DRAFT FOR PUBLIC REVIEW

Report to the California Legislature

ENVIRONMENTAL HEALTH CONDITIONS IN CALIFORNIA'S PORTABLE CLASSROOMS

PUBLIC REVIEW DRAFT

A joint report submitted by:

California Air Resources Board
California Department of Health Services

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California Environmental Protection Agency

Air Resources Board

Gray Davis, Governor

Department of Health Services

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ACRONYMS

Acronym	Definition
AAAAI	American Academy of Allergy Asthma and Immunology
AAQS	Ambient Air Quality Standards
AB	Assembly Bill
ACSA	Association of California School Administrators
AHERA	Asbestos Hazard Emergency Response Act
ALA	American Lung Association
ANSI	American National Standards Institute
ARB	California Air Resources Board
ASHRAE	American Society of Heating, Refrigerating, and Air-conditioning Engineers
CAASA	California Asthma Among the School-Aged
Cal/OSHA	California Department of Industrial Relations, Occupational Safety and Health Administration
CASBO	California Association of School Business Officers
CASH	Coalition for Adequate School Housing
CCR	California Code of Regulations
CDC	Federal Center for Disease Control
CDE	California Department of Education
CDFA	California Department of Food and Agriculture
CEC	California Energy Commission
CHPS	California Collaborative for High Performance Schools
ClWMB	California Integrated Waste Management Board
CLPPP	Childhood Lead Poisoning Prevention Program
DGS	California Department of General Services
DHS	California Department of Health Services
DOE	U. S. Department of Energy
DPR	California Department of Pesticide Regulation
DSA	California Division of the State Architect, Department of General Services
EPA, U.S. EPA	U.S. Environmental Protection Agency
GAO	U.S. General Accounting Office
HEPA	High efficiency particulate arrestance
HSC	California Health and Safety Code
HVAC	Heating, ventilating, and air conditioning
IAQ	Indoor air quality
IDEC	Indirect-direct evaporative cooling
IEQ	Indoor environmental quality
IESNA	Illumination Engineering Society of North America
IPM	Integrated Pest Management
IREL	Indoor Reference Exposure Level
LAUSD	Los Angeles Unified School District
LEED™	Leadership in Energy and Environmental Design
LBNL	Lawrence Berkeley National Laboratory

NAAQS	National Ambient Air Quality Standards
NIOSH	National Institute for Occupational Safety and Health
O&M	Operation and Maintenance
OEHHA	California Office of Environmental Health Hazard Assessment
OPSC	California Office of Public School Construction, Department of General Services
OSHA	U.S. Occupational Safety and Health Administration
PAH	Polycyclic aromatic hydrocarbon
PBO	Piperonyl butoxide
PCS	Portable Classrooms Study
PEL	Permissible Exposure Limit
PM	Particulate matter
PRG	Preliminary Remediation Guidelines
REL	Reference Exposure Limit
RH	Relative Humidity
RTI	Research Triangle Institute
SB	Senate Bill
SBS	Sick Building Syndrome
SCE	Southern California Edison
SFMA	School Facilities Manufacturers Association
UC	University of California
UCLA	University of California, Los Angeles
VOC	Volatile Organic Compound, Volatile Organic Chemical
WHO	World Health Organization

ABBREVIATIONS AND SYMBOLS

Term	Definition
^oC	degrees Celsius
CFM	cubic feet per minute
CFU	colony forming unit
cm^2	square centimeter
CO	carbon monoxide
CO_2	carbon dioxide
dBA	decibel (referenced to 1 ampere)
^oF	degrees Fahrenheit
kg	kilogram (one thousand grams)
l/min.	liters per minute (flow rate)
m^2	square meter
m^3	cubic meter
µg	microgram (one-millionth of a gram)
µg/g	micrograms per gram (concentration)
$\mu g/cm^2$	micrograms per cubic meter (surface area)
$\mu g/m^3$	micrograms per cubic meter (concentration)
mg	milligrams (one-thousandth of a gram)
mg/kg	milligrams per kilogram (concentration)
ml	milliliter (one-millionth of a liter)
ng	nanogram (one-billionth of a gram)
ng/g	nanograms per gram (concentration)
No.	number
pCi/l	picoCurie per liter
PM2.5	particles with aerodynamic diameter less than 2.5 microns
PM10	particles with aerodynamic diameter less than 10 microns
ppb	parts per billion (such as one grain of sand in a billion grains of sand)
ppm	parts per million (such as one grain of sand in a million grains of sand)
T	temperature

