

# The Healthy and High Performance School

## A Two-Part Report Regarding the Scientific Findings and Policy Implications of School Environmental Health

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# The Healthy and High Performance School

Part 1. Science-Based  
Recommendations  
to Prevent or Reduce Potential  
Exposures to  
Biological, Chemical, and Physical  
Agents in Schools

Part 2. Improving Student Health  
Improving Student Achievement  
and  
Saving Money for Schools

**Science-based recommendations  
to prevent or reduce potential exposures to  
biological, chemical, and physical agents in schools**

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List of some public and not-for-profit institutions Internet sites on school environmental quality, and select private companies on IEQ-promoting classroom construction or finishing materials

## LIST OF ACRONYMS USED

ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers, a professional organization (e.g., writes guidelines)
CARB	California Air Resources Board
CO	carbon monoxide
CO <sub>2</sub>	carbon dioxide
dB (A)	A-weighted decibels, a measure of noise indoors or outdoors
IEQ	indoor air and environmental quality
HCHO	formaldehyde
HVAC	heating, ventilating, and air conditioning systems
LBNL	Lawrence Berkeley National Laboratory
L <sub>eq</sub> decibels	time-weighted average noise level, measured in A-weighted
MDL	analytic method detection limit
MVOC	microbial volatile organic compounds
portables	modular classrooms, also termed portable or relocatable
ppm	parts-per-million (molar volume, in air)
ppb	parts-per-billion (molar volume, in air)
RC	relocatable classroom
RH	relative humidity, in indoor or outdoor air
T	temperature, in indoor or outdoor air
UC	University of California
USEPA	United States Environmental Protection Agency
USGAO	United States General Accounting Office
VOC	volatile organic compound, a toxic or odorous chemical

# ABSTRACT

Previous U.S. Government Accounting Office reports documented survey results on the generally poor conditions of school facilities as of the early 1990s. More recently, the American Society of Civil Engineers conducted a survey that reported widespread poor conditions. In addition, previous review papers examined studies across different time intervals ending prior to 2002 on the relationships between educational facility indoor air and environmental quality (IEQ), including adequate ventilation, and occupant health and productivity. Beyond work done throughout California and the Nordic countries, research on IEQ specifically related to new or refurbished traditional school construction, or modular portable or relocatable classrooms, has been limited. This paper is not another review on the quantitative and qualitative IEQ measurements and/or quantitative and self-reported health symptom data collected in schools or from school age children at home. Instead, we present a concise review of peer-reviewed literature related to school IEQ. Then, in the context of limited resources facing American schools, we present practical science-based recommendations to improve and promote good school IEQ and hence prevent or reduce potential occupant exposure to biological, chemical, and physical agents of concern. We used National Library of Medicine and University of California (UC) library electronic search engines, conference proceeding books, the Internet, and reference lists of papers and reports gathered. We included 302 citations directly involving or highly related to school IEQ and occupant health, attendance, and productivity or performance. The references were 147 peer-reviewed journal papers; 98 papers or abstracts published in conference proceedings and journals (1990-2003); 26 U.S. government and national laboratory reports; 13 state of California and Washington-sponsored reports or policy documents; 3 World Health Organization documents; 13 reports by not-for-profit research institutions (universities, four professional societies, nine); and, 2 doctoral theses (UC). Tables summarize 18



recommendations justified by references in this review. This report was written for various school stakeholders and for policy makers at the federal and state levels to drive change in local school districts.

## **Introduction**

Many environmental, social, cultural, and personal factors (e.g., health, gender, age/developmental stage, time-location-activity patterns) influence children's exposure to pollutants across media and pathways in the microenvironments they inhabit during daily activities (Cohen Hubal et al., 2000), including differential susceptibility among infants, toddlers, young schoolchildren, and adolescents (Golub, 2000). Schools are one such microenvironment.

Federal reports on environmental threats to children's health (USEPA 1996, 2000, 2002a) have requested more research on toxic air contaminants and biological agents in urban community-based field studies in microenvironments where children spend time (e.g., homes, schools). Earlier federal government reports provided results of surveys on the generally poor conditions of American school facilities as of the early 1990s (USGAO, 1995, 1996a-b). The American Society of Civil Engineers conducted a more recent survey, which reported widespread poor conditions (ASCE, 2003).

The aforementioned USEPA reports also called for improved risk communication and environmental education. Risk communication of school research results, environmental education and recommendations must inherently be based on the best available scientific knowledge, which is condensed and delivered in a clear manner to targeted stakeholders (Shendell et al., 2002a; Shendell, 2003a-b). Asthma, a respiratory malady with acute and chronic effects, has been the leading cause of school absenteeism (millions of days) due to chronic illness in the United States (Mannino et. al, 2002; USEPA, 2002a and 2002b). In addition, a national survey by the American Lung Association and the National Association of School Nurses (ALA-NASN, 2003) reported that asthma among students of minority and under-served populations was an increasing problem. The surveyed nurses believed there were insufficient financial and information resources available to them to address health concerns among these students. In particular, more than half of the surveyed school nurses stated overall awareness of asthma triggers and awareness about asthma management strategies among parent/caregivers were poor.

Previous review papers have examined studies, for different time intervals ending prior to 2002, concerning relationships between educational facility indoor air and environmental quality (IEQ), including adequate ventilation, and occupant health and productivity (Heath and Mendell, 2002; Angell and Daisey, 1997; Daisey and Angell, 1998; Wargocki et al., 2002; Daisey et al., 2003). Beyond work done throughout California and the Nordic countries, research on school IEQ specifically related to new or refurbished traditional construction (e.g., Boone et al., 1997) or modular classrooms (portables) (e.g., Naylor, 1997; Ross and Walker, 1999) has also been limited. There was one environmental psychology study examining classroom design, in terms of mobility

related to occupant density ( $\text{m}^2 \text{ person}^{-1}$ ) and fixed versus movable objects like furniture, on everyday teacher tasks and performance (Martin, 2002). Martin's conclusion was the importance of classroom environmental quality awareness in the training and continuing education of teachers.

This paper will not be a similar review on the quantitative and qualitative IEQ and/or quantitative and self-reported health symptom data. Instead, based on reported studies from 1990 (or earlier, for journal articles) to fall 2003, the limited, schools-based peer-reviewed literature, government reports and Internet sites, and conference proceedings, were concisely summarized to determine what science-based, practical recommendations could be made. The proposed recommendations can help inform school stakeholders to act to prevent or mitigate IEQ problems. The goal is to enhance the learning and work environment of students and staff.

## **Methodology**

We used National Library of Medicine and University of California (UC) library electronic search engines and conference proceeding books owned by the authors or accessed through colleagues. In addition, we also examined the reference lists of papers and reports gathered, and were aware of previous or new government and professional association reports and school IEQ initiatives. We focused on work available to the public in print, or by Internet, in the English language. The primary keywords were school, school children, classrooms, portables or relocatables or modular classrooms, and attendance. The secondary keywords were the IEQ topics covered in this paper. The IEQ topics appear below.

1. Observed moisture damage
2. Biological agents in air and dust (bacteria, fungi, allergens)
3. Toxic and odorous volatile organic compounds, including formaldehyde
4. Direct measures and indicators (carbon dioxide) of ventilation
5. Temperature and relative humidity (as thermal comfort parameters)
6. Particles and dusts, and chemical residues like pesticides
7. Carbon monoxide
8. Persistent organic pollutants (polychlorinated biphenyls, phthalates)
9. Specific metals (arsenic, lead, mercury)
10. Asbestos
11. Radon gas
12. Lighting
13. Noise

The peer-reviewed journals of relevance covered the period 1968-fall 2003. Final federal and state of California government reports of relevance available to the public were included; case studies or less formal consultant reports were excluded; unpublished non-peer reviewed reports were also excluded. National and international conference proceeding books searched (years available) were:

1. The triennial International Conference on Indoor Air Quality and Climate (1990-2002)
2. The triennial Healthy Buildings Conference (1997, 2000)

3. Annual conference of the International Society of Exposure Analysis (2000-03)
4. Annual conference of the International Society for Environmental Epidemiology (2002-03)

We identified and have included 302 citations directly involving or highly related to school IEQ and occupant health, attendance, and productivity or performance. The references are:

- 147 peer-reviewed journal papers;
- 98 papers or abstracts published in conference proceedings and/or journals (1990-fall 2003);
- 26 U.S. government and national laboratory reports;
- 13 state of California (12) or Washington (1) agency-sponsored reports or policy documents;
- 3 World Health Organization documents;
- 13 reports by not-for-profit research institutions (universities, four; professional societies, 9); and,
- 2 doctoral theses (UC).

### **Concise Review of School-based Studies with IEQ Measurements, and Outcomes**

In general, most school IEQ studies, whether or not they also examined qualitative or quantitative outcome measures, focused on specific agents. These will be discussed in a concise manner by topic. Some studies assessed general or subjective IEQ and health outcomes (Rindel et al., 1987; Smedje et al., 1996a, 1997a; Lundin, 1999; Pettinen et al., 2000; Turk et al., 2002).

In general, school absenteeism can be an indicator of the student or teacher's overall health, although attendance patterns result from a complex interaction of many factors (Weitzman, 1986; Chen et al., 2000). Possible associations between types of ventilation, ventilation system renovation or replacement, low ventilation rates, temperature and relative humidity, and/or potential chemical, physical, and biological exposures inside traditional classrooms with student attendance and/or adverse learning or health (student and staff) outcomes have been investigated. (Pepler, 1968; Green, 1974, 1985; Norback et al., 1990; Ruotsalainen et al., 1995; Myhrvold et al., 1996; Myhrvold and Olsen, 1997; Smedje et al., 1997a-b; Wålinder et al., 1997a, 1997b, 1998; Meyer et al., 1999; Åhman et al., 2000; Smedje and Norbäck, 2000, Kim et al., 2002; Sahlberg et al., 2002; Shendell et al., 2003c).

Studies also investigated impacts on child attendance of:

1. Ambient air pollutants (Romieu et al., 1992; Hwang et al., 2000; Makino, 2000; Gilliland et al., 2001), and a hypothesis on ambient and indoor particles (Rosen and Richardson, 1999);
2. Environmental tobacco smoke and children's absenteeism related to respiratory illness (Gilliland et al., 2003);
3. Absenteeism and/or performance related to asthma (Parcel et al., 1979; Silverstein et al., 2001);
4. Various factors on teacher attendance (Ferris et al., 1988).

### ***Biological Agents***

#### ***Leaks, moisture damaged materials: Underlying conditions to biological growth if not addressed***

Based on location on school grounds, weather, local irrigation, and crawl space cross-ventilation, portable and traditional classroom floors constructed of plywood, as well as roofs and inside walls, may be subject to water condensation build-up, then damage. Moisture build-up can also occur in school kitchens (Lignell et al., 2000). Water-damaged building materials containing cellulose and other available nutrients, with or without light, provide a potential breeding ground for fungi (mold) and bacteria. These agents are measured as culturable and/or non-viable spores. Previous studies have demonstrated water-damaged indoor environments are pollutant sources. Measured air and surface concentrations of bacteria and fungi and diversity, including species of potential health concern, were higher than in non-problem buildings (Samson et al., 1994; Haverinen et al., 1999a; Rand, 1999; Sigsgaard et al., 1999; Savilahti et al., 2000; Lappalainen et al., 2001; Meklin et al., 2002a-b). In addition, a case study in the U.S. (Morey et al., 2002) examined whether fungi could enter the occupied air space of school buildings when envelope construction materials were damaged, or enter due to leaks and breaks due to poor design, poor construction, poor siting (for portables), or inadequate commissioning. Barry et al. (2003) reported from a case study that proper school HVAC system design can prevent water condensation on cooled surfaces of building materials, and subsequent moisture damage and mold growth. This appears most pertinent to regions like New England and the southeastern U.S., which have hot, humid conditions in late spring-early fall.

In a Finnish school study reported by Haverinen and colleagues (1999a), the documented moisture damage was caused primarily by poor ventilation and water leaks. The school was subsequently repaired with community input following communication of visual inspection and measurement results. Drainage and crawl space ventilation was improved and damaged materials were replaced. In another Finnish study of 41 buildings at 30 schools (31 moisture damaged, 10 not damaged), there was no clear association between building recorded characteristics and water damage status (Koivisto et al., 2002). However, the authors stated the most common reasons for moisture damage were technical aging of materials (27%)-- especially floors in concrete/brick frame buildings (possibly due to unvented crawl spaces) and external walls in wood frame buildings-- and water leaks (13%).

Meklin et al. (2000) studied 32 Finnish schools (30 with health data available) in 1994-99, which they divided into two groups: moisture damaged; non-damaged, reference schools. Though no statistically significant differences were found in measured total concentrations of airborne culturable fungi, some identified fungal groups differed. Furthermore, children in moisture damaged schools reported significantly more respiratory symptoms.

Meklin et al. (2002a) reported on a case study of two Finnish primary schools constructed

of concrete; one was found to be moisture damaged. In the five years between the baseline and follow-up assessments, which included self-administered health questionnaires, IEQ sampling, and surface moisture recorders, the damaged school was renovated. The renovation of the moisture damaged school resulted in significant decreases in the geometric mean airborne concentrations of culturable bacteria ( $p=0.006$ ) and culturable fungi ( $p=0.002$ ). Differences between the damaged school before repairs (higher) and the reference school (lower) with respect to those airborne concentrations, and number of microbial genera identified, did not persist after repairs. In addition, after repairs, significant decreases ( $p<0.05$  or better) in reported prevalence of eye symptoms, cough with and without phlegm, and rhinitis, as well as other general symptoms, were observed. A case study of staff from a Danish school rebuilt after a long history of water damage also reported the prevalence of mucosal and general symptoms, including eye irritation (from 29% to 7%), significantly declined (Sigsgaard et al., 1999, 2000).

Haverinen et al. (1999b, 2002) reported on a case study of a Finnish upper secondary school before and after comprehensive repairs of moisture damage (see Haverinen et al., 1999a). Self-administered student health symptoms questionnaires, technical inspections, and relevant IEQ sampling were conducted. For students attending the school and responding to the questionnaire twice (1996 and 1997,  $n=157$  of 245) or three times (1996, 1997, 1999,  $n=49$ ), their paired, individual level observations were examined. Results showed significant ( $p<0.05$  or better) declines in the prevalence of eight symptoms at first follow up, including rhinitis and difficulties in concentration. The crude prevalence was lower for 11 symptoms -- including rhinitis, asthma, eye symptoms -- but higher for eight symptoms at second follow-up. Though the small sample size likely precluded significant findings at second follow-up, the authors stated overall results suggested no new cases of symptomatic students were expected after repairs.

Rudblad et al. (2000, 2001) reported results of a study of a Swedish school with a long history of dampness. Staff and 1<sup>st</sup> grade students (90, 45 each from damp and reference schools) were included. They used, before and one year after renovation, a standardized health questionnaire and two types of quantitative health symptom tests—mucosal sensitivity based on a nasal histamine provocation test, and presence of atopy based on a skin prick test. No differences were observed among students from the damp and reference schools. However, in the damp school after renovations, differences were seen among staff and students—staff demonstrated more mucosal symptoms, but prevalence of atopy among students was about a factor of two higher. These results suggested possible differential susceptibility, in problem and non-problem (or post-renovation) buildings, due to age, gender, underlying health status, and/or agents not studied.

Patovirta et al. (2003) conducted a case study of one moisture-damaged school and one reference school in Finland with teacher health questionnaires, spirometry, and blood samples in the spring before (1997) and after (1999 and 2000) remediation was completed. Asthma prevalence at baseline among participants in the moisture and mold-damaged school ( $n=31$ ) was 26%, but no new cases appeared during follow-up after repairs. In addition, eye irritation and several respiratory symptoms decreased in prevalence during follow-up.

