

# Indoor Air Quality in Northwest Schools

***An electronic newsletter for school Indoor Air Quality (IAQ) exclusively for Northwest schools***

**Fall Quarter 2003**

**The U.S. Environmental Protection Agency (EPA) has developed a new Web resource titled Indoor Air Quality (IAQ) Design Tools for Schools.**

[www.epa.gov/iaq/schooldesign](http://www.epa.gov/iaq/schooldesign)

It was designed to help school districts and facility planners design the next generation of learning environments so that the school facility will help — rather than hinder— schools in achieving their core mission of educating children. Approximately 56 million Americans — or 1 in 5 people — spend a significant portion of their day in one of about 118,000 public and private primary and secondary schools.

To keep pace with population growth, reduce overcrowding and comply with class-size reduction mandates, it is estimated that 6,000 new schools will need to be built in the next several years. Many thousand more schools will have to be renovated as districts continue to upgrade deteriorating school facilities. Facility designers and school officials are increasingly embracing “high performance” school designs, which use an integrated, “whole building” approach to school planning that incorporates current technology to protect health while saving energy, natural resources and money. For example, a typical 450-student elementary school today pays over \$45,000 annually for energy related utilities. Incorporating energy efficient design improvements into the design and building of the school could save that school \$13,000 annually. These savings do not include the potential benefits of improved occupant health, productivity and performance from integrating high performance design features.

continued on page 2

## **School Indoor Air Quality Newsletter for Northwest Schools**

A quarterly electronic newsletter exclusively for NW schools.

Please circulate this subscription opportunity throughout the Northwest to those who may be interested.

There are two ways to subscribe:

1) To view the newsletter, click here:

<http://www.energy.wsu.edu/buildings/IAQ.htm>

The newsletter contains a link for subscription information.

2) Or, send a blank email message to: [subscribe-iaq@listserv.energy.wsu.edu](mailto:subscribe-iaq@listserv.energy.wsu.edu)

You will receive a confirmation message. When you reply to that message you will be subscribed and will receive all future postings. You can easily unsubscribe at any time.

This broadcast email list not only provides automatic delivery of the quarterly School IAQ Newsletter, but includes announcements about news of interest, training events, grant opportunities, and other information useful to school districts, agencies, and stakeholders involved in school IAQ and operations and maintenance.

The newsletter is an opportunity for all interested parties to communicate, and add to the collective wisdom.

*“Incorporating energy efficient design improvements into the design and building of the school could save that school \$13,000 annually.”*



## Tools for Schools (TFS) Around the Region

# Success Stories

### Message to Dave Blake, Northwest Air Pollution Authority:

Dave:

*We have used this remodel time to transition to H2Orange2 as our primary cleaner for virtually everything except major restroom disinfecting and floor stripping. We have found that if the solution is given time to do the work, it will clean almost anything, and the mixing stations are very convenient and easy to use.*

*We are using Kleenco's Earthwatch Sassafras cleaner for our gym floors with very good results. We are using all triple filter back pack vacuum cleaners and are starting to transition to microfiber clothes for dusting and wiping.*

*We have also added additional air filter maintenance to all of our air handlers and are phasing out the use of solvent based rubber cements and markers. Thanks again for all of your work and help in implementing these changes, which are definitely improving the air quality and environment at our schools.*

**Carl Haan**

Lynden Christian Schools

**To: Dave Blake**

**Subject: green cleaning update**

Dave, this is to update you on our progress so far in our school (Mt. Erie Elementary). During the summer, we replaced all the carpeting in the building, removed the carpet from the halls and put in tile. What an improvement! The night custodian and I were pictured in our local newspaper with mention that we were part of the green cleaning pilot program. We put an article in the P.T.A. newsletter that goes home with all of our students telling their parents about the pilot program. We have documented and removed all hazardous chemicals from all of the classrooms and offices. We have switched out all of our cleaning products to Green Seal certified H2 Orange2 products made by Envirox. Each classroom and office has been issued a spray bottle of cleaner and a microfiber cloth to use as needed to wipe up their areas. Several of our teachers have cleaned up their cluttered areas in their rooms, and have started to containerize their materials on their shelves. A few of them have also hung curtains across the front of their shelves to eliminate the dust problems. Overall I feel that we are off to a positive start.