GLOSSARY OF TERMS

Term	Definition
Active/Passive Sampling	Active sampling depends on a mechanical process like pumping to collect the sample at a known rate, such as was used for VOC and aldehyde sample collection. Passive sampling involves non-mechanical processes, like diffusion, such as was used in Phase I for the formaldehyde sample collection.
Air Changes per Hour	ACH, the volume of air moved in one hour. One air change per hour in a room, home, or building means that the equivalent of the volume of air in that space will be replaced in one hour.
Air Flow Rate	The rate at which air moves into a space. Expressed in units of air changes per hour or cubic feet per minute.
Air Handling Unit	HVAC unit. Refers to equipment that includes a blower or fan, heating and/or cooling coils, and related equipment such as controls, condensate drain pans, and air filters. Does not include ductwork, registers, or grilles, or boilers and chillers.
Allergen	A chemical or biological substance (e.g., pollen, animal dander, or house dust mite proteins) that induces an allergic state or reaction, characterized by hypersensitivity.
Ambient Air Quality Standards (AAQS)	State (ARB) and federal (EPA) enforceable regulations designed to protect the public from the harmful effects of traditional pollutants in outdoor air.
Asthma	A chronic disease of lung tissue involving inflamed airways and breathing difficulty, and an increased sensitivity to allergens and contaminants in the air.
Biological Contaminants	Agents derived from or that are living organisms (e.g., viruses, bacteria, fungi, and mammal, arthropod, and bird antigens) that can be inhaled and can cause many types of health effects including allergic reactions, respiratory disorders, hypersensitivity diseases, and infectious diseases. Also referred to as biological agents.
Comfort measures	Factors that determine human perception of thermal comfort, including temperature, relative humidity, and draft

Dampers	Controls that vary airflow through an air outlet, inlet, or duct. A damper may be immovable, manually adjustable, or part of an automated control system.
Detection Limit	Limit of detection, the lowest detectable concentration of a pollutant for a sampling and/or analytical procedure. This varies with different measurement methods.
Fungi	A group of organisms that lack chlorophyll, including molds, mildews, yeasts, mushrooms.
Integrated Pest Management (IPM)	An ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques including non-chemical prevention and control measures, habitat manipulation, modification of cultural practices, and use of least hazardous pesticides
Mail survey	An information gathering study that utilizes the mail for distributing and returning the information, using questionnaires or other written forms
Micron	A unit of length equal to one millionth of a meter; a micrometer.
Microorganism	A microscopic organism, especially a bacterium, fungus, or protozoan.
Natural ventilation	The movement of outdoor air into a space through intentionally provided openings, such as windows and doors, or through non-mechanical ventilators, by wind, air pressure differences, or other natural, non-mechanical means.
Permissible Exposure Limits (PELs)	Enforceable pollutant exposure limits determined by OSHA that are designed to protect healthy adult workers in industrial environments from adverse health effects associated with pollutant exposure. None of these limits are targeted toward protecting children.
Pesticides	A pesticide is any substance or mixture of substances intended to prevent, destroy, repel, or mitigate any pest. Though often misunderstood to refer only to insecticides, the term pesticide also applies to herbicides, fungicides, and various other substances used to control pests. Under United States law, a pesticide is also any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant.

Polycyclic aromatic hydrocarbons (PAHs)	A class of stable organic molecules made up of only carbon and hydrogen. They are a standard product of combustion from automobiles, airplanes, woodburning, cigarettes, and some types of cooking. Many of these molecules are highly carcinogenic and very common.
Portable Classrooms	Classrooms that are designed and constructed to be moveable and transportable over public streets, also known as temporary or relocatable classrooms.
Quality Control (QC)	Internal checks on the operation of sample collection and/or sample analysis. Methods for determining the operation include blanks, spiked samples, flow checks, and duplicate samples. QC measures can be used to determine accuracy, bias, and precision of the data reported.
Real-time Monitoring	This type of environmental measurement gives instantaneous information at the point of sampling; measurements are recorded as often as every minute, every second, or in fractions of a second.
Reference Exposure Level (REL)	The concentration level at or below which no adverse health effects are anticipated for a specified exposure duration. RELs are based on the most relevant, adverse health effect reported in the medical and toxicological literature for the population group known to be most sensitive to the chemical. RELs are designed to protect the most sensitive individuals in the population by the inclusion of margins of safety. Since margins of safety are incorporated to address data gaps and uncertainties, exceeding the REL does not automatically indicate an adverse health impact will occur. OEHHA provides acute (1-hour) and chronic (lifetime, non-cancer), RELs for a number of chemicals, and has developed an 8-hour “indoor” REL for formaldehyde.
Relative Humidity	The measure of moisture in the atmosphere, expressed as a percent of the maximum moisture the air can hold at a given temperature.
Return Air	Air removed from a space by the HVAC system to be recirculated or exhausted.

