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ABSTRACT

This report examines how indoor air quality (IAQ) affects a child's ability to learn and provides several case studies of schools that have successfully addressed their indoor air problems, the lessons learned from that experience, and what long-term practices and policies emerged from the effort. The report covers the effects from building-related illnesses, from mild symptoms of distress, the estimated loss in performance, measured loss in performance, the measured effects of temperature and humidity and case studies of three schools. Comments provide information on the "IAQ Tools for Schools Kit" that schools can use to improve and maintain good indoor air quality. Appended are case studies of William Blackstone Elementary School, King-Murphy Elementary School, and G.W. Carver and Charles Drew Elementary Schools. (Contains 12 references.) (GR)



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The Problem



The Cause

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The Consequences

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

Indoor Air Quality and Student Performance

How Does Indoor Air Quality Affect A Child's Ability To Learn?

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 can reduce a person's ability to perform specific mental tasks requiring concentration, calculation, or memory.

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 operations
- Use integrated pest management to minimize the use of pesticides

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.

Specific Studies

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 persons with allergies or asthma. Adverse consequences can easily result when IAQ problems are not addressed properly.

Effects from Building-Related Illnesses

Children do not perform as well when they are sick or absent from school. Indoor air quality problems can result in absences because of respiratory infections, allergic diseases from biological contaminants, or irritant reactions to chemicals used in virtually every part of the school. Some conditions in the school environment are closely associated with the incidence of sick building syndrome and asthma symptoms^{1,2}, and asthma-related illness is one of the leading causes of school absenteeism, accounting for over 10 million missed school days per year.³ In addition, persons with asthma or other sensitivities may

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Asthma-related illness is one of the leading causes of school absenteeism, accounting for over 10 million missed school days per year.

have reduced performance in the presence of environmental factors that trigger their asthma. All of these “building-related illnesses” result from the lack of effective indoor environmental quality management. In extreme cases, schools sometimes have to be closed until problems are investigated and solved.

Effects from Mild Symptoms of Distress

What about people who do not have a diagnosable illness, but simply don't 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.” When these types of symptoms are made worse by being in a building, they are referred to as “sick building syndrome.”

Estimated Loss in Performance

Motivation can often overcome small burdens of environmental stress so that children's performance may not decline. However, continued environmental stress can drain children's physical and mental resources and ultimately affect their performance. Evidence from office workers suggests that when individuals experience just two symptoms of discomfort, they begin to perceive a reduction in their own performance. That perception increases as the number of symptoms increases, averaging a 3% loss with 3 symptoms, and an 8% loss with 5 symptoms.⁴ It follows that when large numbers of students and staff experience signs of discomfort related to the air inside their school, teaching and learning performance will likely degrade over time.

Measured Loss in Performance

Studies relating direct performance measurements to changes in indoor air quality are just now emerging. For example, a recent European study of 800 students from eight different schools provides data on IAQ, health symptoms, and students' ability to concentrate.⁵ 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. Carbon dioxide itself is not a health threat at levels found indoors, but since the main source of carbon dioxide in buildings is exhaled breath, and the main mechanism for removal is ventilation, high carbon dioxide levels in classrooms are an indication of low ventilation rates and, therefore, high levels of pollution. In classrooms where carbon dioxide levels were high (low ventilation rates), student scores on the concentration tests were low; and their health symptom responses were high. The results were statistically significant and tend to confirm that with IAQ management, including source control and adequate ventilation, student performance can improve.