More later,

**Von Storme**

Anacortes School District

## New Web resource for schools

continued from page 1

IAQ Design Tools for Schools complements the IAQ Tools for Schools Program, which helps existing schools prevent and solve IAQ problems. IAQ Design Tools for Schools provides voluntary guidance for school personnel, architects and engineers, builders and contractors, parents and the community on key school construction and renovation issues such as:

- Incorporating high performance building features into the design process.
- Controlling pollutants and their sources.
- Selecting and designing heating, ventilating and air conditioning systems.
- Controlling moisture to prevent mold and damage to building materials and systems.
- Remediating mold.
- Specifying and maintaining portable classrooms.
- Renovating existing schools.
- Providing links to resources on a wide range of high performance construction issues, such as acoustics, daylighting, life-cycle costing, commissioning and more.

IAQ Design Tools for Schools draws from EPA expertise as well as other resources that have emerged from state and private sector initiatives.

Smart School Design, Construction, and Renovation = Healthier and Higher Performing Kids EPA 402-F-03-012

## Region 10 Tools For Schools Implementation process

As part of the Region 10 Tools For Schools Implementation process schools create their own indoor air quality program. Using the three step process, schools select from a menu of suggested program elements designed to assist in this process.

Listed below are those program elements that were most popular – 20 percent or more of the schools selected these items

<b>% of School</b>	<b>Element Adopted</b>
23%	Adopt and enforce practical “standard of care” guidance for custodial care of the facility
21%	Coordinate with ventilation systems operator to develop and use maintenance checklists and maintenance calendars & logs to ensure routine checks are made and preventive maintenance (PM) servicing is completed — (see EPA’s Building Air Quality Manual for sample forms)
23%	
21%	Obtain the use of carbon dioxide (CO2) measurement equipment — by loan or purchase — to make routine measurements throughout the facility at times of peak occupancy for the longest period of time in order to document worst case scenario.
31%	Make sure ventilation air is supplied to all classrooms and “portable classrooms” at all times when these spaces are occupied (many heating and A/C units only deliver air when the thermostat is calling for heat or air conditioning — no air is delivered when the space is comfortable).
28%	Training will be provided to all ventilation systems operators on the subjects of ventilation and IAQ, equipment and measurement of air flows, assessment of unplanned air flows, and pressure control
25%	Ensure reports of comfort or indoor air problems are handled appropriately and promptly.
21%	Personal safety training and equipment will be provided for O&M staff to protect them during assessments, maintenance, and cleanup activities
36%	O&M staff will be trained in proper handling, cleanup, and disposal of chemicals, moldy materials, and know when to request professional help.
25%	Contractors: formally advise mechanical and other contractors providing services to your facility that your school is participating in the EPA Tools for Schools Program and will be requiring “good management practices” in terms of the heating/ventilation systems, selection and use of low-emission products, control of fumes & dust during work, emphasis on energy saving equipment, careful and absolute protection of ductwork during construction (drywall dust) and thorough cleanup
29%	An IAQ Response Plan will be developed to ensure serious health-related problems — or time-sensitive situations (carbon monoxide, spills, leaks, electrical, etc) are addressed immediately and correctly
20%	Assure that no toxic chemicals (e.g., Drano, Raid) are stored in cabinets under sinks.

## Assessment of Cleaning Effectiveness

### Summary of Findings from U.S. Environmental Protection Agency Research

The Frank Porter Graham Child Development Center is a four story, 20-year-old, 95,000 square foot building with 66 percent carpet, occupied by 214 adults and 62 children. The building has daycare, office, research, medical and lab spaces. It is located in Chapel Hill, NC, in a suburban area close to two high-traffic roadways undergoing continuous road construction.

The study design compared measured indoor air quality “before” (Sept.-Dec.) and “after” (Jan.-June) deep cleaning (conducted in 1993).