Sick Building Syndrome	A set of symptoms (including headache, fatigue, and eye irritation) typically affecting workers in modern airtight office buildings, believed to be caused by indoor pollutants (such as formaldehyde fumes or microorganisms).
Stratified Random Sampling	The study samples are selected randomly from each of several subgroups (strata) of the target population, previously determined. The sampling rate or selection probability for each strata can differ, depending on the study design.
Supply Air	Air delivered to the conditioned space by the HVAC system and used for ventilation, heating, cooling, humidification, or dehumidification. It is usually a combination of outdoor air and return air.
Target study population	All California K-12 public schools that had portable classrooms in both the spring and fall of 2001 (spring of 2001 only for Phase I), and all classrooms in those schools
Traditional classrooms	Classrooms in permanent, site-built school buildings
Variable Air Volume System	Air handling system that conditions the air to a temperature using a varying amount of outside airflow based essentially on the outdoor temperature.
Ventilation	The process of intentionally supplying and removing air by natural or mechanical means to and from any space.
Volatile Organic Compounds (VOCs)	Compounds that evaporate quickly from the many housekeeping, maintenance, and building products made with organic chemicals. These compounds are released from products that are being used and that are in storage.
Weights (or sample weights)	Weighting factors that are used in statistical analyses to remove the bias due to differential sampling rates and to reduce the bias due to differential rates of non-response, providing results that reflect estimates for the entire population being studied.

EXECUTIVE SUMMARY

INTRODUCTION

The California Portable Classrooms Study was a comprehensive study of environmental health conditions in California's public school classrooms. It was conducted jointly by the Air Resources Board (ARB) and the Department of Health Services (DHS) at the request of Governor Gray Davis and the State Legislature (AB 2872 Shelley; California Health and Safety Code §39619.6; see Appendix I). The study was prompted by concerns that California's schools, especially portable classrooms, might not provide healthful environments for students or teachers. These concerns were based on the potential for mold contamination, inadequate ventilation, poor temperature control, elevated levels of volatile chemicals, and excessive use of some pesticides. The study was funded to help understand the extent of these problems and to determine whether any warranted response by the state and/or schools or school districts.

The results of this comprehensive study provide important information for State and local decision-makers regarding the degree to which our classrooms provide a safe, healthful, and productive learning environment for California children. This report to the California Legislature provides an overview of the study, summarizes conditions identified in the study that need to be addressed at the State and local levels, and discusses options for improving conditions in both portable and traditional classrooms. The information presented in this report is based on the study results, findings from the scientific literature, and input provided by state agencies, school districts, consultants, manufacturers and interested stakeholders.

PURPOSE AND SCOPE OF STUDY

The purpose of the California Portable Classrooms Study was to:
- Conduct a comprehensive study and review of the environmental health conditions in portable classrooms.
- Identify any potentially unhealthful environmental conditions, and their extent.
- In consultation with stakeholders, identify and recommend actions that can be taken to remedy and prevent such unhealthful conditions.

The Legislature also directed that the study include a review of design and construction specifications, ventilation systems, school maintenance practices, indoor air quality, and potential toxic contamination including mold and other biological contaminants. Recommendations were to be developed to address the need for modified design and construction standards, emission limits for building materials and furnishings, and other mitigation actions needed to assure protection of children's health.

The study was conducted in two phases. Phase I consisted of a mail survey of 1000 schools randomly selected statewide. For each school, the facility manager and three teachers (two from portable classrooms and one from a traditional classroom) were asked to complete detailed questionnaires on all aspects of the classrooms pertaining to environmental quality. Additionally, formaldehyde sampling tubes were sent to about two-thirds of the schools, for deployment in the three classrooms. In Phase II, comprehensive chemical, biological, and environmental measurements were obtained in 201 classrooms at 67 schools randomly selected statewide. As in Phase I, two portable classrooms and one traditional classroom were studied at each school.

The State contracted with Research Triangle Institute (RTI), a not-for-profit scientific research organization, to conduct the primary field work of the study for both Phase I and Phase II. ARB's Research Screening Committee, an external scientific peer review group that assures the quality of research funded by the ARB, reviewed and approved all experimental design and study materials related to RTI's participation. ARB and DHS each conducted certain tasks of the study as well. For example, ARB pre-tested the passive formaldehyde samplers used in Phase I, managed the RTI contract, and coordinated stakeholder participation, while DHS conducted a preliminary survey of school districts, analyzed dust samples for allergens, and reviewed the biological sampling conducted by RTI. Both agencies were fully involved in project oversight, review of the results, and preparation of this report.