Another controlled study of adults shows a similar relationship between the presence or absence of an indoor pollution source, health symptoms, and mental function.⁶ In this study, a health symptom questionnaire was completed by 30 female subjects who performed various kinds of mental tasks typical of office work in groups of six at a time. They worked in a realistic office environment specifically designed to have good IAQ, with low pollution levels. Because carpeting that is not adequately maintained can sometimes act as a source of pollution, a 20-year-old used carpet from another building was used to represent a potential pollution source. The carpet was periodically introduced on racks behind a screen so that subjects had no way of knowing when the carpet was present. The women were tested in typing, arithmetic, logical reasoning, memory, and creative thinking during several trials with and without the carpet present. During the trials without the pollution source, the subjects' performance was improved. The number of words typed increased 6.5%*, typing errors were reduced by 5%***, the addition test scores increased 3.8%** , and logical reasoning test scores improved by 3-4%***. When the pollution source was present, there



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was an increased prevalence of headaches during tasks requiring concentration, suggesting that at least part of the affect on performance was from pollution-related adverse health effects. In a later study using the same procedure, increasing ventilation rates also provided a statistically significant improvement in human performance.⁷

* Statistically significant at 99%; ** at 95%; and *** at 90%

Measured Effects of Temperature and Humidity

In addition to indoor pollution and ventilation, studies confirm that various human activities such as typing or driving a vehicle are diminished when people are demonstrably too cold or too hot. Temperature is also implicated in studies of sick building syndrome. Maintaining temperature at the high end of the comfort zone tends to increase symptoms, while temperatures at the low end of the comfort zone tend to reduce symptoms. Similarly, individuals perceive the quality of the indoor air to be better when temperature and/or humidity are toward the low end rather than the high end of the comfort zone.^{8,9,10}

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. Study results were different for boys and girls, and the effects varied for different types of tasks. But, in general, the evidence strongly supports the need to avoid extreme conditions and to provide for as much individual temperature control as possible.^{11,12}

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. However, the lack of complaints 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 kinds of school and office environments. That is, the reductions in performance were recorded in circumstances that could easily have gone unnoticed because of the absence of complaints.

What You Can Do

School systems should take advantage of available programs such as the *IAQ Tools for Schools Kit* to improve and maintain 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. The *IAQ Tools for Schools Kit*, is designed to be a no-cost, or low-cost approach to improving indoor air quality. The Kit is free to schools and school districts. To order the Kit:



EPA Kit

PO Box 37133

Washington, DC 20013-7133

Fax: 703-356-5386 or call: 1-800-438-4318

Visit the *IAQ Tools for Schools* web site at www.epa.gov/iaq/schools and download the Kit, learn about training opportunities, and read about schools around the country who are using the Kit.

The Solution

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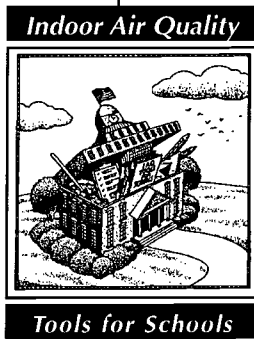




CASE STUDY

WILLIAM BLACKSTONE ELEMENTARY SCHOOL

Boston Public Schools, Massachusetts



William Blackstone Elementary School, located in Boston's South End, is part of the Boston Public Schools system. Of the 120 schools in the system, three were chosen to implement EPA's *Indoor Air Quality Tools for Schools (IAQ TFS)* Kit and program. Of these three schools, Blackstone Elementary was the first to do so.

Approach—Project Description

School Description

The five-story school building was constructed in 1975 using the typical design of that time—brick walls, mostly flat roofs, plexiglass windows, and visible duct work. For years, indoor air quality (IAQ) was an issue at Blackstone Elementary. The school nurse noticed that the asthma rate was higher than the national average of two cases per classroom. Staff were also aware of serious problems with water intrusion during heavy

rains, stained and collapsed ceiling tiles, peeling paint and stains on the walls, rust on support beams, and water damage to equipment and furniture.

IAQ Team

In January 1999, the IAQ Team at Blackstone Elementary was the most prepared to meet regularly to implement the program. The school's IAQ team met six times from January to June 1999, using the *IAQ TFS* Kit as the basis of their discussions. The Blackstone team consisted of school district officials, the school principal, the school nurse, teachers, parents, custodians, and EPA regional staff.

The IAQ team and a ventilation engineer from the Boston Public Schools system conducted a walkthrough inspection of practically every area of the school. School staff were given the appropriate documents from the Kit, including checklists covering all areas of the building. About 80 percent of the checklists were returned.