The “before” conditions consisted of regular “routine cleaning” by two full-time university housekeeping staff. The “after” conditions consisted of “deep cleaning” of walls, furniture, light fixtures, bathrooms, windows, tile floors and carpets by outside professional companies. New cleaning equipment and supplies were introduced and housekeeping staff was trained to use new equipment and to follow a standardized “improved” housekeeping program.

Special emphasis was placed on environmental management strategies, including source and activity management:

- Providing for safety;
- Cleaning for health first and appearance second;
- Maximizing extraction of pollutants from building envelope;
- Minimizing chemical, particle and moisture residue;
- Minimizing human exposure to pollutants;
- Cleaning to improve the total environment, and;
- Disposing properly of cleaning wastes.

Deep cleaning during the study involved removal of dust from all horizontal and vertical surfaces: walls, light fixtures, furniture, books, windows, etc. Vinyl tile flooring was stripped and re-waxed, ceramic tile flooring in bathrooms mechanically scrubbed and disinfected, carpeted areas cleaned by hot water extraction (steam cleaning) and rapidly dried.

Improved housekeeping program included: alternative cleaning formulations and efficient vacuum cleaners fitted with low-emission collection bags. New mats were placed at entrances to reduce infiltration of

particles and pollutants. The housekeeping staff and supervisor received professional training in conjunction with new equipment and supplies.

### Findings:

#### Airborne dust Burdens = 52 percent reduction

Routine Housekeeping = 11.9 ug/m<sup>3</sup>  
Improved Housekeeping = 5.7 ug/m<sup>3</sup>

#### Most probable cause of improvement:

Efficient vacuum cleaners and bags  
Walk-off mats  
Damp dust clothes  
Frequent vacuuming and dusting  
Deep cleaning of entire building  
Dust control on hard surfaces

#### Total Volatile Organic Chemicals (VOC) = 49 percent reduction

Routine Housekeeping = 324 ug/m<sup>3</sup>  
Improved Housekeeping = 166 ug/m<sup>3</sup>  
Most probable cause of improvement:  
Cleaning chemicals with lower VOC content  
Extraction from carpets  
Balanced heating, ventilation, air conditioning system

Total Bacteria = 40 percent reduction

Gram-Neg Bacteria = 88 percent reduction  
Endotoxins = 72 percent reduction

#### Total Fungi = 61 percent reduction

Penicillium = 87 percent reduction  
Aspergillus = 75 percent reduction  
Cladosporium = 23 percent reduction

#### Most probable cause of improvement:

Rapid use of disinfectants after accidents  
Control of food and perishables  
New extraction equipment  
Hot water extraction of carpets  
Moisture control  
Removal of contaminated sources (mold in wall, rotten tree stump)  
Walk-off mats

### Implications:

Airborne dust mass, measured as total suspended particles (TSP) provided the most meaningful particle data.



Carpet dust mass was reduced immediately after deep cleaning

– particularly on floors with the highest dust loads.

Carpet dust mass loads quickly returned to “before” cleaning levels soon after deep cleaning – confirming carpet as a “sink” or collector of particles.

However, “airborne dust mass was decreased after deep cleaning and continued lower even though the total mass from dust in the carpets had quickly returned to original levels.

Airborne levels of bio-pollutants correlated with the airborne dust mass, and the bacterial correlation is statistically significant.

Levels of bacteria and fungi from non-floor surfaces correlated with airborne levels of bacterial and fungi — providing evidence that surface pollutants can be reflective of airborne levels and airborne levels can be reflective of surface contamination.

Levels of carpet dust bacteria have a statistically significant correlation with airborne bacteria indicating a relationship between the two – demonstrating the need for cleaning (pollutant removal) as an environmental management tool for maintaining acceptable air quality.

Elevated air and surface levels of gram-negative bacteria, actinomycetes, *Penicillium*, and *Aspergillus*, which can be strong indicators of a problem building, can also be used as indicators in a non-problem building. These indicators are useful to assess the absence, need for, or ineffectiveness of an existing cleaning program.

Isolated occurrences of elevated levels of indicator fungi (*Penicillium*, *Cladosporium*, *Aspergillus*) and bacteria (gram-negatives, actinomycetes) suggest the need for frequent, effective cleaning to keep the building under control.

## Overall Results:

Ambient, environmental pollution can be significantly controlled through an effective and managed indoor cleaning program.