The final report was due to the Legislature in June, 2002. However, its completion was delayed for several reasons, including the September 11 attack, which delayed access to schools; the loss of some members of the study team; laboratory analysis delays for some environmental samples; and the organizational and practical difficulties associated with conducting, reporting, and reviewing such a comprehensive, statewide project.

STAKEHOLDER PARTICIPATION

As directed in HSC §39619.6, ARB and DHS consulted with relevant state agencies and stakeholders at key points in the study. A website and email distribution list were established to keep interested stakeholders up to date on the progress of the study. ARB and DHS consulted with the Department of Education, the Department of General Services (including the Division of the State Architect and the Office of Public School Construction), the Office of Environmental Health Hazard Assessment, and other interested state agencies prior to the study regarding the overall study design and detailed information to be obtained, and upon completion of the final research report from RTI. Stakeholder input was obtained through comment periods and through several public workshops conducted both prior to the study and upon completion of the draft report.

BACKGROUND

A "portable classroom" is defined as "a classroom building of one or more stories that is designed and constructed to be relocatable and transportable over public streets…" (California Education Code, §17070.1[k]). Portable classrooms also are often referred to as relocatable classrooms, and occur in a variety of styles and forms. Based on a DHS survey of school districts, just under one-third (about 30%, or 80,000) of the

State's 268,000 kindergarten to 12th grade (K-12) public school classrooms in the 2000-2001 school year were portable classrooms. It is estimated that about 80,000 to 85,000 are currently in use as classrooms in California.

Portable classrooms serve an important need in California K-12 public schools. They are more quickly constructed and deployed to school sites, they can be moved from school to school, and they often have a lower first-cost than traditional, site-built buildings. These features allow schools great flexibility in meeting fluctuating enrollment levels. In the late 1990s, their availability enabled the state to achieve class size reductions aimed at improving learning achievement. Until 1998, the State required school districts requesting funding to design new schools with at least 30% of portable classrooms. This requirement was imposed as a cost-saving measure. With the Leroy F. Green School Facilities Act of 1998 and passage of Proposition 1A, this restriction was lifted, and school districts were given greater local control in the design of their schools, along with a revised formula for financing, based on per-pupil grants.

Health and Economic Impacts

In recent years, concerns have risen among teachers, parents, and the public regarding potential health risks at schools, especially associated with portable classrooms. The concerns have focused on immediate health complaints such as eye irritation, allergies, asthma, headache, and fatigue, as well as the carcinogenic, neurologic, and other risks of chronic exposures to air toxics, such as formaldehyde, lead, and pesticides. Chemical contaminants and biological agents, along with other indoor environmental problems in the classroom, have frequently been the focus of attention.

California public school buildings house more than six million children in grades K-12, close to 300,000 teachers, thousands of administrators and support staff, plus countless parent and community visitors on a daily basis. Many of these individuals spend a considerable portion of their time for years within the confines of school buildings. Thus, ensuring healthful conditions inside classrooms is a critical factor in both teachers' and students' health and performance. Both may suffer the detrimental effects of poor environmental conditions; however, children generally are more vulnerable than adults to environmental contaminants and injury.

Asthma is among the most significant health problems associated with poor indoor environmental quality (IEQ) in schools. Asthma is a chronic disease of lung tissue involving inflamed airways and an increased sensitivity to contaminants in the air. Asthma is the number one cause of chronic school absences, and it may account for as many as 3 million lost days of school missed by California students annually. In California, asthma prevalence for children is about 10%, and is highest among children 12 to 17 years of age. Schools with poor IEQ contain many known asthma triggers – airborne particles, chemical contaminants, and allergens such as dust mites, cockroaches, mold spores, and animal dander.

Poor environmental conditions in schools can also affect school productivity and student performance. The available evidence suggests that IEQ problems, such as low outdoor air ventilation rate and less daylight or light, may reduce the performance of building occupants, such as students in schools.

An economic analysis of the costs of the impacts of poor IEQ on the educational sector has not been conducted. However, it is estimated that the benefits of improving IEQ in schools could total as much as $600 million -- from reduced respiratory disease, reduced allergies and asthma, reduced eye and throat irritation, and worker performance unrelated to health. This takes into consideration only the impacts on teachers and school staff; it omits analogous effects on productivity and performance among the many more students sharing the school environment.

In addition to the benefits of improved health and productivity, properly maintained buildings prove to be more cost-efficient, because fewer resources are needed under prevention-oriented programs than when neglect leads to costly repairs or untimely replacement for major facilities.