Problem Identification

Problems identified by the checklists and walkthrough included the following:

- An above-average number of asthma cases and illnesses typically associated with indoor air quality problems (headaches, nausea, etc.).
- Water damage, such as mold and mildew; missing, stained, and broken ceiling tiles; fungal growth on ceiling tiles; and damaged ceiling and wall plaster.
- Thermal discomfort, such as widely fluctuating temperatures, too high or too low humidity levels, and cold drafts.
- Ventilation problems, such as poor air circulation and lack of exhaust fans in some bathrooms.
- Cleanliness problems, such as dust accumulation around the supply vents and surrounding ceiling tiles, infrequent dusting and vacuuming, and pest problems.

“Every school has a Healthy Schools Team dedicated to making their school safer and healthier. We received some great press from implementing the Kit—the local newspapers wrote several articles about our Healthy Schools Team.”

*-Robin Chappell
District Health
Official*

(over)

WILLIAM BLACKSTONE ELEMENTARY SCHOOL

Boston Public Schools, Massachusetts

EPA's IAQ TFS Kit gave the team the leverage it needed to persuade the school district to improve the environmental problems in the school.

Lessons Learned

Short-term Improvements

Based on the information found in the walkthrough, the IAQ team brainstormed and identified specific solutions for improving the indoor air quality at Blackstone Elementary School. In addition, EPA's IAQ TFS Kit gave the team the leverage it needed to persuade the school district to improve the environmental problems in the school. Once the Superintendent was informed of the school's IAQ issues and the team's recommendations, Blackstone Elementary was placed on a high-priority list for roof repairs and other renovations.

A number of improvement projects have been completed, including roof repairs during the summer of 1999. Current plans call for installing new energy-efficient lighting and new ceiling tiles. Additionally, carpeting will be removed and replaced with tiles in some classrooms. The school nurse intends to document student health and asthma cases over the next year to establish a link between the indoor environment and children's health.

Long-term Practices and Policies

Blackstone Elementary is now in its second year of IAQ TFS implementation and hopes to collect information on the improved health of students and staff. Much of the credit for the school's progress rests with the principal, Ms. Ruiz-Allen, who took over the project after the first meeting and welcomed all ideas. She was instrumental in getting the Superintendent involved and ensuring that the repairs were done quickly. The presence of officials from EPA Region 1, the Boston Public Health Commission, and Boston Public Schools at the meetings also proved key in Blackstone's success, as these groups created a strong sense of purpose and assured the team that their IAQ problems were not impossible to fix.

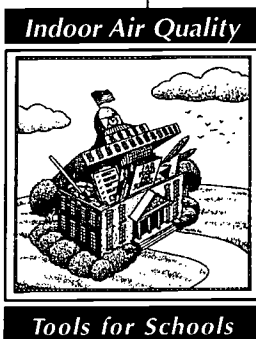
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CASE STUDY

KING-MURPHY ELEMENTARY SCHOOL

Clear Creek School District, Colorado



King-Murphy Elementary School, part of the Clear Creek School District, is located in Evergreen, Colorado, about 30 miles west of Denver. Two hundred and fifty students in grades K through 6 attend the school.

Approach—Project Description

School Description

The two-story King-Murphy Elementary School was built in 1982, using a passive solar design. The heating, ventilating, and cooling (HVAC) system consists of unit ventilators and five new rooftop units for heating and cooling the second-floor classrooms.

Prior to the indoor air quality (IAQ) campaign at King-Murphy, the school district hired a new Facilities and Maintenance Director. He negotiated a performance contract with an energy service provider, who would design a plan, install energy-efficiency technologies,

and guarantee their performance. The contract covered upgrading the school's HVAC system and installing a district-wide energy management system (EMS). District staff knew that IAQ problems existed in some of their schools and were committed to considering the effects of energy efficiency upgrades on IAQ as the upgrades were planned and implemented.