Three markers in nasal lavage fluid of the inflammatory potential of airborne microbial agents, collected from staff (n=28) in a moisture-damaged Finnish school, were significantly increased ( $p < 0.01$  for each) during the working period compared to a vacation period (Roponen, 2003).

Other studies in Nordic countries have reported measurements of allergy, respiratory symptoms, and infections among students in moisture and mold-damaged schools or day care centers (Koskinen et al., 1995; Taskinen et al., 1997, 1999; Savilahti et al., 2001). There were also studies with skin-prick tests (Immonen et al., 2001) and of the effect of exposure to airborne (1 $\rightarrow$ 3)-beta-D-glucan (Rylander, 1997; Rylander et al., 1998) or to a microbial disinfectant introduced through the ventilation system (Sesline et al., 1994).

#### *Biological, non-infectious agents in air and dust*

##### Bacteria and fungi, and cell wall components or metabolites

In several case studies in Finland and the U.S., the most common fungal groups reported from culturable indoor air samples were *Penicillium*, *Cladosporium*, *Aspergillus*, yeasts, and non-sporulating isolates (Sigsgaard et al., 1999, 2000; Kalliokoski et al., 2000, 2002; Meklin et al., 2002a; Morey et al., 2002; Barry et al., 2003). Total culturable airborne bacteria as well as cell envelope components have also been measured (Liu et al., 2000). A laboratory-based environmental chamber study with samples of materials used in school construction and interiors identified metabolites, most of which were non-reactive, from microbes growing on particleboard, gypsum board, and wood (Claeson et al., 2002). However, potentially odorous aldehyde emissions decreased during microbial growth.

Kalliokoski et al. (2002) assessed kitchens, dining halls, and classrooms of six moisture-damaged schools and two reference schools within the Finnish school study population already described. Average total airborne concentrations of culturable fungi, across study areas within buildings, were higher in the moisture-damaged than reference schools, and the difference was statistically significant in the classrooms.

Smedje et al. (1996b) studied measured indoor pollutant concentrations in 96 classrooms and self-administered questionnaire responses on health symptoms of 1410 adult employees (85% response) from 38 participant schools (of 40 randomly selected) in county of Uppsala, Sweden. They reported a significant association between physician-diagnosed asthma and total airborne fungi (odds ratio (OR) 1.6, 95% CI 1.1-2.7,  $p=0.023$ ) and four microbially produced volatile organic compounds (MVOCs; OR ranged 1.2-3.8, 95% CI did not include 1,  $p < 0.05$ ). Sahlberg et al. (2002) studied sick building syndrome symptoms (SBS) among school staff in the same schools. They repeated questionnaires three times (1993 $\rightarrow$  1410 participants or 85%, 1995, 1997) and IEQ measures twice (98 classrooms in 1993, 101 classrooms in 1995). They reported a positive, significant association between total airborne bacteria (number  $m^{-3}$ ) and eye symptoms (adjusted OR 2.5 per 10-fold increase, 95% CI 1.3-4.9,  $p < 0.01$ ). The Copenhagen school study also reported a significant association between visible moisture damage with mold growth and increased prevalence of SBS (Meyer, 1999).

Norbäck et al. (2002) assessed 1414 participating students from 10 schools in Shanghai, China (of 1435, 99%) with a self-administered questionnaire in winter 2000. In 30 home-classes, indoors and outdoors, qualitative inspections and quantitative sampling of airborne total and viable (culturable) bacteria and fungi as well as MVOC, and settled dust for markers of these biological agents, were conducted. Forty-five percent of the students reported respiratory infections, which were positively and significantly associated with culturable airborne fungi ( $p=0.04$ ), culturable airborne bacteria ( $p=0.02$ ), and a MVOC, 3-methylfuran ( $p=0.04$ ). Studies in Taiwan have also suggested indoor exposure to bioaerosols may have health implications in schools (Su et al., 2001) and child care centers (Li et al., 1997a-b).

### Allergens

Allergens in floor and surface dust in school classrooms, which likely were transported on children's clothes from homes (Berge et al., 1998), may influence the prevalence and severity of asthma symptoms and allergies (Dybendal et al., 1989; Dybendal and Elsayed, 1992; Munir et al., 1993; Dotterud et al., 1997; Patchett et al., 1997; Perzanowski et al., 1999a-b; Almqvist et al., 1999, 2001; Smedje and Norbäck, 2001a-b; Douwes et al., 2003). Pollen allergen, however, is predominantly from outdoor air (Kvernes et al., 1999; Matson et al., 2002).

Wady et al. (2003) sampled allergens and microbial components in settled dust in two schools (one rural, one urban) in each of Jordan, Poland, and Sweden. Dust was collected on plates suspended from ceilings at children's breathing zones. Though the marker of bacterial biomass exhibited minimal variation, markers of identified groups and fungal biomass varied considerably. These results suggested different potential exposures to microorganisms inside school classrooms between countries, seasons, and urban versus rural settings.

Ramachandran et al. (2002) compared IEQ and outdoor measures at a newer school building with an older school building in metropolitan Minneapolis, MN. Reported measurements were below current sensitization or symptoms guidelines (IOM, 1993; AIHA, 1996) for cat allergen (*Fel d 1*,  $8 \mu\text{g g}^{-1}$ ) and dust mites *Der p 1* and *Der f 1* ( $2 \mu\text{g g}^{-1}$  or  $10 \mu\text{g g}^{-1}$ , respectively). Also, most cockroach allergen (*Bla g 1*) measurements were low ( $<\text{MDL}$  (method detection limit) to  $3 \mu\text{g g}^{-1}$ ). Tortolero and colleagues (2002) assessed 385 classrooms in 60 elementary schools in southeast Texas. They reported only 2.5% of rooms had *Der f 1* exceeding recommended guidelines, and only 10% of rooms were over the recommended threshold for *Bla g 1* though it was found in every school. These findings may reflect adequate cleaning practices. Wickman et al. (1999) examined the effect of general cleaning, ventilation, and occupant pet ownership on allergen levels in day care centers.

Floor dust was collected from 23 classrooms in county of Uppsala, Sweden, where floors were cleaned daily by staff and desks wiped by students 1-5 times per week. Floor dust was also collected from 30 classrooms in Shanghai, China, where students cleaned floors and desks daily. Four allergens (*Der p 1* and *Der f 1*, *Bla g 1*, and mold allergen *Alternaria alternata*, *Alt a 1*) were never reported above MDL. Again, these results were

likely due to the good cleaning practices. Furthermore, *Fel d 1*, dog (*Can f 1*), and horse (*Equ cx*) allergens were almost always below MDL in the Chinese schools, but always much higher than the MDLs in the Swedish schools. One could infer this was not only because of cultural characteristics and outdoor surroundings, but also because of the relatively higher frequency of reported desk cleaning among schools in Shanghai. (Mi et al., 2002)

A mechanical HVAC system with a common fine filter has been demonstrated to remove 95-99% of birch tree pollen grain allergen (*Bet v 1*), depending on the filter efficiency rating (Ekberg et al., 2000). Matson et al. (2002) measured indoor and outdoor air concentrations of *Bet v 1* in one pre-school and one day care center in Sweden. Indoor/outdoor ratios (I/O) were below one, confirming the dominant outdoor source. The I/O was over a factor of three lower when the HVAC was off, windows were closed, and occupant activity was minimal compared to when the HVAC was on, windows were open, and occupant activity was high. When windows were closed but the HVAC on and activity high, the relative difference was about a factor of two. These results suggested several open windows, relative to operation of the mechanical HVAC system with filtration, drove indoor *Bet v 1* levels.

#### *Summary: Biological agents*

In conclusion, these studies collectively suggested remediation of moisture and mold-damaged school buildings, particularly classrooms, and primary prevention through diligent operations, maintenance, and cleaning practices, improved IEQ and occupant health. In addition, the studies on measurements of biological agents in school classrooms around the world collectively suggested levels in air and surface dust are generally low relative to outdoors, especially when good hygiene practices are present.

#### ***Chemical Agents and Particles***

##### *Toxic and odorous volatile organic compounds (VOCs)*

Materials used to construct and furnish portable classrooms, and traditional school buildings especially if new or modernized, may off-gas toxic and odorous volatile organic compounds (VOCs) including formaldehyde (HCHO) and acetaldehyde as a function of age, temperature, and relative humidity (Lewis, 1991; CARB, 1993; Hodgson et al., 1993, 1999, 2000, 2001, 2002, 2003; Norbäck, 1995; Zhang et al., 1994; Kelly et al., 1999; Claeson et al., 2002). Associations between emissions from such materials and other indoor sources with adverse child respiratory outcomes were investigated (Jaakkola et al., 1999, 2000; Herbarth et al., 2003). These studies included potential exposure to HCHO, a known human sensory and respiratory irritant (CARB, 1991; USEPA, 2003a) and allergen (Wantke et al., 1996; Garrett et al., 1999). Nikolic (2000) studied IEQ over 20 consecutive winter days in classrooms of two primary schools in Nis, Yugoslavia; “school 1” was located in an industrial zone near a busy street, and “school 2” was situated away from major outdoor pollution sources and enclosed by vegetation. Low integrated daily indoor HCHO concentrations were associated with no new construction materials and furnishings; measured concentrations in “school 1” were relatively higher



than in “school 2” possibly due to relative proximity to primary and secondary ambient HCHO sources.

Several VOCs, especially odorous compounds, and potential endocrine disrupters and neurotoxicants including phthalates, have been found in constituents of various consumer products and measured in indoor air of homes, offices, and schools. These included personal care products (hair, facial beauty, nail polish and remover), cleaning compounds, and teaching supplies and materials (Wallace et al., 1991, Hodgson, 1999; CARB, 1991, 1993, 2001; Smedje and Norback, 2001a; Martins et al., 2003). The European Union task force on school IEQ cited the presence of multiple VOC sources such as paints, cleaners, interior finish materials and furnishings (Carrer et al., 2002). A recent laboratory toxicology study reported acute respiratory irritations and behavioral abnormalities in normal mice after exposure to eight different felt-tip markers and a white dry-erase board cleaning solution, which emitted a mixture of VOCs (Anderson and Anderson, 2003). School studies have suggested the use of chemical cleaning compounds and air fresheners during occupied hours and/or during overnight custodial cleaning, when there was likely inadequate ventilation, drove measured concentrations of VOCs (Cavallo et al., 1993; Torres et al., 2002; Shendell, 2003; Shendell et al., 2002d, 2003a; Batterman et al., 2003a).

Reactive, unsaturated organic chemical compounds (e.g., d-limonene, alpha- and beta-pinene), which are common constituents of cleaning compounds with recognizable odors, and other VOCs in heterogeneous reactions on indoor surfaces, especially in the presence of ozone entering from the outdoors, may produce concentrations of other pollutants of health concern. These include fine and ultrafine particles and oxidation products. (Wainman et al., 2000; Wolkoff et al., 2000; Fielder et al., 2002; Klenø and Wolkoff, 2002; Rohr et al., 2002; Wilkins et al., 2002; Fan et al., 2003).

*Building interior finish materials and furniture: “sources” and “sinks” of VOCs and particles*

Carpets and other flooring surfaces, adhesives, and office equipment typically found in schools such as photocopiers and laser printers, have been demonstrated in laboratory environmental chamber and field studies to be sources of VOCs (Hansen et al., 1987; Hodgson et al., 2001, 2002, 2003; Lee et al., 2003). Other studies focused on carpets and open shelves (flat, exposed surfaces) as sinks for and thus sources of indoor pollutants such as dust, which can contain particles, allergens, and/or pesticide residues (e.g., Hansen et al., 1987). Floor carpets, which can cover a large surface area and vary in pile thickness, can hold a large quantity of dust unless properly vacuumed. In a study of 181 classrooms in 48 schools in the county of Uppsala, Sweden (Smedje and Norbäck, 1999a), HCHO concentrations and settled dust were higher in classrooms with more fabrics ( $p < 0.05$ ) and with more open shelves ( $p < 0.001$ ). This finding persisted after adjusting for measured ventilation rates, which correlated ( $p < 0.01$ ) with several IEQ measures.

*Particles generated, tracked in as soil, and/or re-suspended, including pesticide residues*

Particles with aerodynamic diameters in the respirable ranges—coarse (2.5-10  $\mu\text{m}$ ), fine (0.1-2.5  $\mu\text{m}$ ), and ultrafine ( $< 0.1 \mu\text{m}$ ) – are of public health concern. Numerous studies have supported their role, when measured in ambient air, personal air, and in the indoor air of residential or occupational settings, in adverse respiratory and cardiovascular outcomes. Sources of particles in schools include soil tracked in from the outside; re-suspension from carpets or smooth flooring acting as reservoirs (sinks), as a function of occupant activity and overall maintenance (cleaning); penetration of the building envelope from the outdoors; delivery through a mechanical HVAC system with insufficient filtration; and, generated by combustion sources within buildings (e.g., boiler room). For example, Elfman et al. (2000) conducted a case study of the reopening of a refurbished, thoroughly cleaned school in Sweden. Airborne levels of particles increased over the first two months and varied due to occupant activity.

Few studies have been conducted regarding pesticide residues, and/or metals and polycyclic aromatic hydrocarbons of potential health concern, in settled dust collected from carpets, smooth flooring, and other surfaces inside classrooms. Insecticides and pesticides inside classrooms (Fischer and Eikmann, 1996) or on school grounds may be used in varying quantities, frequencies, duration, and times of day and seasons. In the California Portable Classrooms Study (CARB, 2003c), chlorpyrifos was found above MDL in over 80% of monitored portable and traditional classrooms. Morgan et al. (2003) presented preliminary results on concentrations of chlorpyrifos and its metabolite, 3,5,6-trichloro-2-pyridinol, in day care centers of 130 recruited North Carolina pre-school age children. Levels in dust were about 1-2 orders of magnitude relatively higher than in samples from adjacent outdoor soil, hand wipes, indoor air, and urine. Wilson et al. (2003) reported preliminary results (1<sup>st</sup> year) of a pesticide exposure study of preschool children. Chlorpyrifos has been subjected to a mandatory phase out of its sale and use in homes and schools since late 2001. However, use of existing stock purchased prior to federal and local legislation could occur in homes and schools, with or without proper notice. Thus, measured concentrations could represent recent and/or historical use.

A study of senior high school students and personnel (8853 and 1023, respectively, 16 schools) in metropolitan Stockholm reported a high prevalence of dust and dirt, and high indoor air temperatures, as perceived IEQ problems from self-administered surveys (Andersson et al., 2002). Reported symptoms were higher among students, and females in general. In the previously described Swedish study by Sahlberg et al. (2002) of SBS among school staff, there was a positive and significant association between respiratory dust ( $\sim\text{PM}_{10}$ ) and respiratory infections (adjusted OR 1.31 per  $10 \mu\text{g m}^{-3}$  increase, 95% CI 1.06-1.58,  $p < 0.05$ ). Smedje and Norbäck (1999b) conducted a study with two separate rounds of classroom assessments and self-administered questionnaires of 1476 pupils (of 2034 invited) between ages 7-13 from 39 schools (of 40 randomly selected) in county of Uppsala, Sweden. Students attending schools with higher amounts of measured settled dust on floors and furniture and dog allergen had a higher incidence of current asthma symptoms. However, asthma symptoms were lower among students attending schools where new HVAC systems had been installed between the two investigations in 1993 and 1995. These results may reflect how mechanical HVAC

systems, which filter the combination of fresh outdoor air and recycled indoor air, can reduce indoor levels of dust particles and constituents. Nevertheless, some studies have suggested, based on laboratory experiments and office building assessments, HVAC system filters can be sources of chemical and microbiological pollutants including odors (e.g., Souto and de Oliveira Fernandes, 2000).