Indoor Environmental Regulations and Guidelines for Public Schools

While school design and construction are subject to codes and regulations (discussed further below), there are few specific standards or guidelines on environmental conditions specifically addressing schools. Generally, Cal-OSHA (Department of Industrial Relations) enforces several regulations relevant to schools as workplaces: CCR Title 8 Section 3362 requires that workplaces be maintained in a sanitary condition, and subsection (g) requires that all types of water intrusion be avoided, and remedied when leakage occurs. Cal-OSHA also enforces the implementation of the Injury and Illness Prevention Program required under Section 3203, which requires development of a plan and training of appropriate staff to assure the health and safety of the school employees. Finally, Section 5142 requires ventilation systems to be operated and maintained as they were designed to be, in order to provide sufficient fresh outdoor air.

The following guidelines and standards are applicable to, or can be applied to, school environmental conditions, but few are required to be met, and those that are in regulation are often not well enforced.

♦ **Air Pollutants**

There are standards set to protect workers in the work environment, and outdoor air quality standards and guidelines set to protect the general public. However, none of these are targeted toward protecting children, and only worker exposure levels are required to be met within school settings.

- Permissible Exposure Levels (PELs) developed by Cal-OSHA are limits for chemical air pollutants in industrial and other work environments.
- Federal and State ambient air quality standards (AAQS), established by U.S. EPA and the ARB, respectively, are developed to protect the general public from the

harmful effects of traditional pollutants in outdoor air. California's AAQS are currently under review to ensure that they are protective of sensitive populations including children.
- Chronic and acute Reference Exposure Limits (REL) developed by Cal/EPA's Office of Environmental Health Hazard Assessment (OEHHA) are non-regulatory guidelines to prevent harm from toxic air pollution.
- In the absence of indoor air quality guidelines or standards, the AAQS and OEHHA's RELs for acute and chronic effects may serve as useful guidelines for acceptable classroom air quality, but may not be fully protective of children.
- OEHHA has developed an interim 8-hour REL of 27 ppb, 8-hour averaging time, for formaldehyde, an almost ubiquitous indoor air pollutant, to identify the level below which irritant effects would not be expected to occur during typical day-time occupancy of buildings. Other 8-hour RELs are not yet available.
- Cancer potency factors developed by OEHHA can be used to judge potential cancer risk.

♦ **Ventilation**

Requirements for heating, ventilation, and air conditioning (HVAC) systems in California stem from several sources.
- Title 24 of the California Code of Regulation (CCR) addresses energy efficiency, and also specifies minimum outdoor air flows for different types of buildings; for classrooms, this is 15 cubic feet per minute (CFM) per person or 0.15 CFM per square foot, whichever is greater.
- Cal-OSHA (CCR Title 8) enforces an HVAC standard for workplaces that requires that ventilation systems supply at least the minimum amount of outside air that was required at the time the system was last permitted.
- The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) provides professional guidance on minimum ventilation rates for human health and comfort. While not regulatory, ASHRAE Standards, specifically Standard 62, *Ventilation for Acceptable Indoor Air Quality,* is an important reference for California's ventilation codes and recommended comfort levels. However, ASHRAE's standards are not targeted specifically toward children.
- Carbon dioxide concentrations can serve as an indicator of ventilation sufficiency. Guidelines using indoor carbon dioxide concentrations as an indoor air quality indicator are available from ASHRAE and other sources, and range from about 800 to 1200 parts per million (ppm) as a "not to exceed" level.

♦ **Temperature and Relative Humidity**

Indoor thermal conditions are generally not subject to regulation (except for extreme temperatures). ASHRAE 's Standard 55-1992 provides guidance on thermal comfort, which can be a complex function of season, occupant activity, clothing, air movement, and other factors.
- ASHRAE's acceptable temperature range is 68-75°F in the heating season and 73-79°F in the cooling season under typical humidity and airflow conditions.
- ASHRAE's acceptable range for relative humidity is 30% to 60% under common conditions; higher humidity also should be avoided to prevent mold growth.

- **Noise**

  Voluntary standards and guidelines for classroom noise have only recently been developed.
  - The American National Standards Institute (ANSI) and the World Health Organization (WHO) recommend 35 decibels (dBA) as a limit for background classroom noise.
  - The California Collaborative for High Performance Schools (CHPS) set the maximum noise level for unoccupied classrooms at 45 decibels as a prerequisite for the designation of a high performance classroom.
  - The outdoor noise limit in many California communities is 55 dBA.

- **Lighting**

  The Illumination Engineering Society of North America (IESNA) has established guidelines of a minimum of 30 foot-candles of light for large type/high contrast materials, and a level of 50 foot-candles for small type and/or low contrast materials.

- **Lead in floor dust**

  The U.S. EPA standard is 40 micrograms of lead in dust per square foot for bare floors or carpets. The maximum allowable lead level is 250 micrograms per square foot for interior window sills. These standards are based on surface wipe samples and were developed for the protection of the most susceptible group, children under 6 years of age.