An organized cleaning program based upon environmental management principles and fundamental environmental protection guidelines contributed to improved IAQ through a reduction of total suspended particles, total VOC, and culturable bacteria and fungi.

While airborne pollutants increased during deep cleaning activities, they never reached levels of concern to the researchers, and were shown to decrease rapidly to levels well below the “pre-cleaning” concentrations.

## Implications for future needs:

Evaluate cleaning as a first measure for remediating a problem building with no apparent pollutant source.

Develop easy-to-use, economical, and standardized methods for routinely assessing cleaning effectiveness.

Define “clean” (building, carpet, surfaces) with representative indoor pollutant ranges for non-problem buildings.

## Northwest Schools:

This school year the Washington State University (WSU) Cooperative Extension Energy Program and the Northwest Air Pollution Authority will be working with Northwest schools to evaluate existing school cleaning programs and collaborating to develop individual pilot programs to improve school cleaning in a cost-effective and practical manner.

A special emphasis is being placed on “green cleaning” products. To participate, contact Rich Prill ([prillr@energy.wsu.edu](mailto:prillr@energy.wsu.edu)) or Dave Blake ([dave@nwair.org](mailto:dave@nwair.org)).

## Visual Inspection – Cleaning

Visual inspection for cleaning is not as accurate as actual measurements and the quality might very well differ depending on the person performing the evaluation.

The difficulties of visual evaluation are due to the variations in surface materials, color and roughness related to the visibility of the dust layer. The direction and intensity of light sources in the vicinity of the surface are important for the visibility of the dust. Also, optical properties of the dust on the surface are important.

Northwest schools will collaborate on methods to evaluate school cleaning this year. To participate, contact Tim Hardin, Rich Prill or Dave Blake.

## Associations between classroom carbon dioxide concentrations and student attendance in elementary schools in Washington and Idaho\*

By Derek G. Shendell and Richard Prill

Lawrence Berkeley National Lab Report No. 53586

### Study Highlights:

In this study, 1,000 parts per million (ppm) increases in the difference between indoor and outdoor CO<sub>2</sub> concentration were associated with 10 percent to 20 percent relative increases in student absence, and the associations were statistically significant. One potential explanation for our findings is the lower ventilation rates, indicated by higher carbon dioxide (CO<sub>2</sub>), cause increased communicable respiratory illnesses, probably by increasing the indoor concentration of airborne infectious particles produced during coughing or sneezing.

There is limited information on the relationships between indoor air and environmental quality (IEQ) in classrooms and student health, absence or academic performance. Only a few studies have been conducted on the associations of student health, and even fewer on student absence or learning, with types of ventilation systems, ventilation rates, indoor air temperature and relative humidity, concentrations of chemical and microbiological pollutants, and/or the amount of daylight.

Total ventilation — a combination of unintentional air infiltration through the building envelope, natural ventilation through open doors and windows, and mechanical ventilation — provides a means for reducing indoor concentrations of indoor-generated air pollutants. The ventilation standard developed by ASHRAE (62-2001) specifies a minimum ventilation rate of 15 cubic feet per minute per person. Ceiling- or wall-mounted heating, ventilation and air conditioning (HVAC) systems are often used to mechanically ventilate classrooms, although HVAC systems may provide less ventilation than intended because of design and installation problems and lack of maintenance, and because they are often not operated continuously during occupancy.

The indoor concentration of carbon dioxide (CO<sub>2</sub>) is often used as a surrogate for the ventilation rate per occupant. A CO<sub>2</sub> concentration of 1,000 ppm has often been used as an informal dividing line between “adequate” and “inadequate” ventilation. Despite the limitations of CO<sub>2</sub> concentrations as a measure of ventilation rate, higher concentrations have



been associated with increased health symptoms and absence from work in studies of adult office workers.



Available data indicate many classrooms have ventilation rates below the code minimum or have CO<sub>2</sub> concentrations above 1,000 ppm. Therefore, the extent to which lower ventilation rates affect student health, absence and performance is of particular interest. We explored the

hypothesis that higher indoor CO<sub>2</sub> concentrations, minus the outdoor concentrations, are associated with higher rates of student absence.