The Copenhagen study on school facility conditions and building related symptoms (BRS), based on 7884 of 11978 returned employee and student self-administered questionnaires, included 75 schools and 78 of 112 identified classrooms. Among the results, data suggested the *in vitro* inflammatory potentials of settled dusts collected from floors were significantly higher ( $p < 0.0001$ ) among the ten schools with the highest mean prevalence of eight reported BRS (“worst”) compared to the ten “best” schools. The substance within the dust’s organic fraction causing inflammatory potential was not identified. (Meyer et al., 1999; Allermann et al., 2002).

Norbäck et al. (2000) and Wålinger et al. (1999, 2000, 2001) reported on the use of acoustic rhinometry, nasal patency, and nasal lavage fluid biomarkers as quantitative indicators of effects of settled dusts, cleaning practices and products, and building characteristics, in Swedish schools.

#### *Carbon monoxide and combustion-related pollutants from nearby outdoor sources*

Sahlberg et al. (2002) reported low levels of carbon monoxide (CO) in a previously described Swedish school study (average  $0.2 \mu\text{g m}^{-3}$ , range  $< 0.1-0.9$ ). Shendell (2003) reported CO concentrations inside Los Angeles Unified School District portable classrooms of varying ages in winter 2001. The mean and median weekend and daily morning and afternoon integrated averages were low ( $< 2$  parts-per-million (ppm)). However, the maximum reported indoor value was on a morning when researchers observed and teachers reported medium-sized diesel and gasoline fueled trucks idling while delivering supplies for the cafeteria and main office stockroom before and into school hours. The specific influence of school buses, particularly conventional, older buses powered by high or low sulfur diesel fuel, on children’s exposures was recently studied by the University of California (CARB, 2003a; Fitz et al., 2003; Behrentz et al., 2003; Sabin et al., 2003; Winer et al., 2003). Although the study focused on the range of exposures inside buses during different commuting routes, under various defined conditions, there were specific aspects of their findings and concurrent policy actions relevant to school IEQ. Loading and unloading children at the participating schools contributed less to overall commute-related exposures, due to the low concentrations in ambient air found at those locations and the relatively shorter lengths of time involved. The investigators made several recommendations to reduce children’s exposure to bus-related pollutants, including reducing idling time. In December 2002-July 2003, the California Air Resources Board initiated and approved an airborne toxic control measure (CARB, 2003b). This action limits school bus idling prevalence and duration within 100 feet of school buildings (e.g.,  $< 30$  seconds while loading students at school). Similarly, the USEPA initiated in April 2003 the “Clean School Bus USA Program” to reduce unnecessary idling and to increase the retrofitting or replacement of older diesel school buses (USEPA, 2003b).

In summary, neither buses nor trucks powered by diesel or gasoline engines should be allowed to remain idling near school facility outdoor air intake vents, which is particularly a concern for portable classrooms or buildings with wall-mount, not rooftop, HVAC systems. Such a policy would reduce indoor concentrations of CO, particles, and other vehicle-related combustion pollutants such as polycyclic aromatic hydrocarbons and nitrogen oxides.

### ***Physical Agents and Related Characteristics of Schools***

#### *Direct measures, or carbon dioxide concentrations as indicators, of inadequate ventilation*

Portable and traditional classrooms including childcare facilities are usually more dependent on mechanical ventilation to provide fresh outside air than windows, if operable, and doors. ASHRAE Standard 62 (1999) stated  $15 \text{ ft}^3 \text{ min}^{-1} \text{ person}^{-1}$  of filtered outdoor air should be supplied to the occupied indoor space. Review articles (Angell and Daisey, 1997; Daisey and Angell, 1998; Daisey et al., 2003) have stated reported ventilation and CO<sub>2</sub> data from the U.S., including federal NIOSH investigations, indicated inadequate outdoor air ventilation in many school classrooms and poor HVAC system maintenance. A USEPA school evaluation program for radon reduction (26 schools, eight regions) found most schools did not meet current standards for school ventilation (Chmelynski and Leovic, 1992; Parker, 1992). Each school reported having one or more ventilation problems, and the various HVAC systems were usually not designed or operated properly. One case study examined effects of operable window installation in a “sealed” school without mechanical HVAC (Landrus et al., 1987).

The California Energy Commission (1995) found measured ventilation rates (air changes per hour, ACH or AER,  $\text{hr}^{-1}$ ) in one-third of classrooms tested were  $< 50\%$  of the level required by state codes and ASHRAE Standard 62. Quantitative measurements of ventilation rates for school classrooms have also been conducted during unoccupied hours with sulfur hexafluoride tracer gas decay (Shaughnessy et al., 1997; Turk et al., 1997) and during occupied hours with a non-toxic perfluorocarbon tracer gas (Shendell, 2003; Shendell et al., 2003b). Ruotsalainen et al. (1993) reported quantitative spot measurements of exhaust air flow as an indicator of ventilation system performance in day care centers in Espoo (metropolitan Helsinki), Finland at the time of measured equilibrium carbon dioxide (CO<sub>2</sub>) levels.

Measured indoor air concentrations of CO<sub>2</sub>, produced by human respiration, and CO<sub>2</sub> decay curves have been used worldwide as indicators of inadequate ventilation in schools. (Bakke and Levy, 1990; Norbäck et al., 1990; Thorstensen et al., 1990; Kurnitski and Enberg, 1997; Myhrvold and Olsen, 1997; Rodríguez et al., 1997; Shaughnessy et al., 1997; Turk et al., 1997; Lee and Chang, 1999, 2000; Smedje and Norbäck, 1999a; Braganza et al., 2000; Scheff et al., 2000; Kinshella et al., 2001; Corsi et al., 2002; Pasanen et al., 2002; Prill et al., 2002; Ramachandran et al., 2002; Ribéron et al., 2002; Sowa, 2002; Tortolero et al., 2002; Batterman et al., 2003b; Fox et al., 2003)

A European Union task force, which examined 73 journal papers or conference proceedings from 1990-2000 on IEQ in European schools, reported inadequate ventilation in schools as indicated by elevated CO<sub>2</sub> concentrations and relative humidity (Carrer et al., 2002). After new ventilation systems were installed in 12 of 100 classrooms in the 39 randomly selected schools in the previously described Swedish school study in county of Uppsala, Smedje and Norbäck (2000) reported the measured AER increased and concentrations of several monitored pollutants as well as relative humidity declined. In 15 Finnish school buildings, which received ventilation renovations (mechanical or natural), although indoor air temperatures remained high before (mean 23°C) and after (mean 22°C) renovations, the measured indoor CO<sub>2</sub> concentration range decreased from 1200-2400 ppm to <1250 ppm (Jalas et al., 2000).

Gunnarsen (2000) reported on a historically poorly maintained Danish school and the remediation of its mechanical ventilation system, windows, temperature controls, and ceiling heights. The interventions resulted in some IEQ improvements due to enhanced user controls. Hunter (1990) reported on interventions in a windowless secondary school in Toronto, Canada to improve the mechanical HVAC system-- increasing outdoor air intake and air circulation, new humidification system and heat exchangers. The result was quantitative compliance with thermal comfort guidelines.

#### *Indoor air temperature and relative humidity, thermal comfort*

Ventilation, mechanical and/or natural through windows, also affects occupant thermal comfort, a combination of indoor air temperature (T) and relative humidity (RH) as well as air velocity and clothing; ASHRAE Standard 55 (1992) provides guidelines for acceptable occupant thermal comfort during winter (heating season) and summer (cooling season). However, ASHRAE Standard 55 (1992) was developed for adults, typically in the office environment, and it is not known how well these conditions apply to children in school environments. Furthermore, the Standard 55 guidelines may not always be appropriate for tropical climates such as Hawaii (Kwok, 1997, 1998). Indoor air T and RH are also influenced by occupants through occupant density and their activity levels, i.e., respiration and perspiration. School studies in Las Vegas (Shaughnessy et al., 1997), Santa Fe, NM (Turk et al., 1997), Los Angeles (Shendell, 2003; Shendell et al., 2003b), Copenhagen, Denmark (Thorstensen et al., 1990) and Uppsala, Sweden (Smedje and Norback, 1999a; Sahlberg et al., 2002) reported measured AER, T, and RH.

The recently completed LBNL relocatable classroom (RC) study (Apte et al., 2002, 2003) suggested mechanical ventilation, natural ventilation as desired and possible, and appropriate teacher T set points could allow RCs to achieve both good IEQ and compliance with acceptable seasonal T and RH ranges in ASHRAE Standard 55 (1992). In the LBNL study, though there was negligible vertical T stratification when HVAC systems operated, when ASHRAE Standard 55 was not met it was usually due to measured indoor air RH. In the LBNL and UCLA school studies (Shendell et al., 2002b, 2003b; Shendell, 2003), indoor air T and RH measured adjacent to the dry-erase board at three different heights, and/or near the teacher work station at standing height, were influenced by several factors. These included afternoon cooling and morning heating demands on mechanical HVAC system operation; attributes of the mechanical HVAC

system technologies; occupants; ambient conditions; and, teacher T set point preferences.

Measures of indoor air RH can also serve as indicators of condensation build-up on interior surfaces, and thus potential moisture damage of materials and subsequent mold growth. For example, Bates and Mahaffy (1996) investigated 13 classrooms in six schools in Florida. Indoor air and carpet concentrations of dust mite allergens and airborne culturable fungi, relative to outdoors, were low. Nevertheless, reported occupant health complaints and musty odors, and visible mold, were associated with higher (> 70%) average indoor air RH.

### *A-weighted Noise Levels*

Noise is any unwanted, extraneous sound. People can detect minute changes in sound level; an increase of three A-weighted decibels (dB (A)) is just noticeable, five dB (A) is clearly noticeable, and 10 dB (A) is considered twice as loud (ASHRAE, 1989). At birth, the human inner ear has completely developed; hair cells and nerve fibers cannot regenerate once destroyed by noise (Lancet, 1991; Clark and Bohne, 1999; WHO, 2001b). Children, during their formative years of academic development, require better acoustic quality than adults in classrooms, especially given good speech recognition is necessary for optimal comprehension and learning during the processes of language and reading acquisition (WHO, 2001a-b). Children are ineffective listeners to speech (i.e., cannot hear and understand) in noise until adolescence (Nelson, 2003). Children with hearing impairments, and learning and/or attention disorders, are especially susceptible and have unique needs, as do those learning in a second language (Nelson, 2003).

Typical classroom sources of noise are listed below.

1. Noise from the outdoors, such as playgrounds, construction, and nearby traffic.
2. Mechanical noise, for example, when the HVAC system and adjacent classroom surfaces vibrate to produce airborne noise. A survey by Parker (1992) found the unit ventilator was the most popular HVAC system in U.S. schools, but noise and operating limitations-- the fan must always be on to effectively provide adequate ventilation-- have reduced its popularity.
3. Noise from other indoor sources. These include occupants, TV/VCR, and lighting ballasts and dimmers (transformer humming), including reverberation.

There have been to our knowledge, however, few published scientific studies on quantitative exposure to noise levels in American school classrooms due to indoor and outdoor sources, although non-regulatory guidelines have been established (see Appendix I). One study was conducted in New Zealand (Blake and Busby, 1994). A study conducted by the University of Florida at Gainesville suggested noisy classrooms may hinder student learning ability; students had difficulty hearing the teacher when > 12 feet away and noise levels exceeded the average background of 50 dB (A), even though normal conversation is about 60 dB (A) (Wakefield, 2002). Braganza et al. (2000) reported on one of the USEPA school IEQ demonstration studies. One set of measurements Tuesday-Thursday during occupied hours at four indoor sites and one outdoor location per school were conducted at eight public schools across the U.S. prior to energy efficiency retrofits and interventions, e.g., implementation of USEPA *Tools for*

*Schools.* Across the eight schools, mean sound levels ranged 45-62 dB (A) and the maximum five-minute sound levels ranged 70-81 dB (A). These data were consistent with the recent study of new California RCs by LBNL (Apte et al., 2002, 2003; Shendell et al., 2002b-c)-- mean school day  $L_{eq}$  across classrooms and wall-mount HVAC systems were approximately 56 dB (A). There was one previous study in California schools in traditional buildings (CDE, 1986).

The acoustic design goal for a mechanical HVAC system, where specific noise control techniques are a function of space-use requirements, is usually a low-level background sound (ASHRAE, 1989). Measurements in dB (A) compensate for the human ear's lower sensitivity to lower frequency and very high frequency sounds (ASHRAE, 1989). Thus, though dB (A) correlates well with human judgment of relative loudness, the metric does not correlate as well with human judgment of relative noisiness or subjective sound quality, i.e., comparing sounds with distinct spectral or tonal characteristics including frequency (ASHRAE, 1989). High-frequency sounds may be relatively more hazardous to human hearing, and high-frequency, intermittent, and impulsive sounds may be more annoying due to their temporal unpredictability. A large proportion of low-frequency components in noise may have adverse effects (WHO, 2001a).

Scientific evidence has suggested chronic noise exposure in communities near air, road, and/or rail traffic, as a stress and distracting stimulus, can lead to noise-induced hearing loss, annoyance, sleep disturbance, stress, mental health and behavior problems, and decreased school performance and cognitive delays. These include trouble with word discrimination, reading, problem solving, memorization, and interference with speech communication. There was also evidence of elevated blood pressure and heart disease in adults and children. (Slater, 1968; Wyon, 1970; McLean and Tarnopolsky, 1977; Ising et al., 1980, 1990; Gunn et al., 1981; Cohen and Weinstein, 1981; Westman and Walters, 1981; DeJoy, 1984; Siebert, 1989; Clark, 1991; Duncan et al., 1993; Powers, 1993; Sanz et al., 1993; Bond, 1996; Soli and Sullivan, 1997; Evans et al., 1998, 2001; Lercher et al., 1998, 2002; Maxwell and Evans, 2000; Passchier-Vermeer and Passchier, 2000; Booker, 2001; Haines et al., 2001a-c, 2002a-b, 2003; Manlove et al., 2001; WHO, 2001 a-b; Van Kamp et al., 2002, 2003; van Kempen et al., 2002; Wakefield, 2002; Jovanovic, 2003).

#### *Fluorescent lighting and daylighting*

Lighting and daylighting through windows and skylights have recently been studied in relation to physical development and academic performance (Hathaway, 1995; Hescong Mahone Group, 1999). In addition, the study by Sahlberg et al. (2002) of SBS among Swedish school staff reported several relevant findings. Illumination (per 100 lux increase) and lighting effect (per 10 W m<sup>-2</sup> increase) were significantly associated with decreased fatigue, a general symptom (adjusted OR (95% CI) of 0.90 (0.84-0.99) and 0.59 (0.38-0.90), respectively, p<0.05). Lighting effect (per 10 W m<sup>-2</sup> increase) was also significantly associated with fewer eye symptoms (adjusted OR (95% CI) 0.43 (0.21-0.90), p<0.05). The daylight factor, which was based on each 10% increase in window area (m<sup>2</sup>) per floor surface area (m<sup>2</sup>), was significantly associated with fewer headaches, a general symptom (adjusted OR (95% CI) 0.62 (0.39-0.99), p<0.05).