Design and Construction of Portable Classrooms

Since the mid-1970s, the basic shape of portable classrooms used throughout California has remained mostly unchanged: 12x40 feet modular units fitting together in pairs (or more), with a metal roof, and a wall-mounted heat pump with air conditioning. Generally, the windows are relatively small, although they are often operable. Exteriors and floors are usually plywood or composite wood siding, and interior walls are most often vinyl-covered tackboard. In recent years, designs with a concrete wall as well as two-stories have become more common. Most importantly, numerous improvements have been made in roofing, siding, windows, heating and air conditioning, lighting, and insulation.

All public school facility construction within the State of California, including portable classrooms, must comply with the California Building Standards Code. This code is contained in Title 24 of the California Codes of Regulation (CCR). The State has some of the nation’s most stringent energy efficiency standards, which are contained in CCR Title 24 (Part 6) and include provisions on the building envelope, water-heating systems, lighting systems, and heating, ventilation and air conditioning (HVAC) systems. The Department of General Services (DGS) oversees the design, construction, and financing of educational facilities.

- The Division of the State Architect (DSA) is responsible for reviewing design plans and construction for all new school facilities, additions, alterations, and modernization projects, including portable classrooms. Although the building design plans and the State Building Standards Code address all aspects of the school design and construction, the DSA plan-check focuses exclusively on three areas: the structural design (i.e., seismic safety), handicap accessibility (i.e., compliance with the Americans with Disability Act and related standards), and fire & life safety concerns (e.g., sprinklers, fire alarms). DSA also certifies inspectors, which schools are required to hire to oversee on-site school construction and portable manufacture.

♦ The Office of Public School Construction (OPSC) administers state appropriations for public school facilities construction and modernization, relocatable classrooms leasing, and deferred maintenance funding. OPSC purchases and maintains a set of portable classroom units as part of the State Relocatable Classroom Program. This program was initially established to provide classrooms on an emergency basis, but portables now are also used by districts impacted by excessive growth and modernization projects.. The State owns approximately 6000 portables that are leased to school districts on an as-needed/as-available basis. The State purchases about 200 new portables per year, on average. Funding for portables comes primarily from lease revenues. Current costs for a portable classroom range from about $25,000 to $47,000; districts lease them for $4000 per year.

The OPSC continually reviews the classroom specifications to assure that they meet or exceed Title 24 requirements. Current OPSC specifications exceed the minimum Title 24 standards in several areas, including:

- An interior moisture barrier is required at all metal roof structures to prevent moist interior air from contacting metal elements and producing condensation.
- Wall insulation requirements have been upgraded from R-11 to R-13, and ceiling insulation has been upgraded from R-19 to R-22.
- All windows are now dual glazed “low e”.
- Lighting systems include T8 fluorescent type with photoelectric control.

OPSC also has taken and/or plans to take other steps to improve the state portable classroom specifications for their impact on indoor environmental quality. For example, all adhesives used for carpet or rubber baseboard installation must be water-based adhesives, and lighting systems are designed to provide 50 foot-candles at the desk level. OPSC’s wallboard has been tested and contains no detectable formaldehyde residue. However, OPSC plans to require that tackboard wall material and fiberglass insulation contain no detectable formaldehyde. They are also considering several options for quieting noisy ventilation systems.

OPSC also administers the Deferred Maintenance Program (DMF), which provides funding to school districts for major repairs and upgrades, such as new roofs and plumbing. However, funding for the DMF is variable, fluctuating from year to year. Extreme Hardship Grants are available for urgent projects needed within one year for health and safety or structural reasons.

.Programs for Improved School Buildings

Several programs are underway in California that already are addressing some of the problems identified in this study. These programs were begun either before or during the period of this study, and provide mechanisms to implement some of the recommendations discussed in this report. These programs include:

- State new school construction and modernization bonds. California has recently made historic investments in new school construction and modernization of older schools. Last year Governor Davis signed legislation to place a $25 billion school bond package on the state ballot. California voters approved the first bond in November, 2002 providing school districts with $11.4 billion in funding for new construction and modernization of K-12 schools. Already more than $6 billion has been allocated to school districts statewide to begin new construction and modernization projects. New bond funding will reduce the need for portable classrooms in California schools, and where the need remains, will provide funding to replace aged portable classrooms with classrooms that meet high environmental and health standards. The remaining $13 billion bond is scheduled to go before the voters on the March 2004 primary ballot.