IAQ Team

The school formed an *IAQ Tools for Schools (TfS)* steering committee in October 1998, led by the principal and the custodian. The team also included the District Facility Maintenance Supervisor, a teacher, a student from the Environmental Science Club, and a parent. They developed a 5-month plan for implementing *IAQ TfS*.

Problem Identification

The first IAQ meetings revealed very real concerns, including hazardous waste removal and management, exhaust fumes in the building, irregular filter replacement schedules, general inadequacy of the air-handling system, and overheating from the south-facing clerestory windows. The potential for radon gas was also a concern because the school is located near mountains containing old coal mines. Seepage of the radon gas from these mines was an issue not to be overlooked. All concerns were ultimately addressed by implementing *IAQ TfS*.

The teachers completed their IAQ checklists in December, and the head custodian and principal coordinated completion of the remaining lists. Then the team reviewed the checklists and prepared for a walkthrough. The walkthrough consisted of one-on-one interviews with teachers who had identified specific concerns, and visual inspection of certain areas of the school with identified or potential problems. Staff measured and recorded carbon dioxide (CO₂) levels and room temperatures, along with any observations and interview information, on a spreadsheet.

The walkthrough revealed that diesel fumes from idling buses entered several rooms on the south side of the building through the unit ventilators. The team also noted that the outside air dampers were set to allow air in only when the temperature is above 40° F to prevent freezing coils, thus leaving classrooms without adequate outside air during most of the heating season. Radon testing showed low radon levels (below EPA's action level) throughout the school.

Although many IAQ issues were identified, the team was aware of concerns about the impact of the new program on the maintenance staff's workload, as they were already very busy. The Facilities Director addressed these concerns and also assured the maintenance staff that the IAQ issues and operational changes identified were not a critique of their performance. The IAQ work at the elementary school commenced soon after.

"The IAQ TfS Kit prompted us to track our student health problems, like asthma and allergies, and try to relate them to our past IAQ improvements. We've really been noticing the number of student absences decreasing since the IAQ improvements were initiated."

*-Art Benton
Facilities and
Maintenance Supervisor*

(over)

KING-MURPHY ELEMENTARY SCHOOL

Clear Creek School District, Colorado

"I got a lot more out of IAQ Tools for Schools than I anticipated. The program has really helped us because we are addressing things that needed to be fixed and we can take this to other schools [in our district]."

*-Art Benton
Facilities and
Maintenance
Supervisor*

Lessons Learned

Short-term Solutions

As a result of the walkthrough in January 1999, the team developed a set of IAQ policies for King-Murphy Elementary School. Staff are advised to do the following:

- Keep unit ventilators clear of books, papers, and other items.
- Maintain the temperature between 68° and 72° F.
- Keep warm-blooded pets out of classrooms or, when they visit, limit time of exposure and ensure good ventilation.
- Be aware of the cleaning schedule and expectations for keeping horizontal surfaces clean.

Staff are also encouraged to know the proper procedures for storing and discarding chemicals. Material Safety Data Sheets on the chemicals will be kept on file and updated whenever necessary. The district sought a waiver from Health and Human Services to use a bleach alternative for weekly cleaning, and that has become the rule. The policies were communicated to all staff and included in the new-teacher and beginning-of-year information packets.

The school also worked with its energy service provider to address IAQ problems related to the HVAC system. The contractor adjusted the outside air dampers and added glycol to the water pipes to increase the amount of outside air during the heating season. Timers were installed to shut off the outside air supply during the 15-20 minutes the buses are loading. This will prevent diesel fumes from entering classrooms on the south side of the building through the unit ventilators. The school arranged to install tinted clerestory windows to reduce overheating in upstairs classrooms. Plans were also made to replace metal air filters with pleated paper filters, which are up to 80-percent efficient. The school's preventive maintenance plan specifies that the filters are to be replaced every 90 days.

The IAQ team members noticed a dramatic improvement in their comfort levels and a decrease in IAQ-related complaints between the first and last scheduled IAQ meetings.

