were associated with poor drainage of HVAC condensation including: condensation drain lines that ran uphill; drains without vents and trap depth that did not exceed the suction pressure of the fan; and roof top air handlers that drained condensation onto the roof top directly below OA intakes.

Only one NIOSH school investigator explicitly noted that air filters in ventilation systems were heavily loaded with dust. However, all NIOSH school on-site investigations occurred with the prior knowledge of school administrators and facilities staff and thus, it is possible that easy to correct deferred maintenance such as filter replacement may have taken place prior to the HVAC system evaluations. Eleven (22%) of the NIOSH school HHERs identified low air filter efficiency as a factor associated with indoor air problems. Nine of 28 NIOSH school HHERs since 1991 have recommended replacing filters with medium efficiency, pleated filters with efficiencies of at least 35 to 60% according to the dust spot test specified in ASHRAE 62-1989. Two other sets of NIOSH investigators emphasized that filters must be properly seated in the filter racks to prevent air from bypassing the filters.

In addition, four NIOSH school HHERs revealed indoor air quality problems associated with air filter bypasses. In one case, missing end caps on filter plenums resulted in build up of debris on coils, providing a substrate for bioaerosol growth as well as a source of bioaerosols for the occupied space. In another school, it was found that filters had not been maintained for 16 years and the coils were dirty.

Two NIOSH school HHERs cited inappropriate storage in the building's HVAC system as a possible cause of indoor air complaints. Housekeeping and maintenance products were stored in the return air access area of the HVAC system in a West Virginia junior high school. In the case of a Florida elementary school, chemicals were stored in a mechanical room.

Poor outside air (OA) intake locations that contributed to school indoor environmental problems were cited in ten NIOSH HHERs. Examples included idling school bus diesel exhaust sucked into the schools' OA intakes; OA intakes for roof top air handling units located near plumbing waste vents; OA intakes located next to a roof rubber membrane seam sealer which would emanate an odor as it heated up over the course of the day; and OA intakes located next to an air conditioning cooling tower.

Re-entrainment or backdrafting problems were reported in 11 school HHERs. These included schools in which boiler exhaust stack located in close proximity to the outside air intake; another in which the boiler exhaust was sucked into six classrooms served by a hall exhaust fan; and a school in which boiler exhaust was sucked via an underground utility tunnel through holes located beneath classrooms unit ventilators due to hallway exhaust fans.

Water Leaks in the Builsing Shell Water leaks were associated with indoor air quality problems in 28 of the 49 (57%) NIOSH school evaluations. The primary concern about water leaks is mold contamination. The cases included mold contamination of ceiling tile from a roof leak that occurred during reconstruction of the roof; numerous roof leaks and broken, missing,

and water stained ceiling tiles that existed for five years and that were so severe that classes were canceled; and mold and mildew associated with a chronically leaking roof in a windowless Florida school.

Inadequate Source Exhaust Half of the NIOSH school HHERs that identified building factors associated with indoor air quality problems cited inadequate spot exhaust of pollutant generating activities including a household-type bathroom exhaust fan that was the only means to vent combustion products when a kiln was fired and no exhaust ventilation for woodworking equipment in the industrial arts classroom; no local exhaust ventilation for photocopiers that used liquid toner that was a significant source of Volatile Organic Compounds; and an unvented flammable storage cabinet and the inappropriate use of particulate/charcoal filters ("Smoke-Eaters") instead of local exhausts for welding and a metal foundry furnace.

There is little mention of carpet associated with indoor environmental quality problems in the HHERs. In one NIOSH HHER, investigators recommended that carpet should be removed from areas where it is likely to be chronically exposed to stagnant water. Furthermore, they recommended that carpet shampooing should not be done when the carpet will remain wet over long periods due to inadequate ventilation or lack of heat, and chemicals should not be used as a long-term primary control strategy for control of mold.

Maintenance, Replacement or Renovation Activities Without Sufficient Control of Generated Airborne Pollutants

Thirteen of 49 (26%) NIOSH school HHERs reported indoor air quality problems associated with maintenance and replacement or other construction-related activity that was carried out without adequate control of pollutants that were generated by those activities. The NIOSH cases included: maintenance personnel that used a turpentine solution to remove gum from carpet; complaints about burning eyes, headaches, nausea, and respiratory problems following application of coal tar to the roof of an occupied school; complaints in a windowless school where there was no provision to control contaminants from reroofing from entering the building after the filters in the HVAC systems were sprayed with a disinfecting deodorant that was not intended for such use; and a combination of new carpeting installation, gym floor sealing, and repainting that were related to occupant health symptoms that declined over time.

NIOSH HHER investigator Kelly (5, 6) reported on two similar complicated cases involving Pennsylvania elementary schools where the solution to one problem became the cause of another. As part of asbestos abatement programs, vinyl floor tile were removed and then, an organic solvent was used to remove tile adhesive from the concrete floor slab. Following health complaints from occupants, school officials attempted unsuccessfully to mask the odor using deodorizers in one school and in the other they used "bake-out" procedures as well as ion and ozone air purification systems and caulking slab joints. Next, the carpet was removed from two of the classrooms and the concrete slab was treated with a sealant which provided short-term improvement. To avoid similar problems in the future, Kelly recommended a plan to prevent elevated VOCs following mastic remover should be contractually specified; VOC monitoring by an independent consultant should be done before and after mastic remover use; the work area should be isolated from other areas and it should be mechanically exhaust ventilated; and with elevated VOC concentrations, the work area should be ventilated at a higher than normal rate.

DISCUSSION

NIOSH HHERs offer a perspective into the building-related factors associated with school indoor air quality complaints in the United States. Often, NIOSH investigations revealed multiple problems in complaint school buildings. Insufficient amounts of outside air being supplied to occupied spaces was the most common problem identified in the NIOSH school investigations and was reported in 84% of the school HHERs. Since the majority of NIOSH school investigations were conducted in only three states, it is unknown how representative the findings are of building-related factors associated with indoor air quality complaints in U.S. schools. However, there have been a number of reports in the literature that suggest that ventilation problems may be fairly common in complaint schools (7, 8, 9).

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