Newer, improved fluorescent light bulbs, fixtures, and electronic ballasts may provide energy, economic, and pollution reduction benefits due to longer life spans and changes in component materials. At present, there is little peer-reviewed published data for conclusions on health and performance in schools due to relative advantages or disadvantages of artificial versus natural light. However, work emerging on this topic suggests benefits to daylighting. We can thus support some comments. First, glare from incident sunlight on to or reflecting off surfaces (e.g., desks, computer screens) should be reduced to the extent practical. Second, there is a guideline regarding quantity of light to be provided indoors to students (IENSA, 2000 discussed in Shendell et al., 2002b): 50 foot-candles for low contrast materials, 30 foot-candles for high contrast materials. Third, student desks should not be placed directly in front of windows due to the potential negative impact on learning (reading) and thermal comfort. Finally, when indirect natural light through windows or skylights is sufficient, fluorescent lights should be turned off. This will save energy and money and assist school occupants whose health and learning are affected by artificial light, a condition termed Irlen Syndrome or Scotopic Sensitivity Syndrome. The condition is caused by hypersensitivity to the physical properties within light sources (spectrum of colors, wavelengths). Several medical studies have examined this class of learning disabilities in school children, which includes reading disorders and attention deficits (Lehmkuhle et al., 1993; Robinson et al., 1995). Other medical studies have examined the practicality and short and long-term efficacy of interventions for children, e.g., Irlen tinted lenses, colored versus clear plastic transparencies on books (Robinson and Miles, 1987; Saint-John and White, 1988; Whiting et al., 1988; Cotton and Evans, 1990; O'Connor et al., 1990; Robinson and Conway, 1990, 1994; Williams et al., 1992; Menaker et al., 1993; Tyrrell et al., 1995; Jeanes et al., 1997).

***Persistent organic pollutants and possible endocrine-disrupting chemicals:  
Present concerns possibly present in older schools***

Polychlorinated biphenyls (PCBs) are likely present in schools with fluorescent light fixtures not replaced after 1979. PCBs, with low electrical conductivity, had been used in the small magnetic capacitors and in the insulating potting material (USEPA, 2001). Newer, more energy-efficient, and higher quality light producing T-8 or T-5 electronic capacitor-based ballasts, which are generally recommended for “green,” sustainable design, do not contain PCBs. U.S. production of PCBs stopped in 1978 under the Toxic Substances Control Act of 1976. Older ballasts breakdown and become susceptible to leaks and fires, hence accidental exposures to PCBs.

PCBs and other persistent organic pollutants, especially endocrine-disrupting chemicals, have been shown in ecotoxicology and laboratory toxicology studies to mimic hormones across gender and disrupt the endocrine system. These changes might lead to other adverse health consequences, e.g., child neurobehavioral and physical development, reproductive health of young female teachers (Gabrio et al., 2000; Heindel, 2000; Suk et al., 2003). Potential exposures of young children at school may occur due to mouthing, chewing, or gnawing soft, flexible toys and other materials containing or covered with



residues of such chemicals. The present concerns include pesticide residues, fertilizers on grounds, and plasticizers including phthalates. Phthalates can be found in foods, consumer products, and certain interior finish materials (Jaakkola et al., 1999, 2000; Simoneau, 2003; Suk et al., 2003).

The phthalates of high present concern in the media and to governments in Europe, Japan, and the U.S. are di-2-ethylhexyl phthalate (DEHP), dibutylphthalate (DBP), diethylphthalate (DEP), and diisononyl phthalate (DINP). DEHP was recently listed (October 24, 2003) by the California Office of Environmental Health Hazard Assessment, under Proposition 65 (Safe Drinking Water and Toxic Enforcement Act of 1986), as a known toxicant for developmental and male reproductive endpoints based on laboratory toxicology studies (OEHHA, 2003). In 1986, the U.S. started a voluntary agreement with manufacturers to remove or limit phthalates in plastic, soft flexible toys. The European Union and Japan recently established bans on DINP and/or DEHP to protect pre-school children (<3 and <6, respectively).

Polyvinyl chloride (PVC) flooring contains plasticizers like phthalates, and because it is of low cost and easy to maintain and to clean, it has been used in school classrooms and other areas around sinks and lab benches. Koch et al. (2003) reported, based on first morning urine samples of 36 German kindergarten children ages 2-6 and 19 adult staff and parents, widespread exposure to DEHP, with levels of metabolites in urine higher in children than in adults tested. Jaakkola et al. (1999), in a matched case-control study of newborns (n=251 pairs) followed for two years, reported a significant elevated risk of bronchial obstruction when PVC flooring was present compared to wood or parquet flooring (adjusted OR 1.89, 95% CI 1.14-3.14). In a population-based cross-sectional study of 2553 Finnish children, though only about 3% reported the presence of plastic wall materials at home, there were statistically significant relationships between this crude exposure variable and lower respiratory tract symptoms (wheezing, coughing, phlegm production), but not asthma or pneumonia (Jaakkola et al., 2000). Nevertheless, overall, Longnecker et al. (2003), who led a conference seminar in 2000 on endocrine disruption for a group assisting initial planning of a proposed U.S. National Children's Study, reported present evidence is not strong for endocrine disruption in humans with background-level exposures.

### ***Asbestos, radon, and specific heavy metals of concern***

#### ***Asbestos***

Exposure to asbestos through inhalation of loose fibers of this naturally occurring mineral substance, which can be found in ceilings and walls (e.g., fire retarding insulation on structural beams, soundproofing materials), has been shown to cause lung disease in humans and animals. Federal requirements for schools for inspection, notification, and containment in bound form or for the proper removal of loose, friable asbestos fibers (keep wet, seal off work area) were formally established by the Asbestos Hazard Emergency Response Act of 1986 (USEPA, 2003c).

#### ***Radon***

Radon is an inert, colorless, odorless, radioactive gas. Epidemiological studies have demonstrated a causal association between radon and lung cancer. Radon derives from uranium, which is present in soils and rock. The USEPA has published several reports with data and suggestions for the mitigation of radon gas entry into schools in geographically susceptible areas, due to known geology and soil conditions (USEPA, 1989, 1994; Chmelynski and Leovic, 1992; Leovic and Craig, 1994). These included discussions of design and construction of foundations and ventilation systems, and ventilation system installation, operations and maintenance issues. The California Department of Health Services conducted a statewide survey in elementary school classrooms in 1991-92 (Zhou et al., 1998). Schools were grouped by zip codes in three geographical regions based on bedrock geology uranium potential. Adjusted analyses suggested about 5% of California elementary schools had at least one classroom with average annual indoor air radon concentrations above the USEPA intervention action level, 4 picocuries L<sup>-1</sup>.

### *Specific heavy metals*

#### Arsenic

Arsenic can be found inside schools if it is tracked into the classroom in soil on shoes or clothing, especially after recess on playgrounds and in sandboxes near equipment constructed with wood treated with certain preservatives, e.g., chromated copper arsenate (CCA). In addition, portable classrooms are usually sited on prepared areas, which include the use of CCA-treated wood to raise the modules above ground level to allow cross-ventilation. Certain pesticides used on school grounds may also contain arsenic (CARB, 2003c). The California Portable Classrooms Study reported some classrooms had levels of arsenic in settled floor dust above the MDL, and in relatively more portables than traditional classrooms (CARB, 2003c). The USEPA enacted a voluntary phase-out of CCA, and CCA is no longer on the approved list of chemical pesticides. New York State has banned new installations of CCA playground equipment and requires mitigating old equipment and playground surfaces.

#### Lead

One of the American public health goals, as stated in the environmental health focus area of “Healthy People 2010” (USCDC, 2003), was to eliminate the incidence of elevated blood lead levels in children ages 6 and under (current guideline defined as > 10 µg dL<sup>-1</sup>). Likely sources of lead in school classrooms, as exhibited in some classroom settled floor dust samples from the California Portable Classrooms Study (CARB, 2003c) and samples of interior paint chips collected from older school buildings during a previous California survey (CDHS, 1998), were:

1. peeling or chipping paint applied prior to 1970, which contaminates dust on indoor surfaces or adjacent outdoor soil, since soil can be tracked in on shoes or enter through natural ventilation; and,
2. poorly contained and monitored renovation activities in the classroom or an adjacent area.

Nielsen et al. (2003) conducted an intervention case study in Denmark of children’s exposure to lead in contaminated soil following adjacent outdoor playground activities

(dermal, hand-to-mouth). There were two kindergartens with interventions and one reference kindergarten classroom, at different schools. Measurements in the soil and from child hand wipes before and 5-7 weeks post-intervention were in agreement and suggested the reduction of potential exposure to lead. Variations in the amount of lead on children's hands, however, also suggested variability introduced within and between individuals due to behaviors and playing patterns.

### Mercury

Exposure to mercury, in its elemental or bioaccumulative organic (methylated) forms, has human and ecological health effects. In schools, older fluorescent bulbs contained mercury, but many new, energy efficient bulbs, which also produce higher quality light, do not. Some states like Vermont have banned mercury from light bulbs and required labeling. In addition, mercury may be present in secondary schools with chemistry laboratories, and in general in health clinics (thermometers) and thermostat and computer hardware. If potential sources are identified as present, they should be carefully contained and their use managed until replaced with alternatives and properly disposed of as hazardous waste. Also, new sources should not be introduced. To date, there are no clean up standards for spills inside schools. The USEPA and the University of Wisconsin have developed Internet sites on these topics (see Appendix I.1).

### **Practical science-based recommendations for short and long-term actions**

A few conference papers (Bakke, 1999; Kumar, 1999; Sävenstrand et al., 1999), a university-based Region 10 initiative (WSU, 2002), and USEPA Internet sites ("IAQ Tools for Schools," "IAQ Design Tools for Schools," (see Appendix II.1) presented general and specific common sense, voluntary advice for schools regarding good IEQ in school facilities. We applaud these efforts, and information should be used as applicable. We present practical recommendations, for short and long-term actions, for school stakeholders based directly on the available science reviewed and summarized here on a broad range of IEQ topics (Tables 1-2).

Numerous studies in the Nordic countries of Denmark, Finland and Sweden, which documented observed positive effects of renovation of moisture damaged school buildings on measured IEQ parameters and occupant health complaints, were referenced. In summary, before renovations, there was a higher prevalence of reported respiratory and general symptoms among students and teachers responding to self-administered questionnaires in damaged compared to reference schools. After repairs, those differences did not exist or were not statistically significant. Thus, leaks and subsequent moisture damage of building and interior finish materials, including furnishings, should be prevented to avoid fungal and bacterial growth. Also, similarly, schools should replace wet, damaged materials, and completely dry out the underlying surface as soon as possible.

Frequently washing floors and other surfaces like desks would maintain good general hygiene and help minimize levels of airborne culturable bacteria and pet allergens transported to school classrooms on clothing. This recommendation, in effect, would

protect children who are highly susceptible to such agents, especially pet allergens, and otherwise avoid exposure to them. Local policies can prohibit pets kept at school or cared for in classrooms.

It would be prudent to use non-toxic or least-toxic cleaners in school facilities, during unoccupied hours but not right before the start of school or near the end of lunch break, as well as non-toxic or least toxic teaching supplies. Implementation of this recommendation would minimize potential exposures and risks from toxic and odorous VOCs, including byproducts of their reactions on surfaces in the presence of ozone from outdoors. A related recommendation to minimize occupant exposure to these chemical compounds would be to allow sufficient time for mechanical and natural ventilation to air out classrooms after being painted or receiving new furniture or teaching materials, e.g., those made of exposed particleboard, a HCHO source.

The following recommendations relate to ventilation. Many studies discussed in this paper provided evidence on the potential multiple IEQ, comfort, and health benefits of providing fresh, filtered outdoor air to occupied classrooms. Schools should ensure compliance with ASHRAE Standard 62, monitored over time with biannual or annual HVAC system inspections and more frequent inspections and replacements of filters. The goal should be to provide enhanced or at least adequate ventilation with filtration of particles and pollen allergens of outdoor origin. It is also known ambient ozone is destroyed on surfaces of HVAC systems when they are operational. Operable windows will enhance natural ventilation and should be available and used, depending on local weather conditions, local safety policies, and potential adjacent outdoor sources of pollution and noise. In addition, the design, installation, and commissioning of whole building or portable classroom wall or ceiling-mounted mechanical HVAC systems must consider year-round ambient conditions. Such precautions could prevent potential scenarios when water condensation builds up on interior surfaces, leading to moisture damage and subsequent microbial growth. Finally, during inspections, current classroom enrollment data should be consulted so damper settings allow provision of sufficient fresh outdoor air (at least  $15 \text{ ft}^3 \text{ min}^{-1}$  per occupant).

In future revisions to Standard 55 on occupant thermal comfort in buildings, ASHRAE could consider criteria more specific to children and schools. An interesting discussion point is the potential trade off between acceptable thermal comfort and adequate ventilation in climates with higher ambient relative humidity, or if the HVAC technology either cannot dehumidify air or cools air using water vapor.

Given noise-induced hearing loss has no physical symptoms, the key to prevention is education (see Bahadori et. al (1993), Clark and Bohne (1999)) and reduction of noise at the source with engineering controls or improved HVAC system technologies (ASHA, 1995; Seep et al., 2000). The recommendations below are indirectly related to mechanical HVAC systems or new construction.

1. Future case studies and surveys of school facilities should assess average occupant exposure to noise from present sources during school hours and, as resources allow, contract an acoustics specialist to determine spectral characteristics (e.g., frequency range) of potential sources and to ensure proper reverberation times.

2. In the LBNL study of new relocatable classrooms (Shendell et al., 2002b-c, Apte et al., 2002, 2003), examination of the minimum measured six-minute dB (A) data suggested alternate interior finish material classrooms had lower background noise levels than standard material classrooms. This may have been evidence of a secondary benefit from the alternative ceiling tiles, their higher noise reduction coefficient rating (NRC) (Shendell et al., 2002c). They were originally chosen since in laboratory environmental chamber experiments they were not HCHO sources (Hodgson et al., 2001, 2002, 2003). As time and financial resources permit, interior finish material NRCs should be considered, especially for large surface areas. Reverberation time, the persistence of sound after the source itself stops or is removed from an unoccupied classroom, may also decrease (Knecht et al., 2002, Nelson, 2003).
3. Follow the example of a California policy, SB 352 (M. Escutia, October 2003), which stated not to build new schools near freeways due to health concerns from air pollution and noise.

With respect to persistent organic pollutants like PCBs and phthalates, few quantitative data from school environment studies exist. Thus, the appropriate recommendation appears to be to encourage primary prevention of exposure in classrooms. Reported guidelines and regulations for radon, asbestos, arsenic, lead and mercury are similar. Schools should remove and substitute potential sources of natural and/or synthetic chemicals known to be, or which may prove to be, hormonally active and of human health concern.

To date, even with federal Executive Order 13101, no federal program has strongly promoted or enforced pollution prevention policies (also called environmentally preferable) for the purchasing of school construction and interior finish materials or classroom teaching, maintenance, and cleaning supplies (APHA, 2001). In addition, a recent national survey (Jones et al., 2003) reported no local school policies related to HVAC systems, including supply air ducting, or IEQ except for environmental tobacco smoke. Nevertheless, limited case studies presented in this paper have demonstrated the institution of indoor air pollutant source controls and interventions to increase outdoor air ventilation in primary schools improved IEQ and lowered the prevalence of reported respiratory symptoms and sensory irritation. Thus, such policies and more programs like the USEPA *Design Tools for Schools* internet site and the California Collaborative for High Performance Schools *Best Practices Manuals Volumes I-IV* (see Appendix II.1) are needed at federal and state levels to drive change in local school districts. Furthermore, for future school studies and general environmental public health tracking, programs with sustained funding are needed to record and monitor student illnesses as well as unintentional injuries incurred on school grounds.

