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Office of Radiation and
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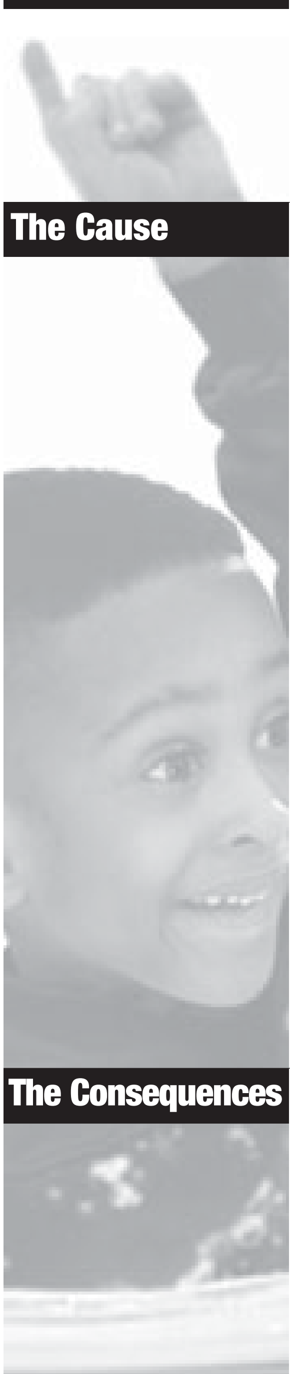
Indoor Air Quality & Student Performance

Revised[1]



The Problem

How Does Indoor Air Quality Affect a Child's Ability to Learn?

Evidence continues to emerge showing that poor indoor air quality (IAQ) can cause illness requiring absence from school, and can cause acute health symptoms that decrease performance while at school. In addition, recent data suggest that poor IAQ may directly reduce a person's ability to perform specific mental tasks requiring concentration, calculation, or memory.

The Cause

Air in most indoor environments contains a variety of particles and gaseous contaminants. These contaminants are commonly referred to as *indoor pollutants* when they affect human health and performance. Indoor temperature and relative humidity can also affect health and performance directly, and can affect human performance indirectly by influencing the airborne level of molds and bacteria.

Most often, poor indoor air quality results from the failure to follow practices that help create and maintain a healthy indoor environment. Common examples include failure to:

- control pollution sources such as art supplies and laboratory activities
- control temperature and humidity
- control moisture and clean up spills
- ventilate each classroom adequately
- adequately perform housekeeping and maintenance
- use integrated pest management to minimize the use of pesticides

Schools should be designed, built, and maintained in ways to minimize and control sources of pollution, provide adequate exhaust and outdoor air ventilation by natural and mechanical means, maintain proper temperature and humidity conditions, and be responsive to students and staff with particular sensitivities such as allergies or asthma. Failure to deal adequately with any of these issues may go unnoticed, but can and often does take its toll on health, comfort, and performance of teachers and students in school.

The Consequences

Specific Evidence

Illnesses Resulting from Poor Indoor Air Quality Increase School Absences

Evidence from schools that various environmental conditions are closely associated with the incidence of objectively measurable adverse health effects is rapidly emerging. Indoor air quality

[1]Substantial portions of this revised document are based on a literature review funded by the Environmental Protection Agency. The literature review was conducted by Mark Mendell from Lawrence Berkeley National Laboratory, and Garvin Heath from the University of California at Berkeley. Evidence of the association between indoor environmental quality and human performance is taken from school settings wherever possible, but it is supplemented by similar evidence in other environments where information from school environments is lacking.

Recent data suggest that poor IAQ can reduce a person's ability to perform specific mental tasks requiring concentration, calculation or memory.

problems can result in increased absences because of respiratory infections, allergic diseases from biological contaminants, or adverse reactions to chemicals used in schools. Building factors or pollution in buildings most frequently and consistently associated with respiratory health effects are the presence of moisture, water damage, and microbiological pollutants;[1,2] animal and other biological allergens;[3] and combustion products,[4] including nitrogen dioxide.[5,6] Other risk factors for respiratory health effects include: moisture or dirt in HVAC systems;[7,8] low ventilation rates;[9,10] formaldehyde;[6,11-15] chemicals in cleaning products;[16,17] and outdoor pollutants or vehicle exhaust.[18-20]

Children's overall performance decreases due to sickness or absence from school.[21-24] Building-associated health effects can increase student or teacher absences from school and degrade the performance of children or teachers while in school. Respiratory health effects, such as respiratory infections and asthma, are the illnesses most closely associated with increased absenteeism. In fact, asthma-related illness is one of the leading causes of school absenteeism, accounting for over 14 million missed school days per year.[25]

Measured Loss in Performance from Indoor Pollution Sources or Inadequate Ventilation