Long-term Practices and Policies

Implementing the *IAQ TJS Kit* was a positive learning experience for the Clear Creek School District. Participants agreed that the onsite involvement of knowledgeable staff from EPA's regional office was key to the successful implementation of the Kit at King-Murphy Elementary School. As a direct result of implementing the *TJS Kit*, the district is now establishing hazardous waste training sessions for all staff members. One year ago such programs were not considered necessary, but the success of the *IAQ TJS Kit* helped pave the way for new environmental issues to be addressed.

District staff are making *TJS* a learning experience for students, too. From the very beginning, the Superintendent requested that the students be included as much as possible. King-Murphy students helped complete checklists, collected particulate samples, and wrote about what they learned. IAQ provided an opportunity for students to get involved in their own education and increase their awareness of the indoor environment.

In a new program beginning September 2000, Art Benton, Facilities and Maintenance Supervisor, is establishing an internship for high school students from the district. They will review the recorded sick days of students and staff from all district schools that implemented the *IAQ TJS Kit* and record the reason for the sick day—whether it can be attributed to asthma, allergies, flu, or simply missing the bus. Also in September, Georgetown Elementary School will begin to participate in the *IAQ TJS* program.

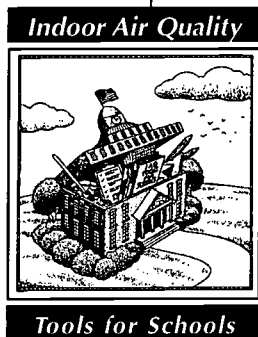
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CASE STUDY

G.W. CARVER AND CHARLES DREW ELEMENTARY SCHOOLS

San Francisco Unified School District, California



G.W. Carver Elementary School, part of the San Francisco Unified School District (SFUSD), is located in the Bayview/Hunters Point community, a suburb of San Francisco near 3-COM Park. In early 1998, the principal at Carver Elementary was overwhelmed by the number of students coming to the main office for their asthma inhalers. The principal expressed her concern about the children's health to a friend working with Kaiser Permanente. As it happened, Kaiser, the American Lung Association (ALA), and the State of California were well aware that people living in San Francisco's Bayview/Hunters Point community had a much higher incidence of asthma and other respiratory illnesses than those living in other parts of the city. Carver Elementary was of particular concern because its students were reporting an even higher rate of asthma cases than at a nearby school.

Approach—Project Description

“As a school nurse, I can see from a medical standpoint how important good IAQ is to schools, but I have gotten a tremendous amount of education from using this Kit; especially from the walkthroughs.”

- Marie Hoemke
School Nurse

Getting Started

Through its *Open Airways* program, ALA was already working with the school nurse from Carver to provide asthma training courses. In March 1998, ALA hosted a roundtable discussion focusing on indoor air quality (IAQ). The event was well-publicized. Attendees included representatives of the Environmental Protection Agency (EPA), ALA, Kaiser Permanente, SFUSD staff including the Deputy Superintendent and the District's Facilities Manager, and others. Their discussion centered on the high asthma rates and kicked off a planning effort for assessing, prioritizing, and remedying IAQ problems in schools.

During the discussion, EPA offered technical assistance to SFUSD schools that would commit to pilot testing EPA's *Indoor Air Quality Tools for Schools (IAQ TFS)* Kit and program. Two schools were chosen as pilots, G.W. Carver and Charles Drew elementary schools, both of which were built in 1974. Carver has approximately 390 students in grades K-5, while Drew has approximately 240 in the same grades. The same nurse serves both schools.

IAQ Team

Following the recommendation in the *IAQ TFS* Kit, the two schools established a joint IAQ team. The team includes the school nurse (who is also the IAQ Coordinator), the facilities manager, maintenance supervisors, custodial supervisors, planners, architects, and representatives from the District's health program.