According to a public health goal in the environmental health focus area of “Healthy People 2010” (USCDC, 2003), our recommendations could contribute towards a new reality. The goal stated, “increase the proportion of the nation’s primary and secondary schools that have official school policies ensuring the safety of students and staff from environmental hazards, such as chemicals in special classrooms, poor indoor air quality,

asbestos, and exposure to pesticides.”

<b>Table 1: School IEQ studies and highly related references identified</b>					
and cited in the review, by type of reference and IEQ category used for					
<i>(NOTE: an individual reference could be used more than once)</i>					
<b>IEQ category or the IEQ topic</b>	Peer-reviewed journal papers	Conference proceedings or published abstracts	Government (federal, CA or WA, or WHO) final reports and guidance documents	Not-for-profit research reports or professional association documents	Doctoral theses
<b>Biological agents</b>	<b>31</b>	<b>35</b>	<b>1</b>	<b>1</b>	<b>0</b>
<i>Leaks, moisture damage</i>	14	16	0	0	0
<i>Bacteria, Fungi</i>	4	12	0	0	0
<i>Allergens</i>	13	7	1	1	0
<b>Chemical agents and particles</b>	<b>20</b>	<b>34</b>	<b>13</b>	<b>0</b>	<b>2</b>
<i>VOCs, toxic and odorous</i>	15	16	7	0	1
<i>Interior finish materials and furniture as "sources" and "sinks"</i>	0	4	2	0	0
<i>Particles, including pesticide residues</i>	5	9	1	0	0
<i>Carbon monoxide and combustion-related pollutants from outdoors</i>	0	5	3	0	1
<b>Physical agents and related characteristics of schools</b>	<b>65</b>	<b>42</b>	<b>11</b>	<b>7</b>	<b>3</b>
<i>Measures of ventilation</i>	11	25	3	1	1
<i>Thermal comfort (T, RH)</i>	3	7	1	1	2
<i>A-weighted noise levels</i>	37	9	6	4	0
<i>Fluorescent lighting and daylighting</i>	14	1	1	1	0
<b>PCBs and phthalates</b>	<b>6</b>	<b>2</b>	<b>2</b>	<b>0</b>	<b>0</b>
<b>Asbestos, radon, and specific heavy metals of concern</b>	<b>0</b>	<b>2</b>	<b>9</b>	<b>0</b>	<b>0</b>
<i>Asbestos</i>	0	0	1	0	0
<i>Radon</i>	0	1	4	0	0
<i>Arsenic</i>	0	0	1	0	0
<i>Lead</i>	0	1	3	0	0
<i>Mercury</i>	0	0	0	0	0
Introduction and other background text	34	15	11	5	1
No. times references used in total	156	130	47	13	6
<u>No. unique references (301 total)</u>	<u>147</u>	<u>98</u>	<u>42 (26+13+3)</u>	<u>13</u>	<u>2</u>
No. references used for multiple topics	9	32	5	0	1

**Table 2:** Summary of recommendations for schools to improve indoor air and environmental quality in classrooms and other areas based on available science

Prevent leaks and subsequent moisture damage of building and interior finish materials, including furnishings.
Similarly, replace wet, damaged materials, including completely drying out the underlying surface, as soon as possible.
Frequently wash floors and other surfaces like desks, which occupants come into frequent contact with, to maintain good general hygiene and help minimize levels of airborne culturable bacteria and pet allergens.
Use non-toxic or least toxic cleaners in school facilities, during unoccupied hours but not right before the start of school or near the end of lunch break.
Use non-toxic or least toxic teaching supplies and materials.
Allow sufficient time for mechanical and natural ventilation to air out classrooms after being painted or receiving new furniture or teaching materials, e.g., those made of exposed particleboard, a formaldehyde source.
Ensure compliance with ASHRAE Standard 62, monitored over time with biannual or annual HVAC system inspections and more frequent inspections and replacements of filters. The goal should be to provide enhanced or at least adequate ventilation with filtration of particles and pollen allergens of outdoor origin. As possible, given weather conditions, local safety policies, and potential adjacent outdoor sources of pollution or noise, operable windows to add natural ventilation can also be used.
Design, installation, and commissioning of mechanical HVAC systems must consider year-round ambient conditions. Such precautions could prevent potential scenarios when water condensation builds up on interior surfaces, leading to moisture damage and subsequent microbial growth
During inspections, current classroom enrollment data should be consulted so damper settings allow provision of sufficient fresh outdoor air (at least 15 ft <sup>3</sup> min <sup>-1</sup> per occupant).
In future revisions to Standard 55 on occupant thermal comfort in buildings, ASHRAE could consider criteria more specific to children and schools.
Future case studies and surveys of school facilities should assess average occupant exposure to noise from present sources during school hours and, as resources allow, contract an acoustics specialist to determine spectral characteristics (e.g., frequency range) of potential sources and to ensure proper reverberation times.
As time and financial resources permit, noise reduction coefficients of interior finish materials should be considered, especially for large surface areas (e.g., ceiling tiles). Reverberation time may also decrease.
Do not build new schools near freeways due to health concerns from air pollution and noise.
For persistent organic pollutants like PCBs and phthalates, as well as radon, asbestos, arsenic, lead and mercury, encourage primary prevention of exposure in classrooms through source control and proper removal and disposal.
Promote strong, monitored programs for pollution prevention in environmentally preferable purchasing of school construction and interior finish materials, and classroom teaching, maintenance, and cleaning supplies. Policies are needed at federal and state levels to drive change in local school districts.
Neither buses nor trucks powered by diesel fuel should be allowed to remain idling near school facility outdoor air intake vents (assuming dampers open). Such a policy would reduce indoor concentrations of carbon monoxide, particles, and other vehicle-related combustion pollutants such as polycyclic aromatic hydrocarbons and nitrogen oxides.
Glare from incident sunlight on to or reflecting off surfaces (e.g., desks, computer screens) should be reduced to the extent practical. This includes not placing student desks directly in front of windows.
When indirect natural light through windows or skylights is sufficient, fluorescent lights can be turned off, which also saves energy and money.



## **Conclusion**

This manuscript provided a concise school indoor air and environmental quality (IEQ) literature review followed by practical recommendations to prevent or reduce potential occupant exposures to biological, chemical, and physical agents of potential concern in American school facilities, in particular classrooms. These recommendations were based on about 300 scientific citations directly involving or highly related to school IEQ. This manuscript can inform various school stakeholders and policy makers at federal and state levels to drive change in local school districts. The goal is to improve and promote good school IEQ, occupant attendance and health, and academic achievement. Timelines and costs of implementation will inherently vary, but most of the proposed recommendations are initially low-cost or can result in long-term savings.

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## APPENDIX I

Existing noise guidelines for school environments at local, state and international levels

(Washington State Department of Health (WADOH), 2000; WHO, 1999; 2001a-b; ASA, 2002; Wakefield, 2002; Nelson, 2003)

Specific Microenvironment	Leq, dB(A)	Time	Reference
School classrooms and pre-schools, indoors	35	During school hours	WHO, 1999; WHO, 2001a-b
School, playground, outdoors	55	During recess or physical education	WHO, 2001a-b
Industrial arts, vocational education and trade classrooms, chemistry fume hoods and/or dust exhaust systems operational when unoccupied, indoors	65	During class hours	WADOH, 2000
Vocational education and music areas, indoors	115	One second or longer	WADOH, 2000
School classrooms, unoccupied, indoors NOTE: also included 0.6 second max. unoccupied reverberation time	35 ( <i>in 2003, due to Americans with Disabilities Act</i> )	During school hours	ASA, 2002; Wakefield, 2002



## APPENDIX II.1

List of some state and federal government sponsored Internet sites on school IEQ and energy

California Collaborative for High Performance Schools, *Best Practices Manuals* (Vol. 1-4)

<http://www.chps.net/>

National Center for Education Statistics, United States Department of Education (USDoEd)

<http://nces.ed.gov/pubsearch>

National Clearing House for Educational Facilities

<http://www.edfacilities.org/rl>

State of California Department of Energy,

“The Bright Schools Program: Energy-Efficient Schools for a Brighter Future”

<http://www.energy.ca.gov/efficiency/brightschoools/info.html>

State of California, Division of the State Architect, “Sustainable Schools Website”

<http://www.sustainableschools.dgs.ca.gov/sustainableschools/>

*NOTE: Will include links to pages on “Environmentally Preferable Purchasing” of*

*materials for school design and construction or modernization activities*

State of California Fire Marshall

[http://www.fire.ca.gov/FireMarshal/PDF/class\\_more.pdf](http://www.fire.ca.gov/FireMarshal/PDF/class_more.pdf)

State of California Interagency Working Group on Indoor Air Quality (IAQ)

(Department of Health Services, Environmental Health Laboratory Branch, IAQ Section),

“Advisory on Relocatable and Renovated Classrooms (12/1996)”

<http://www.cal-iaq.org/>

State of Minnesota Department of Health, children’s environmental health issues, including a page dedicated to schools

<http://www.health.state.mn.us/divs/eh/children/schools.html>

University of Wisconsin (USEPA funded, through Great Lakes National Program Office),

“Mercury in Schools Project”

<http://www.mercuryinschools.uwex.edu/>

USDoEd, information for school planning for natural disasters, violent incidents, terrorist attacks

<http://www.ed.gov/emergencyplan>

United States Department of Energy, “EnergySmart Schools Program Campaign”

<http://www.eren.doe.gov/energysmartschools>

USEPA “IAQ Design Tools for Schools”

<http://www.epa.gov/iaq/schooldesign>

USEPA “Healthy School Environments”

<http://cfpub.epa.gov/schools/index.cfm>

USEPA, “State Mercury School Programs”

<http://www.epa.gov/mercury/index.html>

USEPA “Tools for Schools” Program materials  
<http://www.epa.gov/iaq/schools/index.html>

## APPENDIX II.2

List of some public and not-for-profit institutions Internet sites on school environmental quality, and select private companies on IEQ-promoting classroom construction or finishing materials

AASA “Green School Project”

<http://www.aasa.org>

ACSA, “State Education Policy and Politics” column and list of articles

<http://www.acsa.org/news>

Alliance to Save Energy’s (ASE) School Energy Efficiency Task Force

<http://www.ase.org/greenschools>

American Nurses Association,

“Safe Workplaces and Healthy Learning Places: Environmentally Healthy Schools”

<http://nursingworld.org/mods/mod250/cesafull.htm>

Association of Higher Education Facilities Officers (APPA)

<http://www.appa.org/>

Beyond Pesticides, information on state policies and programs on use of pesticides at schools

<http://www.beyondpesticides.org>

California Coalition for Adequate School Housing (CASH)

<http://www.cashnet.org>

California Healthy Schools Campaign, information for schools to eliminate pesticide use

<http://www.calhealthyschools.org>

Children’s Health Environment Coalition (CHEC), “Healthy Schools: A Resource List”

[http://www.checnet.org/healtheducation/articles-detail.asp?Main\\_ID=487](http://www.checnet.org/healtheducation/articles-wysiwyg://2/http://www.checnet.org/healtheducation/articles-detail.asp?Main_ID=487)

Environment and Human Health, Inc. (CT), list of 12 steps to healthier schools

<http://www.ehhi.org>

Evans Consulting, “Irlen Syndrome accommodations at school or work”

[http://www.evansconsult.org/is\\_accom.htm](http://www.evansconsult.org/is_accom.htm)

Healthy Kids: The Key to Basics, information for children with asthma and other chronic conditions while at school and nurses who treat them

<http://www.healthy-kids.info>

Healthy Schools Network

<http://www.healthyschools.org>

National Education Association (NEA), links to programs and information on IEQ and asthma

<http://www.nea.org/>

National Parent-Teacher Association, information on different legislative categories on schools

<http://www.pta.org/programs/legini.asp>

Northwest Coalition for Alternatives to Pesticides, information to reduce pesticide use in schools

<http://www.pesticide.org>

Selected private sector companies with information on IEQ-promoting classroom

materials:

<http://www.carpet-rug.com/>

“Selecting Carpets and Rugs: Carpet in Schools,” “Indoor Air Quality:  
'Green

Label' Testing Program” (criteria for carpets, adhesives, cushion under  
carpet)

<http://www.healthyflooring.org/Information.html>

“Problems with Fitted Carpets and PVC Floors,” “Suppliers” (list)

<http://www.mbinet.org>, Modular Building Institute

# The Healthy and High Performance School

Improving Student Health  
Improving Student Achievement  
and  
Saving Money for Schools

Healthy Schools Network, Inc., Albany, NY

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## Introduction: New Schools Improve Learning and Health

A revolution is brewing for public education across the nation. This revolution is characterized by communities that have come to realize that the design, construction and maintenance of a school facility is as important to the quality of a child's learning as is teacher training, small class size, and many of the other components of a quality education as commonly accepted by the educational community. The results are new healthy and high performance schools that improve attendance, student health and student achievement. These same dynamics hold true for teachers and all school personnel. Additionally, these benefits can be realized while reaping economic benefits: savings from decreased school energy and maintenance costs; income generated with increased student attendance; savings from decreased liability and litigation risk; and, importantly, goodwill and trust improved with the school and the community. The New York State educational community, while now deliberating many potential changes to state funding for schools, must also apply this knowledge regarding the important benefits of healthy and high performance schools to the current policy debate. Recommendations further delineated in this paper will show how schools in New York State can be made healthier, more efficient and more productive through adoption of new healthy school and facility improvement policies.

New York State policymakers, interest groups, parents, students and teachers are all now keenly attentive to the need to improve student achievement, as spurred by the federal No Child Left Behind Act, and the need for the New York State Legislature to devise an equitable funding strategy for public education to comply with a recent decision of the New York State Court of Appeals. New Yorkers are now engaged in a mighty debate that promises to change, and

hopefully improve, the future of public education. The adequacy, overall condition, and health of the school building must be a part of this debate if we are to completely and comprehensively reform education and provide the best possible student learning experience.

### **Schools: The Unregulated Workplaces of Children**

A school building is the place where student instruction occurs. It is the one constant factor in a child's education. A school building is an undeniably necessary component of student learning. Schools house the classrooms, gyms, cafeterias, auditoriums, offices, laboratories, hallways, and other spaces that are commonly associated with public education. Schools also house millions of children, who breathe the school's air and listen, see and learn in the school's classrooms. Just as the outdoor air, water climate, flora, fauna and multiple other factors combine to create our living environment, the indoor air, structure, furnishings, maintenance and design of a school building combine to create a learning environment, and this environment undeniably shapes the quality of a child's learning experience. The school environment affects a child's health and ability to learn, and could be the determinative factor for some children as to whether they succeed in school or fail.

Children attend school, hope to learn, to grow and to become healthy and productive adults. Children on average spend 30-50 hours per week in school, which makes the school facility the workplace of students. Yet unlike adults, children have no OSHA protection, no PESH protection, and no union protection. Nor can schoolchildren rely on the protection

of the public health infrastructure, since, with the exception of cafeterias and swimming pools, public health departments do not have the authority to investigate school health or injury complaints attributable to the school facility unless invited to do so by the school administration. This makes schools the “unregulated workplaces” of children.