- The Los Angeles Unified School District's (LAUSD) Facility Inspection Program is a comprehensive self-assessment of all district schools for basic health and safety conditions (Bellomo, 2003). After their first round of inspections, LAUSD officials determined that many of the basic problems found could be remedied by custodians or other school personnel, generally at less than $50 additional cost. Some of these basic problems included factors such as blocked fire extinguishers and improper use of electrical cords, important safety items critical to child safety not studied in the Portable Classrooms Study. However, they also included items such as proper storage of chemicals and implementing an Illness and Injury Prevention Program, which also are handled by school personnel. LAUSD has developed a detailed tracking system to assure that problems identified are addressed. LAUSD's "Safe School Inspection Guidebook", a checklist, is provided in Appendix V, and can serve as a good starting point for other districts and schools undertaking a self-inspection.

- The California Collaborative for High Performance Schools (CHPS) is a consortium of public agencies and energy utilities in California working to facilitate the design and construction of "high performance" schools. These schools serve as models of energy and resource efficiency, as well as provide a healthy and comfortable environment conducive to the learning process. The core of CHPS is a set of *Best Practices Manuals* which address school planning and design. This approach allows school boards to declare their intentions to build high performance schools, despite a lack of explicit knowledge of specific components. The CHPS criteria give facility designers latitude to incorporate practices in a manner that best fits the district's application. Only a very small percentage of California districts and schools have utilized CHPS excellent guidance to date.

- U.S. EPA's IAQ (Indoor Air Quality) Tools for Schools is a program developed to help schools identify, diagnose, resolve and prevent indoor air quality problems related to the facilities and the occupants, using a team approach to school IEQ management. U.S. EPA makes their *IAQ Tools for Schools* action kits available at no cost to schools across the nation, and has funded numerous training workshops, including many throughout California. Despite the outreach, awareness and use of the *IAQ Tools for Schools* programs among California school facility staff are still relatively low: in this study, less than 35% of schools reported that they were familiar with the program, and less than 10% of California schools use all or part of the program.

- An Interagency State Workgroup on Relocatable Classrooms was recently formed to identify opportunities to implement Governor Davis' sustainable building goals with respect to portable classrooms. The workgroup is a subgroup of the State Sustainable Building Task Force formed to implement Executive Order D-16-00. The workgroup is in the early stages of reviewing and developing revisions to the State specifications for portable classrooms leased by OPSC. The workgroup will also be coordinating a program to upgrade existing classrooms.

- The Lead-Safe Schools Project was begun in 1998 by the UC Berkeley Labor Occupational Health Program, DHS's Childhood Lead Poisoning Prevention Program, and the state Department of Education. The Project provides training, focused documents and a hotline for training school maintenance department staff regarding sources (primarily old paint) and remediation of lead in California schools. Starting in 2004, the Lead-Safe Schools Protection Act (SB 21, Escutia, Statutes of 2002) requires that schools certify that they will follow all standards for the management of lead hazards when they apply for state modernization funding.

- Integrated Pest Management (IPM). The Healthy Schools Act of 2000 (AB 2260, Shelley) mandated the Department of Pesticide Regulation (DPR) to promote voluntary school IPM programs. IPM includes the use of non-chemical practices to reduce pest populations, using least toxic pesticides to treat infestations above designated thresholds, and training relevant individuals regarding IPM approaches. The Act also directed schools to comply with certain requirements to reduce exposures to pesticides at schools, such as parental notification of pesticide applications, warning signs, recordkeeping at schools, and pesticide use reporting by licensed pest control businesses that apply pesticides at schools. Meeting these requirements is the responsibility of individual school districts, and DPR does not enforce compliance.

METHODS

The sampling approach used in this study was designed to obtain a statistically representative sample of the "target" study population, which was defined as all public schools in California with at least one portable classroom in spring 2001. The study was conducted in two phases. Phase I consisted of a mail survey returned by 384 of more than 1000 schools randomly selected statewide. For each school, the facility manager and three teachers (two from portable classrooms and one from a traditional classroom) were asked to complete detailed questionnaires on all aspects of the classrooms. Additionally, formaldehyde sampling tubes were sent to about two-thirds of the schools, for deployment in the three classrooms. In Phase II, a comprehensive suite of chemical, biological, and environmental measurements were obtained in 201 classrooms at 67 schools statewide. Similar to Phase I, two portable classrooms and one traditional classroom were studied at each school. Quality control checks were performed for field and laboratory measurements, and for entry of questionnaire and inspection data.

RESULTS AND DISCUSSION

Both portable and traditional classrooms were found to have some environmental conditions that need improvement. However, most school buildings and grounds are operated and maintained adequately, and the most serious problems occur only at a small percentage of schools. Remedies to address the problems identified are available. The solutions would require a combination of actions by the State, school districts, individual schools, manufacturers, and others. Many of the solutions are low-cost. Improved operation and maintenance would go a long way to address many of the problems identified. Similarly, the use of no- or low-emitting building and classroom materials often adds only minimal cost.