Problem Identification

EPA brought in an IAQ expert to conduct scientific analyses at the two schools, using state-of-the-art monitors/meters and walkthroughs to evaluate building performance and ventilation. Administrators, teachers, and custodians participated in the first walkthrough. Facilities Management staff participated in a second walkthrough that focused on the more technical aspects of the facilities.

The first walkthrough provided the team with the necessary training to implement the school district's new IAQ Policy, which is centered around the *IAQ TFS* Kit. They learned that various, and sometimes seemingly inconsequential, factors can combine to affect IAQ. For example, the ventilation system at one of the schools had been inadvertently shut off. Although they noticed the warm temperature, school staff were unaware that the system was not operating, and the problem went unreported. A timer, set to turn the ventilation system on and off each day, had been overridden due to miscommunication. A short discussion with the custodial staff remedied a long-standing problem. Other IAQ problems identified during the walkthroughs were addressed, and measures to control IAQ became a part of the schools' normal maintenance practices.

(over)

G.W. CARVER AND CHARLES DREW ELEMENTARY SCHOOLS

San Francisco Unified School District, California

**Visits to
the nurse's
office for
inhaler use
have dropped
by at least
half.**

Lessons Learned

Short-term Results

Staff at both schools made low-cost improvements that provided immediate IAQ benefits—better learning and teaching conditions for the students and faculty without unduly taxing the district facilities staff. The health impact was almost immediate. In February 1999, the SFUSD School Health Programs Department reported, "We are already noting some positive effects from the building maintenance that resulted from the walkthroughs." Some observations worth noting include:

- Visits to the office for the use of asthma inhalers were reduced by half.
- Fewer students keep asthma medicines/inhalers at school, and asthma episodes are less frequent even though the number of students with asthma has not changed.
- Airflow throughout the schools has been greatly improved.

Long-term Practices and Policies

Teachers and staff participate in the IAQ process by completing the *TJS* checklists on a regular basis, which helps school and district staff keep up with IAQ issues as they arise. The IAQ roundtable and the success of the two *IAQ TJS* pilot schools have had a positive, noticeable effect on SFUSD and the community at large. As a result,

- The Superintendent, with the support of EPA, agreed to author an **IAQ Policy** for SFUSD, based on the *IAQ TJS Kit*.
- SFUSD is currently implementing the same measures in 16 more schools, 8 of which have already had IAQ training and walkthroughs. Other schools in the district have attended the training and are anxious to be involved. A new group of schools is being formed for next year.
- Interest in IAQ among community members has skyrocketed. Today, more than 40 people regularly attend meetings to discuss IAQ issues and their potential health effects.
- An **Asthma Task Force** has been established involving school officials, EPA, ALA, University of California at San Francisco Medical Center, Stanford University, and the San Francisco City Health Department. The task force will provide resources to the public, including a telephone hotline and directory of resources.
- An **Implementation Committee**, formed by the school nurse/IAQ Coordinator and a member of the teacher's union, has been established to ensure that (1) the goals set forth at the roundtable and the IAQ problems found during the walkthrough are addressed, and (2) schools follow the IAQ Policy.
- A phone number is now available to school district staff to call for immediate response to IAQ problems (real or potential) such as odors and mold growth.
- The district established an **Integrated Pest Management (IPM)** program, committing to use non-toxic/least toxic methods of pest control.
- The San Francisco Health Department established the **Children's Environmental Health Department**. Staff, including industrial hygienists and nurses, will assess schools, homes, and other buildings for IAQ issues.
- The Mayor's office funded the development of the **Health and Environmental Resource Center**. The Center, which is now also supported by funds donated by the San Francisco (City and County) Board of Supervisors, holds evening training classes and will also train in schools, day care centers, and other sites about asthma and cancer. The Center, along with the Children's Environmental Health Department, is currently developing a partnership with local health care providers.

Direct involvement and support of SFUSD's Superintendent, Deputy Superintendent, and Facilities Manager have been and will continue to be key to the success of the IAQ program throughout the San Francisco Unified School District. The support of EPA, ALA, the City Health Department, and others is also important.

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