Yet children are uniquely vulnerable to environmental contaminants, many of which are found in schools.<sup>i</sup> Growing children are more susceptible to environmental contaminants than adults. Children proportionately breathe more air, drink more fluids, and eat more food than adults. Developing systems are more vulnerable to environmental toxins than are fully developed adults. Children’s behavior, too, makes them more vulnerable. Hand-to-mouth behaviors, which may persist in children with developmental disabilities, increases risk of ingested of toxins. Even children’s proximity to the floor relative to adults make them more vulnerable, since toxic substances in indoor air may be more highly concentrated in carpets or lower to the floor. Yet health standards for children’s exposure to indoor environmental contaminants do not exist. An often-cited U.S. General Accounting Office report notes that children are compelled by law to attend school, yet these school facilities may be unsafe or harmful to student health.<sup>ii</sup>

Children’s exposure to environmental hazards at school contributes to multiple health problems. Poor school indoor air is a major contributor to causing and exacerbating asthma, which is well known to be at epidemic proportions among school age children. Hazards in the school environment are linked to a host of other health problems including respiratory problems, poor concentration, rashes, headaches, gastrointestinal problems, nervous system

disorders, and cancers. Nationally, there has been a dramatic rise in the number of children afflicted with learning disabilities, attention deficit hyperactivity disorder, and autism. These conditions are also linked with environmental toxins that may be found in the school environment. Clearly children’s unique vulnerability to environmental hazards, combined with the lack of any systemic protection for children’s environmental health in school, argues for increased attention to the quality and overall health of the school facility environment.

### **The Science of School Environments**

Healthy Schools Network recently commissioned a report that presents a concise review of scientific literature related to school indoor environmental quality (IEQ). This report, “Science-based recommendations to prevent or reduce potential exposures to biological, chemical, and physical agents in schools”, is a state-of-the-art review of peer-reviewed scientific literature that demonstrates the impact that school environments have on student health and learning. Lead author Derek Shendell, D.Env, MPH, identified 301 citations directly involving or highly related to school IEQ and occupant health, attendance, productivity or performance. The Shendell report concludes with over a dozen recommendations for improving school environmental health and safety based on today’s known science regarding school indoor air quality and related environmental health issues.

This paper will describe the policy implications of the Shendell paper for New York State and draw together existing knowledge, data and research regarding school facilities, children’s environmental health, and school facility impact on student achievement, to demonstrate that school



facility issues are integral to the school reform and equity debates. It concludes with policy options for New York State leaders to

improve student productivity and health through greater attention to school facility issues.

## Section 1. The Condition of School Facilities in New York State

“Although focused on teaching and learning, education reform must also address the need to maintain a safe, secure, and healthy school environment. The capacity of children to learn is impeded if their school environment contains elements which are hazardous to their health” (NYS Board of Regents, 1994<sup>iii</sup>)

“It is well known that there are desperate school building needs in districts all across the State, including dilapidated buildings, outdated facilities and overcrowded classrooms. This crisis was brought on by an aging building stock and decades of "deferred maintenance" -- the technical euphemism for basically failing to maintain our buildings.” (NYS Comptroller 10/97<sup>iv</sup>)

“Sound, safe and modern school buildings are an obvious cornerstone of a good education. Children cannot learn in an environment where classrooms and schools are overcrowded, roofs are leaking, and windows threaten to break and fall on students' heads. The conditions of many schools not only create an inadequate learning environment, but also may actually threaten student safety.” (Alliance for Quality Education, 2003<sup>v</sup>)

### **Overview of The State of New York School Facilities**

*New York State, including New York City, has approximately 4,300 classroom buildings enrolling almost 3 million children<sup>vi</sup>. Of these, about twelve hundred schools and 1.1 million students are located in New York City. Most schools buildings in New York State were built 50 or more years ago<sup>vii</sup>. New York State school buildings are largely regarded as being in very poor shape and in need of major renovation. In New York, as in the nation, more than a third of all public schools need major repairs or total replacement, according to a state-by-state study conducted in 2000 by the National Education Association<sup>viii</sup>. An often-cited US General Accounting Office Report notes that 90% of New York State schools are reported as needing upgrade and repair<sup>ix</sup>. In addition, in this 1995 U.S. General Accounting Office study, over 40% of New York State schools reported unsatisfactory ventilation and heating, while 21% reported poor indoor air quality, 30% poor acoustics, 21% poor*

*physical security of buildings, and 21% percent reported unsatisfactory lighting conditions. The NYS Comptroller in 1997 issued a report on the condition of New York State school facilities. Among its findings was that schools in New York State are in fact, inadequate, and are, on average, about 50 years old<sup>x</sup>. However, this report also notes that age is not the determinative factor in assessing the condition of a school, and in fact many older buildings built well in the 1920s and 30s and well maintained are in better condition than many schools built more cheaply in the 1950s and 60s. Numerous other reports conducted over the past 20 years document the decline in the condition of New York State school buildings, while many others document the extent of this decline nationally (see resources).*

*Currently, a vibrant debate is occurring in New York State regarding new funding for schools. The record is clear that school facilities need extensive resources for reconstruction, expansion and renovation. However, regardless of the amount of funds*

*appropriated for school building aid, policymaker attention must also focus on the core issues of the condition of the school facilities, and how to best use state and local resources to improve learning and health in the school environment.*

### **Environmental Quality of New York State Schools**

In 1994 the NYS Regents Advisory Committee on Environmental Quality in Schools published a report to the full Board of Regents entitled, “Environmental Quality of Schools.”<sup>xi</sup> For the first time in any U.S. state, the environmental health and safety of schools was systemically analyzed and linked to a broad set of recommendations regarding the improvement of school facilities in New York State. Chief among these is a set of guiding principles, adopted by the Board of Regents, for children’s environmental health and safety at school. These principles are:

- Every child has a right to an environmentally safe and healthy learning environment which is clean and in good repair.
- Every child, parent and school employee has a “right-to-know” about environmental health issues and hazards in their school environment.
- School officials and appropriate public agencies should be held accountable for environmentally safe and healthy school facilities.
- Schools should serve as role models for environmentally responsible behavior.
- Federal, State, local, and private sector entities should work together to ensure that resources are used effectively and efficiently to address

environmental health and safety conditions.

These principles establish the starting point for New York State recognition of the importance of school environmental health and safety to student health and learning. While much has been accomplished towards meeting these objectives, clearly there remains more to do. Further in this paper we discuss the critical links of school facility, environment and student health and learning. However, the Board of Regent’s report made several other critical observations, based on several public hearings, the body of knowledge regarding school environmental health and safety to date, and their own expert deliberations relevant to the environmental condition of New York State schools. To summarize a few highpoints of this study’s findings;

- “reports of environmental problems have raised public concerns to new levels”
- “Some students and school personnel have experienced mild to serious health problems which interfere with health, activity and ability to learn”
- “parents and school personnel have become frustrated by a system that, in some cases, has ignored or dismissed their inquiries and complaints about school environmental quality”
- “Decisions must be made at both the State and local levels to determine responsibility and how to address the problems”
- “It should be recognized that when health threats are present, the costs to individual districts and the State Education Department are enormous in terms of staff time and effort, clean-up costs, school closings, and the liability damage to health”

- “The problems are not isolated incidents. They are statewide problems with far reaching effects on the health and safety of our children. The current standards for environmental health and safety are not adequate to protect children.”

All of these statements remain true today.

## **RESCUE**

One result of this Board of Regents report is the Rebuild Schools to Uphold Education (RESCUE) Law of 1998 that mandated a new level of health and safety protections for students and school personnel. The RESCUE Regulations became effective October 7, 1999 and include Parts 155.3 through 155.6 in the Commissioner of Education's Regulation 8 NYCRR 155. RESCUE requirements include:

- School health and safety inspections. Every five years schools must conduct a building condition survey. Every year, they must conduct an annual visual inspection.
- Safety ratings. Every year districts must provide a safety rating of each school.
- Monitoring. Districts are required to establish health and safety committees and a comprehensive maintenance plan, among other requirements.
- Construction and remodeling. Districts are required to enforce specific health and safety protections during remodeling projects.
- School Facility Report Cards. Every year schools should provide a school facility report cards containing information as detailed in the regulation.

The Healthy Schools Network Guide to RESCUE provides a concise overview of the state and local requirements of the regulations and their implications for student and employee health and safety (see Resources section).

The Legislature's enactment of the RESCUE law coupled with state aid for certain requirements was a major school facility environmental health achievement. It gave to the New York State Education Department (SED) for the first time the ability to set statewide standards that would apply to NYC schools. It promised to create and sustain a statewide database of facility needs and issues, building upon the elements of CAPPs (Capital Asset Preservation Program) enacted in the late 1980's. RESCUE also incorporated some of the major recommendations of the Regents Advisory Committee on School Environmental Quality, and sought to build a database on school facility health and safety.

In 1997, a \$2.4 billion School Facility Bond Act was defeated, in part due to lack of implementation information and lack of hard data to support where funds were most needed. Implementation of RESCUE promised to provide school facility data that would withstand the scrutiny of voters on future statewide school facility bond acts. While these factors support strong implementation, enforcement of RESCUE requirements by the State Education Department has been inconsistent, despite a successful state legislative budget amendment to add staff to the SED Office of Facilities Planning. Moreover, to the dismay of public interest groups, the Regents disbanded their Facilities Advisory Committee structure, effectively barring independent knowledgeable groups from

participating in policy implementation discussions.

HSN has encouraged and monitored significant portions of the implementation of the RESCUE regulations since their inception. Among our findings are the following:

- The most notable example of lack of enforcement and oversight by SED is the requirement for school facility report cards, which SED readily admits it has not implemented. This means there is no readily accessible public record of building conditions, or mechanism for comparing school buildings of differing ages, enrollments, student needs, and other external variables.
- Of equal concern is the lack of SED record keeping on RESCUE enforcement actions. We understand that SED keeps no documentation on complaints from parents or personnel, or more specifically on SED calls or memos to the field to individual districts that are out of compliance. This makes any effort to assess school compliance impossible.
- Anecdotally, reports to our office at HSN indicate inconsistent and sometimes no effective enforcement of RESCUE in local schools. We have seen little evidence of enforcement of important health and safety requirements relating to school IAQ, integrated pest management (IPM) and other program requirements. It is not uncommon for us to find that a district does not have a functioning health and safety committee, or uncommon to learn that regulations to protect the health

of occupants of buildings under renovation are being repeatedly ignored by school officials.

- Currently, SED reports that nearly one-fourth of the 4000 non-NYC schools have neglected to submit a building condition survey.<sup>xii</sup> Nearly 500 have failed to submit an annual visual inspection<sup>xiii</sup> (which may have its own set of flaws, inasmuch as schools themselves apply their own health & safety ratings to various facility systems).
- In several meetings with New York City Board of Education (BOE) through the fall of 2001, HSN learned only that BOE had received no instructions from SED on how to comply; conversely, SED had asked BOE how it would like to comply with RESCUE. Either way, there was no leadership to break this stalemate that left one million students and their families without the basic environmental health & safety protections.

A recent audit of the RESCUE program from the NYS Comptroller<sup>xiv</sup> found weaknesses in the Education Departments implementation of the RESCUE program, resulting in school district non-compliance with RESCUE requirements. These findings largely confirm HSN's own findings with regards to mismanagement of the RESCUE regulations. Most notably, the NYS Comptroller found that the vast majority of schools have not implemented a school facility report card, which is consistent with that SED's admission that it has not implemented this initiative. Among other implications, SED's inaction deprives the state of an anticipated resource that could provide necessary data on the overall condition of schools in New York

State. The Comptroller's report also found that, "Department staff generally do not visit or otherwise verify district's compliance with the certain aspects of the RESCUE Program".<sup>xv</sup> This finding is fully consistent with HSN's anecdotal findings, as noted above.

### **The CFE Lawsuit and School Facilities**

The Campaign for Fiscal Equity (CFE) a coalition of advocacy groups, parent groups and community school boards, filed a lawsuit against the State of New York on behalf of New York City school children charging that the state constitutionally under funded New York City schools.<sup>xvi</sup> In 1995, the New York State Court of Appeals ruled that the New York State Constitution requires the State to provide all children a "sound, basic education."<sup>xvii</sup> Further, the Court of Appeals determined that the definition of a sound basic education could only be determined through a court trial. This decision led to a seven-month trial, culminating in a 2001 NYS Supreme Court decision from Justice Leland DeGrasse that the New York State system of funding education was unconstitutional.<sup>xviii</sup> In many ways this trial established a factual record, not just on the state of education in New York generally, but also about the state of New York school facilities.

In the 1995 ruling, the Court of Appeals stated, "Children are entitled to minimally adequate physical facilities and classrooms which provide enough light, space, heat and air to permit children to learn."<sup>xix</sup> The subsequent trial examined the question of physical facilities and classrooms more thoroughly. Justice DeGrasse's decision summarized New York City school facilities with this statement, "A substantial number of BOE's approximately 1100 facilities require

major infrastructural repair to items such as roofs and facades. Many more facilities are plagued by overcrowding, poor wiring, pock-marked plaster and peeling paint, inadequate (or non-existent) climate control, and other deficiencies that speak of a history of neglect. Though it would appear to be self-evident that such conditions would impede, rather than facilitate, the delivery of a sound basic education, this proposition is difficult to prove or disprove...the court finds that there is a causal link between New York City's poor school facilities and the performance of students, though the strength of that link is difficult to measure."<sup>xx</sup>

In this decision, Justice DeGrasse also cited a statement from the New York State Legislature from 1988 in the Legislation that created the New York City School Construction Authority. This statement read, "The legislature hereby finds and declares that the elementary and secondary schools of the City of New York are in deplorable physical condition. Many of the schools are overcrowded, unsafe, unhealthy and unusable. The physical deterioration of the schools is a serious impediment to learning and teaching. If the quality of education in New York City is to be improved, the city's schools must be modernized, expanded and restored to a state of good repair."<sup>xxi</sup>

Justice DeGrasse then proceeded to find that the creation of the SCA did not improve the overall condition of school facilities in NYC, and that in fact, school facilities in NYC have continued to decline. Further, he cited a 1995 report from what was known as the Levy Commission, which had been appointed by the NYC school chancellor to study school facilities. Justice DeGrasse cites, "A Report of the Commission on School Facilities and Maintenance Reform," and stated the following, "The Levy Commission found that the condition of New York City

public school facilities constituted "a school infrastructure crisis." The Levy Commission discovered "shocking conditions in our schools, such as collapsing building facades, thoroughly rusted structural beams, falling masonry, precariously hung windows, and roof gables held together with wire." It found more than 760 buildings had serious problems with their heating and ventilation systems and 424 buildings required wholesale modernization."<sup>xxii</sup>

DeGrasse then discusses a United Federation of Teachers lawsuit, "In 1994, the United Federation of Teachers sued BOE over the conditions of New York City's public school facilities. The late Justice Friedman's 1998 decision notes that BOE did not contest the deplorable conditions in the City's schools. The decision cited a BOE memorandum that found 237 school buildings had immediately hazardous exterior conditions in need of repair. This list of 237 did not include nearly 150 buildings that had defective roofs or other building code violations."<sup>xxiii</sup>

Finally, DeGrasse discussed and summarized testimony regarding the causal link between school facilities and academic outcomes. DeGrasse concludes, "the physical condition of New York City's schools has a negative effect upon the academic performance of the City's public school students. However, the magnitude of that effect is unclear from the evidence at trial."<sup>xxiv</sup> The Appellate Division reversed Justice DeGrasse's decision.

However, in June of 2003, the Court of Appeals ruled again in favor of CFE and ordered New York State to implement funding and accountability reforms to permit New York City school children to achieve a sound, basic education.<sup>xxv</sup> **The Court of Appeals reaffirmed its 1995 statement that "children are entitled to classrooms which provide enough light, space, heat, and air**

**to permit children to learn."**<sup>xxvi</sup> (HSN emphasis added.) However, the Court of Appeals also stated that while CFE had shown that the state of school facilities is deficient, they had not established a correlation between building disrepair and student performance, in general.