Recent studies relate direct performance measurements to changes in indoor air quality. For example, a European study of 800 students from 8 schools provides data on indoor air quality, health symptoms, and students' ability to concentrate.[26] In the study, carbon dioxide measurements were taken in the classrooms and students were given a health symptom questionnaire. A computer-based program scored their ability to concentrate. The main source of carbon dioxide in buildings is exhaled breath. Carbon dioxide itself is not a health threat at levels typically found indoors, but when outdoor air ventilation rates are low, carbon dioxide levels and other pollution levels are not diluted as much and therefore also tend to be high. In the study, student scores on the concentration test were lower and their health symptom responses to the questionnaire were inferior when carbon dioxide levels increased. This finding, which was statistically significant, suggests that reduced ventilation rates (and higher indoor pollution) is associated with a decreased ability to concentrate along with increased adverse health symptoms. Another study[27] of students shows similar results when using subjective reports of performance, while laboratory studies of the effects of a mixture of VOC on adults shows that elevated volatile organic compounds (VOCs) can decrease performance of sensitive adults,[28] though not necessarily on those that are not sensitive.[29]

Studies of adults in office settings generally support these associations. In a controlled study of 30 female adults working in an office environment, a 20-year old used carpet, which served as a pollution source, was periodically introduced on racks behind a screen so that subjects had no way of knowing when the carpet was present.[30] The subjects were tested in typing, arithmetic, logical reasoning, memory, and creative thinking during several trials with and without the carpet present. These tasks are similar to the kinds teachers and students perform in school. During the trials without the carpet, the subjects' performance improved in all tasks by 2 – 6 percent. When the carpet was present, the prevalence of headaches during tasks requiring concentration increased, suggesting that at least part of the effect on performance was from pollution-related adverse health effects. In a later study using the same procedure, increasing ventilation rates with the carpet present resulted in statistically significant improvements in performance.[31]

In a similar although more limited study of typing performance and perceptions of air quality, computers were used as the pollution source. Computers can emit a variety of VOCs as internal temperatures of various components rises. In this study, the air was perceived to be fresher and typing performance improved in the absence of the computers.

Evidence is increasing that health, comfort, and performance of adults improve at higher ventilation rates.[32-36] In addition, a recent controlled study in office buildings found that short-

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term sick leave, often associated with respiratory illness, was significantly associated with low ventilation rates.[10] A subsequent study to test the hypothesis that the sick leave reflected increased respiratory illness failed.[37] The latter study, however, examined a much narrower range of ventilation rates, and related ventilation rates only with sick leave taken during the following week. An alternative explanation supported by sick leave data from this and other studies is that poor indoor air quality increases the probability that individuals will take sick leave even for minor ailments, and delay returning to work during recovery.[38]

Ventilation rates in most schools are below recommended levels, both in the United States and in Europe.[39-44] In fact, in a California study,[39] one third of the schools had ventilation rates that were less than half the recommended levels. Thus, the prevalence of low ventilation rates, combined with the continually growing evidence of the positive impact that outdoor air ventilation has on health and human performance, suggests a clear opportunity for improving IAQ design and management of school facilities. The availability of energy recovery technology in ventilation systems, and the availability of software tools to evaluate the financial implications of this technology,[45] may facilitate acceptance of higher ventilation rates.

Thus, the evidence is increasing in studies of both schools and other settings that indoor pollution or inadequate ventilation can decrease student and teacher performance. These studies reinforce others that relate degradation in indoor air quality with increased frequency of adverse health symptoms or absenteeism. IAQ management in schools, including pollutant source control and provisions for adequate ventilation, appears to provide a healthy indoor environment conducive to improved student and teacher health, higher school attendance, increased school funding, and improved student performance. Furthermore, the pervasive problem of inadequate ventilation in schools provides a significant opportunity to improve school conditions that leads to improved performance of teachers and students.

Effects from Mild Symptoms of Distress

What about people who do not have a diagnosable illness, but simply do not feel well? People may report feeling lethargic, having headaches, having a mild sore throat or itchy eyes, or they may have a sense that the air is "stale," "stuffy," or "too dry."

Motivation can often overcome small burdens of environmental stress so that children's demonstrated performance may not decline. Evidence from adults, however, suggests that continued environmental stress can drain a person's physical and mental resources and ultimately affect their performance. For example, evidence from office workers suggests that, when individuals experience just two symptoms of discomfort (e.g., dry eyes, itchy or watery eyes, dry throat, lethargy, headache, chest tightness), they begin to perceive a reduction in their own performance. That perception increases as the number of symptoms increases, averaging a 3-percent loss with three symptoms, and an 8-percent loss with five symptoms.[46] This suggests that when large numbers of students and staff experience signs of discomfort related to the air inside their school, teaching and learning performance will degrade over time.