### METHODOLOGY

Washington State University (WSU) and the Northwest Air Pollution Authority (NWAPA) recruited primary and secondary schools in the states of Washington and Idaho during the 2000-01 and 2001-02 school years. These schools attended IEQ workshops conducted by WSU or NWAPA and contacted the university or the Pollution Authority for IEQ assistance, or they were recommended by other participating school districts. To select our sample of schools from this group of K-12 schools, we used a two-step process. First, we only considered primary schools serving K-5 or K-6, excluding special education and daycare buildings. Second, because of available resources and travel logistics we focused on: 1) schools in cities or school districts with the most primary schools; 2) schools where the majority of classrooms were served by individual HVAC systems (or none if just wall heaters); 3) schools from which daily attendance data at the student or classroom level were available. Our study, after some schools declined participation or did not have appropriate attendance data, consisted of 436 classrooms from 22 schools (14 in Washington, eight in Idaho) in six school districts (four in Washington, two in Idaho).

The IEQ assessments performed in every classroom consisted of walk-through surveys conducted by a technician together with relevant facilities and administration staff, and short-term measurements of CO<sub>2</sub> during school hours. Two short-term measurements were conducted sequentially inside each classroom and the measurement times were recorded. First, indoor air CO<sub>2</sub> was assessed near the center of the classroom at student breathing zone height, but at least one meter from students and not directly underneath the supply air diffusers. Second, the CO<sub>2</sub> concentration in the HVAC supply air was measured using a capture hood to direct undiluted supply air into the instrument sensor. CO<sub>2</sub> instruments were calibrated weekly according to manufacturer specifications and also cross-compared during short-term outdoor air CO<sub>2</sub> measurements at each school, at locations distant from potential CO<sub>2</sub> sources. Based on the measured CO<sub>2</sub> data, we computed the difference between the measured indoor and outdoor CO<sub>2</sub> concentrations (dCO<sub>2</sub>). This concentration difference is a rough surrogate for ventilation rate because it is based on one-time, short-term measurements made at a wide range of times throughout the school day, but it does not rely on any assumptions.

Attendance data were collected from school administrative staff who allowed field technicians access to school attendance records to enter data into a pre-formatted spreadsheet program. At seven schools in one school district, the enrollment and attendance of each student on each school day was recorded. For schools in every other district, we recorded the number of students enrolled, the number absent and the number in attendance for each classroom and school day. The percentages of students in attendance daily were calculated by pre-coded formulae, and then used for annual average daily attendance (ADA) calculations. The pre-visit ADA, although based on less data than the annual ADA, was not affected by any post-inspection ventilation rate changes motivated by recommendations of the inspectors. Annual average absence was calculated as unity minus annual ADA.

Aggregate data were collected on demographic and socioeconomic variables that could influence student absence and, thus, confound the study findings. These data were obtained for the 2001-02 school year or based on the 2000 national census from several publicly available electronic resources<sup>1</sup>. We collected data at the school level on gender and ethnicity (five categories). We also collected data, at the school level, on percent

participation in the composite of the free and reduced-cost lunch programs to be used as an indicator of student socioeconomic status (SES).

Descriptive statistics were developed, and the associations of independent variables with student attendance were determined using multivariate linear regression models. Models were developed for annual ADA, pre-visit ADA and annual average absence as dependent variables. Independent variables in the final models were as follows: 1) dCO<sub>2</sub> as a continuous variable; 2) the aforementioned student SES indicator, a continuous variable; 3) grade level; 4) type of classroom — traditional or portable; 5) the state in which the classroom was located; 6) the percentage of Hispanic students in the school as an indicator of ethnic composition. We excluded some data from final models.

## SELECTED RESULTS

Most (19 of 20) classrooms were in the main building (i.e., traditional, not portables). There was a fairly equal distribution of classrooms visited across the seven grades, except sixth grade classrooms were visited relatively less often because many primary schools in our study only included K-fifth grades. Visits to study classrooms were fairly well distributed throughout the school day, though the least number of visits occurred during unoccupied periods, e.g., recesses and lunch. Overall, about 19 of every 20 classrooms in this study were found with the HVAC system on or cycling automatically between on or off. About nine of every 10 classrooms visited were found with windows to the outside closed. Forty-five percent of visited classrooms had measured short-term indoor CO<sub>2</sub> concentrations above 1,000 ppm (59 percent in Idaho, 35 percent in Washington).