### **New York State School Facilities: A Record of Inadequacy, But Do Deplorable Schools Effect Children?**

A review of the available research and data regarding the condition of schools in New York State shows widespread agreement that many school facilities are woefully inadequate, yet comprehensive data is lacking. Most research references the US GAO State Survey as a starting point, yet this survey was limited in scope and is now ageing. The New York State Board of Regents attempted to address the woeful inadequacies of school facilities in relation to student health and safety, yet follow-up to these important findings has been uneven, incomplete and disappointing. Attempting to assess the condition on New York State school facilities is stymied by the lack of comprehensive school facility environmental health and safety data, which would have been much more readily available had SED fully implemented the RESCUE program. SED currently collects limited data on the condition of non-New York City schools through its collection of annual visual inspection reports and building condition surveys as required by RESCUE. However, SED's lack of compliance with the legislative requirement for school facility report cards, and its uneven enforcement of RESCUE regulations has had far reaching implications for children's health and safety. Among these failures is depriving the state of useful comprehensive data on the

environmental condition of New York State schools.

The CFE case further established a record of deplorable school facilities, yet to date, the litigants were unable to unequivocally

establish the link between poor school facilities and student performance. The Shendell paper contributes greatly to substantially establishing the fact base for that critical link.



## Section 2. School Facilities and Student Achievement, Health and Well-Being

### **School Facilities Affect Student Health and Learning**

In our companion paper “Science-based recommendations to prevent or reduce potential exposures to biological, chemical, and physical agents in schools”, we present a comprehensive review of scientific literature related to school indoor environmental quality (IEQ). This analysis demonstrates conclusively that the school environment has a clear and undeniable impact on student health and learning. Its relevance to New York State policymakers currently deliberating adequate, equitable and accountable school funding strategies is clear. School facilities are not just warehouses to contain the teachers, students, and products and supplies for a child’s education. School facilities are in fact *indoor environments used for learning during the critical early years of biological development*, and these environments have a substantial impact on student health, achievement, attendance and overall well-being. If neglected or inadequately maintained this learning environment becomes an adversary to education, detracting from student learning by increasing absenteeism and interfering with the student’s attentiveness, concentration, and disposition. However, if the school environment is cultivated and optimized through appropriate building technology and maintenance procedures, the school facility becomes an ally in education, fostering better attendance, improved student achievement and an improved disposition towards learning.

The Shendell paper concentrates on school IEQ and summarizes the available research and scientific knowledge now available in

this emerging field. This paper will not restate the findings of the Shendell paper. Rather, it will provide background information regarding the salient issues concerning school IEQ and make note of these significant findings in relation to the New York State policy debate. The following sections summarize the critical school IEQ issues studied by Shendell, and further summarize their relevance to student health, safety and achievement.

### **Indoor Air Quality**

School indoor air can be times more polluted than outside air. According to the US EPA, “studies show that one-half of our nation’s 115,000 schools have problems linked to indoor air quality. Students are at greater risk because of the hours spent in school facilities and because children are especially susceptible to pollutants. The health and comfort of students and teachers are among the many factors that contribute to learning and productivity in the classroom, which in turn affect performance and achievement.”<sup>xxvii</sup> The EPA also notes “schools that fail to respond promptly and effectively to poor IAQ run the risk of increased short-term health problems, such as fatigue and nausea, as well as long-term health problems like asthma. In serious cases, schools have been shut down and have had to move staff and students to temporary facilities. Delaying remediation of IAQ problems can also be costly and may even lead to liability claims and lawsuits that can damage a school’s reputation. Clearly, IAQ issues are best addressed early and better still proactively.”<sup>xxviii</sup>

Poor indoor air can result from poor and/or improperly maintained ventilation. Sources

of poor indoor air can be from within the school, such as fumes from building materials, building maintenance projects, art and other teaching supplies, laboratory chemicals and supplies, molds and other biological contaminants, pesticides, pests and concentrations of carbon dioxide improperly ventilated from the building.<sup>xxix</sup> Outside sources, such as diesel and automobile exhaust, factory emissions, radon, and generally poor quality outside ambient air can be concentrated indoors, resulting in a magnified health hazard. While most of Shendell's findings focus on research specific to individual contaminants or pollutants, there is a body of research showing an association between poor school ventilation and poor student attendance and adverse student learning and health. Research also demonstrates this association with absenteeism and performance related to asthma, as well as various factors related to teacher attendance. These findings are significant in and of themselves, in that they show that attention to proper ventilation can have a positive impact on student and teacher health, attendance, productivity and capacity to learn.

### **Biological Agents**

Shendell finds a comparatively large body of research related to "biological agents," such as molds and bacteria. Water damaged schools quickly become a breeding ground for mold and bacteria. Water entry into school buildings is commonly associated with leaky roofs, windows, plumbing, and other building elements. Mold growth is of increasing concern to school communities across the state and across the country. Mold is a student health concern because the spores released from mold growth can easily aggravate sensitive individuals, such as those with asthma, resulting in decreased student

attendance and lack of focus and concentration. Mold growth can aggravate the health of students and building occupants, impeding learning, and resulting in school buildings or whole wings closed until the mold problem is remediated.<sup>xxx</sup> Additional research cited by Shendell shows increased respiratory symptoms and infections in moisture and mold damaged schools. Other findings show increased asthma incidence in water-damaged schools. Various studies also indicate that good school cleaning and maintenance practices contribute towards decreased presence of allergens and other biological contaminants, thus decreasing incidence of disease and absenteeism and increasing learning and attentiveness. Schools that are well designed, constructed and maintained minimize water intrusion and incubation of various biological contaminants.

### **Chemical Agents**

Chemical agents and particles such as toxic volatile organic compounds (VOCs), offgassing of school building materials, carbon monoxide, and other toxic substances which may be tracked in or entered into the school building, have also been the subject of research as related to the health and safety of school students and other building occupants. VOCs are chemicals that evaporate easily at room temperature. The resulting fumes can be easily breathed in by room occupants and therefore of special concern for study of school IEQ. VOCs can be found in a multitude of building materials and consumer products, including pressed wood furniture, carpeting, adhesives, office equipment, upholstery, cleaning products, personal care products, vinyl products, pesticides and many more.<sup>xxxii</sup> VOC exposure has been linked to irritation of eyes, nose and throat, headaches, asthma

exacerbation, cancer, central nervous system and other internal organ damage.<sup>xxxii</sup> Studies have shown schools with levels of VOCs from various sources causing or contributing to student health problems and interfering with learning. Inadequate ventilation is also linked to increased concentrations of indoor school VOC. Carpeting in school has been shown to be a repository of VOC tainted dust, increasing VOC levels measured in schools.

Child exposure to polychlorinated biphenyls (PCBs) and other persistent organic pollutants has been linked to adverse health consequences related to neurological, behavioral and physical development, and is a probable human carcinogen.<sup>xxxiii</sup> PCBs, though banned in the United State since 1979, may be present in older fluorescent light fixtures.<sup>xxxiv</sup> Children at school can be exposed to other persistent organic pollutants from pesticide residues, fertilizers, and from exposure to certain foods, consumer products and interior finishes. Soft plastic toys, especially if mouthed or chewed by young children, also pose a risk.

Particles in the school atmosphere, fine enough to be respirable, are also a health concern. Numerous studies have shown that these particles, likely tracked in from the outside, are linked to respiratory and cardiovascular health problems and are prevalent in studied schools. Studies have also linked school particle dust with increased incidence of asthma symptoms.

### **Diesel Fumes**

Carbon monoxide and other combustion related pollutants are other toxins contributing to poor school IEQ. Especially

of concern are diesel buses and delivery vehicles that typically collect and idle at school entrances for dropping-off and picking-up students, or off-loading supplies. Diesel school buses that idle at or near school or classroom air intake vents also pose a serious health hazard. Diesel exhaust is a suspected carcinogen, exacerbates asthma and can aggravate other respiratory problems.<sup>xxxv</sup>

### **Inadequate Ventilation**

Numerous studies have looked at adequacy of ventilation and ventilation systems in schools and classrooms, primarily using measured carbon dioxide levels as an indicator of inadequate ventilation. Carbon dioxide indoors is primarily a byproduct of human respiration, and is not harmful unless found in very high levels. However, carbon dioxide buildup indicates poor ventilation and suggests that other, more harmful toxins are also not being adequately ventilated from the classroom. The prevailing findings from studies reported by Shendell indicate inadequate ventilation in classrooms, as determined by elevated classroom carbon dioxide levels. Studies of school ventilation have also found inadequate temperature and relative humidity controls.

### **Lighting and Acoustics**

Sound and light are additional and important variables in school IEQ. Noise in the classroom interferes with learning, and children typically require better acoustic quality than adults in classrooms. Children with hearing and learning impairments are especially susceptible to noise distraction. Typical sources of unwanted noise in the classroom are from outside (traffic, construction, playgrounds), mechanical noise

(such as noisy HVAC systems) and from various school indoor sources. Shendell finds few scientific studies on the effects of unwanted noise in American school classrooms. Yet the few studies available indicate that unwanted noise will in fact interfere with student learning. Additional studies suggest that exposure to chronic noise in communities near air, road and/or rail traffic leads to hearing loss, stress, behavioral problems, decreased school performance and cognitive delays among other results.

Lighting in schools can be enhanced and improved through better use of maximizing natural daylight, or through use of full-spectrum lighting that mimics the qualities of natural daylighting. Studies indicate that student academic performance and test scores improve when classrooms adopt design and engineering technologies to maximize use of daylighting and full spectrum lighting.

### **Asbestos**

Exposure to asbestos fibers is a known cause of lung disease, including cancer. Remediation of asbestos containing products from schools has been a major initiative nationally and in New York State. It is a serious hazard that has been comprehensively addressed in many publications and reports. Since 1986, schools have been required to address asbestos identification and remediation due to the federal Asbestos Hazard Emergency Response Act (AHERA). AHERA is enforced in New York State schools by the State Education Department, which requires schools to self-report data on AHERA compliance.

### **Radon**

Radon is an odorless, invisible radioactive gas that seeps from uranium in the ground. When radon rises into a school building, it can be collect and form a health hazard, where outside it usually dissipates into the atmosphere. Radon is a cause of lung cancer.<sup>xxxvi</sup> Schools can test for radon, and correct harmful concentrations though foundation design and repair, building maintenance and effective ventilation.

### **Arsenic**

Arsenic is a known carcinogen.<sup>xxxvii</sup> It may be found in schools in playground equipment constructed with pressure treated wood that is infused with arsenic in order to prevent rot and decay. The arsenic leaches from the wood indefinitely however, creating a hazard for children who play on the structure, especially young children who will frequently bring their hands to their mouth, and thereby internally ingest the arsenic residues. Pressure treated wood with arsenic may also be found at schools in various other applications, including picnic tables and benches. Arsenic may also be found in the classroom, as children track in the residue on their clothes and shoes after playing on the outside structures. New York State has banned the use of unsealed pressure treated playground equipment, and the EPA has negotiated a voluntary ban on the further sale of pressure treated lumber.

### **Lead**

Lead has been a recognized environmental health hazard for over 2000 years. Lead is well known as a cause of neurological

damage, especially in young children. Paint applied before 1978 is a common source of lead poisoning for children. The federal government banned lead-based paint from housing in 1978. Some states stopped its use even earlier.<sup>xxxviii</sup> Lead paint that is chipping or peeling may be ingested by young children, as will lead dust that accumulates on painted window frames and doorways. Lead poisoning is also a potential hazard in school construction and renovation projects. Renovation may disturb old lead paint, creating dust and chips that will be tracked or blown into the classroom unless the construction area is properly sealed from the occupied areas of the school. (Although not studied by Shendell in this paper, lead may also be found in school drinking water

that is routed through lead pipes and/or pipes with lead solder.

### **Mercury**

Exposure to mercury vapors is associated with multiple detrimental health effects, including brain and kidney damage.<sup>xxxix</sup> Mercury can be found in old fluorescent bulbs. Children can therefore be exposed to mercury vapor if these lights are broken or shattered. Mercury also exists in many other potential sites in schools, including instructional labs, thermometers, thermostat and computers. Since mercury evaporates rapidly once exposed to the air, any spill of mercury, no matter how small the amount, is a potential health hazard for schoolchildren.

### Section 3. The Healthy and High Performance School

#### **Design and Construction**

Fortunately, there is a cost-effective alternative to inadequate, overcrowded, environmentally unhealthy school facilities that now disrupt and undermine, rather than promote, education and quality learning. Communities across the nation are designing and building healthy and high performance schools that combine state of the art school design and construction technology with good old fashioned common sense to create learning environments that improve learning, promote good health, and cost less to operate than traditional school facilities. Many of the features of a healthy and high performance schools are made possible due to modern technologies, yet many other features are grounded in decades old common sense principles of school construction. The 1925 New York State guide to school construction specifies features such as air-flow, lighting and siting requirements that are consistent with today's guidelines for a healthy and high performance school, yet are no longer required by the state for school construction.<sup>xl</sup>

A healthy and high performance school is an educational facility that is designed and built from an integrated and whole building approach. As reported by Shendell, a growing body of scientific research demonstrates that the school environment has a dramatic impact on student achievement, attendance and health. The healthy and high performance school positively remedies many of these IAQ hazards by integrating environmentally healthy materials, building systems and other environmentally responsible technologies into the essential design of the building. Chief among these environmentally

responsible technologies are state-of-the-art energy efficiency ventilation, insulation and passive energy conservation features. A healthy and high performance school saves up to 40% of the buildings energy costs over the lifetime of the facility.<sup>xli</sup> Contrary to old but common misperceptions, healthy and high performance schools can be built at the same cost as conventional school facilities.<sup>xlii</sup> These schools then save districts substantial funds in decreased energy and maintenance costs over the life of the building. Clean air, non-toxic building materials, daylighting and full-spectrum lighting, state of the art thermal and acoustical engineering and energy efficiency are incorporated into a holistic design and comprehensive construction of a school. Demonstrated benefits include improved student performance, improved child health, improved student attendance and substantial operational savings. High performance schools mitigate poor indoor air quality by using materials that do not off-gas hazardous chemicals, by utilizing properly designed ventilation and air conditioning systems, and focusing on preventative maintenance.<sup>xliii</sup> In addition to superior indoor air quality, healthy and high performance schools provide improved student performance due to better lighting, acoustics and thermal comfort.

Across the country, communities are building Healthy and High Performance (or "green") schools.<sup>xliv</sup> The New Jersey Governor has by executive order required all New Jersey newly constructed and renovated schools to meet green building standards.<sup>xlv</sup> The California Collaborative for High Performance Schools (or CHPS) consists of California's state executive agencies concerned with education and school

construction with California utilities and healthy school advocates.<sup>xlvi</sup> CHPS has developed healthy and high performance school design standards for California schools that have already been adopted by the Los Angeles Unified School District and the schools in San Francisco. Municipalities and school districts across the country have made similar commitments.

In New York State, Governor George Pataki has issued Executive Order 111 that requires public building to meet green building standards.<sup>xlvii</sup> He has also, in this executive order, encouraged schools to do the same. Governor Pataki championed the Green Building Tax Credit, which offers incentives for commercial builders to adopt green building principles in new construction; it does not apply to schools.<sup>xlviii</sup>

On the federal level, the “No Child Left Behind” (NCLB) act, signed by President Bush in January of 2002 defines the term “healthy, high-performance school building” as a school building in which the design, construction, operation, and maintenance —

- (1) use energy-efficient and affordable practices and materials;
- (2) are cost-effective;
- (3) enhance indoor air quality; and
- (4) protect and conserve water.<sup>xlix</sup>

NCLB authorizes a grant program for the states to promote the construction of healthy and high performance schools.