Effects of Temperature and Humidity

In addition to indoor pollution and ventilation, studies suggest that various activities such as typing or driving a vehicle are diminished when people are demonstrably too cold or too hot. Maintaining temperature at the warm end of the comfort zone tends to increase adverse health symptoms, while temperatures at the cool end of the comfort zone tend to reduce symptoms. Similarly, individuals perceive the quality of the indoor air to be better when humidity is at the low end of the comfort zone.[47-49]

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There is also good evidence that moderate changes in room temperature, even within the comfort zone, affect children's abilities to perform mental tasks requiring concentration, such as addition, multiplication, and sentence comprehension. Overall, warmer temperatures tend to reduce performance, while colder temperatures reduce manual dexterity and speed.[50] In general, the need to avoid extreme conditions and to provide for as much individual temperature control as possible is strongly supported.[51-52]

Will Performance Be Affected Even If No One Is Complaining?

Performance can certainly be expected to suffer if conditions are serious enough for people to complain. The lack of complaints, however, is *not* an indication that performance cannot be improved. For example, in the above studies, symptoms were solicited through questionnaires (as opposed to complaints), and tests were performed on individuals in typical school and office environments. That is, the reductions in performance were recorded under circumstances that easily could have gone unnoticed because of the absence of complaints.

Filtration, Housekeeping, and HVAC Maintenance

One study in schools and several with adult subjects also suggest relationships between health symptoms and airborne or surface-level dust[27,53-55] and between health benefits and good housekeeping protocols that thoroughly remove dust from surfaces.[56,57] Some studies show health and comfort benefits from efforts to reduce airborne particles.[58,59] One such study in an office building showed a statistically significant reduction in mental confusion when 95 percent of airborne particles between 0.3 and 0.5 microns in size were removed by filtration.[60] The study also showed reduced fatigue and improved productivity, although these results were not statistically significant.

Early studies in schools have found that air conditioning is associated with lower absentee rates[61] or improved performance,[62] and that schools with humidification systems are also associated with lower absentee rates. More recent and more rigorous studies in offices, however, show the opposite to be true. This discrepancy may be explained by the fact that, while air conditioning and humidification systems are designed to control temperature and humidity (a positive effect), they may also become contaminated with biological pollutants (a negative effect) if they are not judiciously maintained. A review of building investigation reports also suggests significant benefits to health and performance from good HVAC maintenance.[63] Presumably, these benefits result because properly maintained HVAC systems can provide consistently good thermal and ventilation control while also reducing the risk of biological contamination.

Overall, the evidence suggests that good housekeeping designed to control surface dust plus care and maintenance of the HVAC system, including provisions for good filtration performance, are important aspects of school operating protocols designed to improve student health and performance.

Outdoor Pollution

A major component of an IAQ management plan is the control of pollutants that may enter the school from the outdoors. Studies provide evidence of increased school absenteeism from outdoor pollutants such as carbon monoxide[64] and particles.[64-67] This evidence suggests that particular attention to potential exposures from school bus exhausts and other vehicle exhausts and that improved filtration of particles in locations with high levels of outdoor pollution may be advisable.

The Solution

What You Can Do

Because poor indoor air quality results from failure to follow practices that help create and maintain a healthy indoor environment, being proactive in managing potential IAQ hazards will

assist with maintaining the indoor environment of a school facility. School systems should take advantage of available programs to improve and maintain good indoor environmental quality, and specifically, good indoor air quality in their schools. Programs can be targeted to the maintenance of existing school facilities and to new school construction.

The U.S. Environmental Protection Agency has published voluntary guidance that addresses indoor air quality in schools. By applying no-cost or low-cost approaches outlined in the *IAQ Tools for Schools* (*IAQ TfS*) Action Kit, schools can find cost-effective approaches toward making the school environment more conducive to improved health and performance of teachers and students.

The *IAQ TfS* Kit is free to schools and school districts who make the request on school letterhead. To order the Kit contact the IAQ Information Clearinghouse:

IAQ Info
P.O. Box 37133
Washington, D.C. 20013-7133
Call: 1-800-438-4318, Fax: 703-356-5386, or Email: iaqinfo@aol.com
When requesting the *IAQ TfS* Kit, specify EPA document number 402-K-95-001.

Visit the *IAQ Tools for Schools* Web site and download the Kit, learn about training opportunities, and read about schools around the country that are using the Kit.

www.epa.gov/iaq/schools

Additional Resources
A searchable bibliography of studies dealing with indoor health and productivity (including abstracts of many of the references cited below) is available through the Indoor Health and Productivity (IHP) project. To view, visit http://www.IHPcentral.org

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