The dCO<sub>2</sub> variable was significantly ( $p < 0.05$ ) associated with the annual average daily attendance and with the pre-visit ADA. For annual ADA, the parameter estimate indicated a 0.5 percent absolute decrease in attendance, corresponding to a 10 percent relative increase in the average 5 percent absence rate, per 1,000 ppm increase in dCO<sub>2</sub>. For the pre-visit ADA, the parameter estimate indicated a 0.9 percent absolute decrease in attendance, corresponding to a relative 20 percent increase in the average 5 percent absence rate, per 1,000 ppm increase in dCO<sub>2</sub>.

# INDOOR AIR QUALITY IN NORTHWEST SCHOOLS

The traditional classroom type, relative to a portable classroom, was associated with approximately a 2 percent increase in attendance, and with a 2.5 percent decrease in absence in models using absence as the dependent variable. In each case, the associations were statistically significant ( $p < 0.01$ ).

## DISCUSSION AND CONCLUSION

In this study, 1,000 ppm increases in the difference between indoor and outdoor CO<sub>2</sub> concentration were associated with 10 percent to 20 percent relative increases in student absence, and the associations were statistically significant. One potential explanation for our findings is the lower ventilation rates, indicated by higher CO<sub>2</sub>, cause increased communicable respiratory illnesses, probably by increasing the indoor concentration of airborne infectious particles produced during coughing or sneezing.

Since the CO<sub>2</sub> measurements in this study were short-term, five-minute, measurements made on a single school day at a variable time of day, they should be considered only rough surrogates for the long-term average classroom ventilation rates that may affect long-term average absence rates. However, the models did contain variables controlling for SES, classroom type, grade level, ethnic composition and the state in which the classrooms were located. Thus, we have controlled for the most obvious sources of confounding bias, though it is still possible an unknown factor that increases absence is positively correlated with measured classroom CO<sub>2</sub> concentrations.

This study confirms previous findings of high CO<sub>2</sub> concentrations in classrooms, which indicated classroom ventilation rates were often below the minimum rates specified in codes. In this study, almost half of the indoor CO<sub>2</sub> concentrations were above 1,000 ppm and 4.5 percent were above 2,000 ppm.

Although the higher absence rate in portable classrooms was statistically significant, the small sample (25) should be considered. Before drawing conclusions, other studies should compare absence rates in portable and traditional classrooms.

This study was based on analyses of existing data. Thus, general conclusions should not be drawn from the observed linkage of higher CO<sub>2</sub> levels with increased absence. Our study does provide ample motivation for larger studies designed specifically to investigate the linkage of CO<sub>2</sub> concentrations and ventilation rates with absence. This is in part because changes in ventilation

or in other factors affecting student attendance will influence the funding provided to many school districts, since funding is often linked to annual ADA.

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\* **NOTE:** This article was based on a final report also submitted for publication in journal *Indoor Air* by: Derek G. Shendell <sup>1</sup>, Richard Prill <sup>2</sup>, Michael G. Apte <sup>1</sup>, William J. Fisk <sup>1</sup>, David Blake <sup>3</sup>, David Faulkner <sup>1</sup>

<sup>1</sup> Lawrence Berkeley National Laboratory, Indoor Environment Department (EETD), Berkeley, CA

<sup>2</sup> Washington State University Cooperative Extension Energy Program, Spokane, WA

<sup>3</sup> Northwest Air Pollution Authority, Mount Vernon, WA



**(Footnotes)**

**ID Department of Education**

<http://www.sde.state.id.us>

**WA Office of the Superintendent for Public Instruction**

<http://www.k12.wa.us/edprofile>

<http://www.k12.wa.us/>

**OSPI Programs**

‡ child nutrition, data administration, demographics, statistics); National Center for Educational Statistics

<http://nces.ed.gov/ccd/schoolsearch>