Unfortunately, Congress has not yet funded this initiative. NCLB also authorizes the Federal Department of Education to conduct a thorough study off the condition of schools facilities in the United States. This initiative has not yet been completed.

A host of resources are now available for school communities for envisioning and building healthy and high performance

schools (see the section on Resources). The National Clearinghouse for Educational Facilities ([www.edfacilities.org](http://www.edfacilities.org)) has a comprehensive catalogue of healthy and high performance school resources available on its website; most link directly on the web to the referenced source. CHPS, referenced above is one such resource. The Sustainable Buildings Industry Council has considerable quality information regarding the value of healthy and high performance schools, their defining features, and strategies for communities to build them. The Environmental Law Institute issued a report in the Fall of 2003 that comprehensively illustrates how states and communities across the country have organized to design and build healthy and high performance schools. The US Green Building Council has a well-established building certification program for “green” design and energy efficiency known as LEED (Leadership in Energy and Environmental Design). However, LEED is not set up to apply to schools, and the costs of this certification program are beyond the budgets of most school districts. Notably, the United States Environmental Protection Agency has recently released *IAQ Design Tools for Schools*. This initiative provides both detailed guidance as well as links to other information resources to help design new schools as well as repair, renovate and maintain existing facilities.

In New York State, the New York City Office of Design and Construction developed healthy and high performance building guidelines in 1999. While not specifically focused on schools, this report provides a comprehensive set of design features that mold and define a healthy and high performance building. The New York State Energy and Research Development Authority (NYSERDA) provides technical and some financial assistance for schools in designing and implementing certain healthy

and high performance building initiatives. NYSERDA is also developing a comprehensive healthy and high performance school training program for architects and engineers that could provide design professionals nationally with a continuing education certificate program on healthy and high performance schools, although the project has yet to address children's environmental health issues. (See the resources section for a fuller listing of healthy and high performance school materials.)

Designs for a healthy and high performance school will vary from region to region, and in fact as with any well designed building, no two schools will be alike. The key feature is that the whole building, its systems and occupant concerns, are addressed in an integrated way. Regional variations will consider local climate, building occupancy and use patterns, energy consumption patterns and costs. An individual school design will consider these factors, and will additionally consider the specific siting considerations and the planned needs for that specific facility. While healthy and high performance school design is not generally conducive to “cookie-cutter” design strategies, there is a substantial need for State healthy and high performance school standards and guidelines that will inform and direct local New York State school districts on criteria for healthy and high performance school construction. While as mentioned, there are federal guidelines for healthy and high performance school design, there are as yet no specific standards for comprehensive healthy and high performance school design in New York State. Other states and localities have surpassed New York State in taking the lead on developing criteria for healthy and high performance schools.

With recognition of the evidence demonstrating the rich value of a healthy and high performance school, and in view of the actions that other municipalities have taken to advance healthy and high performance school design and construction, and with further recognition of the actions that New York State policy makers have already taken to advance green building principles in other sectors of the State’s economy, certain policy options then emerge for improving school facilities:

- As part of any new policy proposal for funding school construction and renovation school districts should be held accountable to building school facilities that meet healthy and high performance school design standards that improve student health, education, and save funds over the life of the building.
- The New York State Energy and Research Development Authority is uniquely situated to develop comprehensive healthy and high performance school design guidelines for New York State, thereby helping our state to catch-up to other states and communities. This would provide school districts the guidance and technical assistance they need to plan and design healthy and high performance schools locally.
- All new school construction and all major school renovation projects should adhere to these healthy and high performance design guidelines as soon as possible to improve student health and achievement and to protect the public’s investment.
- New York State regulatory agencies need to place a priority on implementation and enforcement of existing regulations affecting school environments, children and all building occupants, and place a new priority on assessing gaps in related policies and programs.



## **Maintenance**

The second major response of policy makers and the New York State school community to the findings of the Shendell report must also include improved maintenance and upkeep of school facilities. The previously mentioned findings of the dismal condition of many schools in New York State point to inadequate maintenance. There are several reasons why schools are poorly maintained.

Local school budget decision makers commonly allocate minimal or inadequate funds for school maintenance and repair. With tight resources, school officials determine that school maintenance is expendable and thus under fund maintenance activities, believing that poor maintenance will not interfere with the school's educational mission. The findings of the Shendell paper dispel this belief.

New York State funding streams provide a perverse incentive for schools to defer maintenance. Although New York State should be commended for providing maintenance and repair funding for schools (proposed by Governor Pataki for SFY '04-'05 to be \$50 million, unchanged from prior year amounts) this funding source is commonly perceived to be inadequate to meet the need and not targeted appropriately. In contrast, state building aid for new construction and renovation is generous (proposed by Governor Pataki to be \$1.36 B for SFY'04-'05, an amount the Governor acknowledges to have grown 154% in ten years.) For most districts, more than half of the costs of a major renovation will be recovered from state building aid. In some localities, the state share is as high as 95%. From a purely fiscal standpoint, schools are incentivized to defer maintenance. Schools will not spend the necessary funds to fix a leaky roof or repair a faulty ventilation

system knowing that state building aid will reimburse most of the replacement cost. Instead, students and staff are left to languish in the resulting unhealthy and perhaps dangerous school environment, waiting for the school to reach such dismal condition that replacement, and state building aid, can be justified.

School personnel, parents, students and members of the larger community are simply not fully aware of the impact of the school indoor environment on student health and learning. Teachers, maintenance personnel, school administrators and students can through good information and knowledge, take effective action (usually at little or no cost) to improve school indoor environmental quality. The Shendell paper recommendations encapsulate many of the strategies that schools can employ to improve the environmental health, safety and achievement of children in school.

In recognition of the need to appropriately maintain school facilities to improve learning and health, the recommendations of the Shendell paper also point to certain state policy actions:

- School maintenance and repair funding should be increased to a level determined to be sufficient to provide enough financial resources for schools to sufficiently maintain their facilities and address necessary repairs in a timely and effective manner.
- School maintenance and repair funds should be prioritized assuring sufficient funding for correcting environmental health and safety maintenance and repair needs.
- A parent Right-to-Know law would assure that parents are notified of environmental health hazards at their children's schools, and that they have

timely access to school information regarding these health hazards.

- Indoor air quality at schools should be improved by schools implementing the IAQ Plans mandated under RESCUE for the evaluation and management of IAQ within their facilities.
- Clean air for children should be promoted by requiring all school busses to operate with clean fuel.
- School children should be protected from exposure to hazardous heavy metals. Provide for annual water testing by schools for lead contamination and protect young children and pregnant students and staff from lead contaminated water and lead paints in schools. Eliminate sources of mercury in schools.
- Protect schoolchildren from unnecessary exposures to toxic and unhealthy molds growing in schools.
- Students and staff should be protected from exposure to pesticides in schools by schools implementing the integrated pest

management (IPM) plans required under RESCUE.

- Establish school site standards that would prohibit schools from being constructed on or near hazardous sites, and that would prohibit the placement of new hazardous facilities adjacent or near existing schools.
- Schools should use environmentally preferred products in maintenance and construction.
- School communities should be provided a vehicle for independent oversight of school facility environmental health and safety with an independent avenue of recourse for complaints related to student and building occupant health and safety.

#### Section 4. Summary

The New York State Legislature has been compelled by the New York State Court of Appeals to consider ways to provide a sound, basic education to children in New York City, and this mandate has been largely interpreted by education constituencies, interest groups and many legislators as requiring a *statewide solution* be devised for financing a sound, basic education throughout New York State.

But as yet, school facilities have not been part of the debate or discussed as part of the solution. Many school facilities in New York State are in terrible shape, and these deplorable conditions have a substantial impact on children's health, their ability to learn, their achievement, and their attendance at school. These issues are separate from but certainly related to where state building aid has been historically allocated, or whether today there are sufficient classrooms, laboratories, libraries, textbooks, or playgrounds to meet the state's learning standards. New York State policymakers would be well advised to take into consideration an emerging body of peer-reviewed research that shows that the environmental adequacy of a school building

environment plays a substantial role in a child's health and learning. The educational community has largely agreed that factors such as smaller class sizes and teacher training significantly affect a child's education. This newer body of research and evidence now argues compellingly that the environmental adequacy of the school facility is also a significant factor in the learning and achievement of a child at school.

The proposals outlined in this paper would improve New York State's children's chances of achieving a sound basic education. These proposals highlight maintenance improvements and school design and construction improvements that create healthier, more productive school environments. Yet these proposals also are cost-effective. Improved maintenance, energy efficiency, improved attendance and more content students, teachers and staff will save money for localities and the state. For this reason alone, it is imperative that healthy school policies be incorporated into the school reform debate.

## ENDNOTES

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- <sup>i</sup> See, American Academy of Pediatrics Committee on environmental Health, *Pediatric Environmental Health*, 2<sup>nd</sup> edition, Elk Grove Village, Illinois, American Academy of Pediatrics.
- <sup>ii</sup> US General Accounting Office, *School Facilities, Conditions of America's Schools*, 1996
- <sup>iii</sup> Regents Advisory Committee on Environmental Quality in Schools, *Environmental Quality of Schools* (The State University of New York, The State Education Department, 1994)
- <sup>iv</sup> New York State Office of the State Comptroller, *School Facilities, Conditions, Problems and Solutions, October 1997*
- <sup>v</sup> Alliance for Quality Education: *Background Facts: All Children Deserve Sufficient Room to Learn in a Safe and Modern Classroom*, 2001.
- <sup>vi</sup> National Education Association, *School Modernization Facts: New York State*, quoting U.S. Department of Education, National Center for Education Statistics, [Common Core of Data Surveys](http://www.nea.org/lac/modfacts/NYfacts.html), <http://www.nea.org/lac/modfacts/NYfacts.html>
- <sup>vii</sup> New York State Office of the State Comptroller, *School Facilities, Conditions, Problems and Solutions, October 1997*
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- <sup>xv</sup> Office of the New York State Comptroller, *Implementation of the RESCUE Program*, Report 2002-S-51, 2002, p.8.
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- <sup>xix</sup> New York State Court of Appeals, Campaign For Fiscal Equity, Inc. et al. Appellants V. State Of New York et al. Respondents, June 15, 1995
- <sup>xx</sup> Supreme Court: State of New York, Campaign For Fiscal Equity, Inc. et al. Plaintiffs V. State Of New York et al. Defendants, January 9, 2001.
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- <sup>xxv</sup> New York State Court of Appeals, Campaign for Fiscal Equity, Inc., et al., Appellants, v. The State of New York, et al., Respondents. June 26, 2003
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- <sup>xxviii</sup> US EPA, *Indoor Air Quality Tools For Schools Program*, (one page factsheet), EPA 402-F-03-011, [http://www.epa.gov/iaq/schools/images/iaq\\_tfs\\_factsheet.pdf](http://www.epa.gov/iaq/schools/images/iaq_tfs_factsheet.pdf)

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- <sup>xxxix</sup> Agency for Toxic Substances and Disease Registry, *ToxFAQs for Mercury*, <http://atsdr1.atsdr.cdc.gov/tfacts46.html>. Also see Agency for Toxic Substances and Disease Registry, *National Alert, A Warning About Continuing Patterns of Metallic Mercury Exposure*, <http://atsdr1.atsdr.cdc.gov/alerts/970626.html>
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- <sup>xliv</sup> Environmental Law Institute, *Building Healthy, High Performance Schools: A Review of Selected State and Local Initiatives*, 2003, [http://www.elistore.org/reports\\_detail.asp?ID=10925](http://www.elistore.org/reports_detail.asp?ID=10925)
- <sup>xlv</sup> [http://www.state.nj.us/cgi-bin/governor/njnewsline/view\\_article.pl?id=800](http://www.state.nj.us/cgi-bin/governor/njnewsline/view_article.pl?id=800)
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- <sup>xlviii</sup> <http://www.dec.state.ny.us/website/ppu/grnbldg/>
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## Resources

### **Children's Environmental Health**

(see Healthy Schools Network's list of internet resources for a comprehensive list of informative websites related to children's environmental health and schools, [http://healthyschools.org/internet\\_resources.html](http://healthyschools.org/internet_resources.html))

Agency for Toxic Substances and Disease Registry, *ToxFAQs*, (a series of summaries about hazardous substances and human health), <http://www.atsdr.cdc.gov/toxfaq.html>

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National Institute for Environmental Health Sciences, *Children's Environmental Health Pamphlet*, [www.niehs.nih.gov/oc/factsheets/ceh/home.htm](http://www.niehs.nih.gov/oc/factsheets/ceh/home.htm), April 2003

*The National Children's Study*, This study is led by a consortium of federal agency partners: the [U.S. Department of Health and Human Services](http://www.hhs.gov) (including the [National Institute of Child Health and Human Development \[NICHD\]](http://www.nichd.nih.gov) and the [National Institute of Environmental Health Sciences \[NIEHS\]](http://www.niehs.nih.gov), two parts of the [National Institutes of Health](http://www.nih.gov), and the [Centers for Disease Control and Prevention \[CDC\]](http://www.cdc.gov)) and the [U.S. Environmental Protection Agency \(EPA\)](http://www.epa.gov). The National Children's Study will examine the effects of environmental influences on the health and development of more than 100,000 children across the United States, following them from before birth until age 21. <http://nationalchildrensstudy.gov/>.

United States Department of Health and Human Services, Centers for Disease Control and Prevention, *Second National Report on Human Exposure to Environmental Chemicals*, National Center for Environmental Health, Division of Laboratory Sciences,

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Revised March 2003

United State's Environmental Protection Agency, *America's Children and the Environment: Measures of Contaminants, body Burdens and Illnesses*, Second edition, EPA 240-R-03-001, February 2003.

### **Healthy and High Performance School Design and Construction**

A comprehensive list of resources related to Healthy and High Performance School design and construction is available at [www.edfacilities.org](http://www.edfacilities.org). This is an excellent resource. A few highlights from this list include the following:

Collaborative for High Performance Schools (CHPS), <http://www.chps.net/>

Environmental Law institute, *Building Healthy, High Performance Schools: A Review of State and Local initiatives*, Environmental Law Institute, Washington D.C., [www.eli.org](http://www.eli.org) September 2003.

Sustainable Buildings Industry Council, *High Performance School Buildings: Resource and Strategy Guide*, 1331 H Street, NW/ Suite 1000, Washington, DC 20005, [www.sbicouncil.org](http://www.sbicouncil.org), 2001

### **School Facilities in New York State**

National Education Association, *School Modernization Facts: New York State*, <http://www.nea.org/lac/modfacts/NYfacts.html>

New York State School Boards Association, New York State Bar Association, *School Law*, 29<sup>th</sup> ed., New York State School boards Association, Inc., 24 Century Hill Drive, Suite 200, Latham, New York 12110-2125, 2002

New York State Office of the Comptroller, *Meeting School Facilities Needs: A Conceptual Proposal for Consideration in the 1998-99 State Budget*, [www.osc.state.ny.us/reports/schools/1997/12-97.htm](http://www.osc.state.ny.us/reports/schools/1997/12-97.htm), December 1997

New York State Office of the Comptroller, *New York City Board of Education, Division of School Facilities Repairs and Maintenance Program Needs to Be Accelerated to Alleviate the Disrepair in City Schools*, <http://nysosc3.osc.state.ny.us/audits/allaudits/093095/a1893.htm>, February 1995

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