The results and recommendations presented below **apply to both portable and traditional classrooms** unless otherwise specified. The primary results include the following:

Ventilation

- In both types of classrooms, the amount of outdoor air was inadequate about 40% of the time (carbon dioxide levels exceeded 1000 ppm), and seriously deficient for about 10% of classroom hours (carbon dioxide levels exceeded 2000 ppm). This is a critical finding; this latter group clearly did not meet state ventilation requirements, and such deficiencies have been associated with increased eye and throat irritation, lethargy, headache and other symptoms that are incompatible with an acceptable learning environment.
- 60% of teachers in portables indicated they turn off the ventilation system at times due to excess noise; 23% of teachers in traditional classrooms reported doing this.
- Portables had more HVAC problems than traditionals, including higher rates of dirty filters (40% vs. 27%) and poor condensate drainage (59% vs. 12%), which can lead to microbial contamination, and blocked outdoor air dampers (11% vs. 3%).

Overall, the HVAC systems delivered adequate outdoor air and total air flows when operated properly, so design capacity is not a problem. Complaints of stuffy room air usually resulted from the HVAC not being operated properly. This occurs primarily for three reasons: the thermostat control limits the amount of time the system fan is operating; the outdoor air damper is blocked or in a closed position; or the teacher simply turns off the system because the noise is disruptive to class activities.

Excessive noise is the primary issue that needs to be addressed by HVAC manufacturers; low noise levels should be specified by schools when purchasing new portables. Operation and maintenance of HVAC systems needs to be improved at some schools; training of facility staff and teachers should be undertaken and regular inspection and maintenance programs followed to avoid larger problems that can result when ventilation systems are not properly operated and maintained.

Temperature and Humidity

- 27% of portables and 17% of traditionals experienced temperatures below ASHRAE's thermal comfort standards for the heating season. Some classrooms of both types also experienced temperatures above the ASHRAE standard range for acceptable indoor temperature during cool weather.
- About 11% of all classrooms had relative humidity (RH) levels below 30%, and 14% had RH levels above 60%, outside of the ASHRAE standards range for acceptable RH. Portable classrooms had slightly higher RH than traditional classrooms.
- Properly operating and maintaining HVAC systems should remedy these problems in most classrooms.

Air Pollutants

- Formaldehyde and other aldehydes:
  - ✓ Indoor concentrations were elevated above OEHHA's interim 8-hour REL for acute eye, nose, and lung irritation in a minimum of 4% of the classrooms.
  - ✓ Levels in nearly all classrooms exceeded OEHHA's chronic REL for irritant effects and OEHHA's one-in-a-million cancer risk level for formaldehyde. This was not unexpected since levels of formaldehyde in most homes and offices exceed these levels as well.
  - ✓ Highest levels occurred primarily in the warmer seasons, which increases off-gassing of volatiles such as formaldehyde.
  - ✓ Portable classrooms generally had higher formaldehyde levels than traditionals.
  - ✓ A higher percentage of portables have building materials known to emit formaldehyde, including pressed-wood furniture, tackable wallboard, and carpets. Formaldehyde emissions and levels in new building materials are estimated to take about 3-5 years to off-gas before they reach relatively low levels.
  - ✓ Alternative low-emitting materials are available and should be used in constructing new portable classrooms.
  - ✓ Other aldehydes (especially acetaldehyde) also were generally found in higher concentrations indoors than outdoors due to indoor sources.

- Volatile organic compounds (VOCs)
  - ✓ Many VOCs were present indoors due to numerous common indoor sources, but at levels similar to or lower than those in other indoor environments.

- ✓ Levels were below acute (immediate effects) risk levels.
- ✓ Some classrooms would exceed the one-in-a-million cancer risk level for benzene and chloroform if the exposure continued for a lifetime. However, shorter term exposures by children would be of limited concern. Additionally, outdoor levels also exceeded this risk level, so most of the risk is likely from outdoor sources.

- Particles
  - ✓ Total particle counts were similar for both types of classrooms for PM10 and PM2.5 size ranges, but the highest levels were seen in portables.
  - ✓ This was likely due to the more frequent use of carpets and rugs in portables, which help to reduce noise but also can serve as a particle reservoir. Proximity to vehicle traffic was likely an important particle source for both types of classrooms: over 50% of both portables and traditional classrooms were within 50 feet of parking lots and roadways.

Floor Dust Contaminants

Persistent contaminants were examined in floor dust samples collected with a specialized vacuum cleaner. Analyses of floor dust can provide insights into potential past and present contaminant exposures that cannot otherwise be obtained with a routine air sample. Metals, pesticides, polycyclic aromatic hydrocarbons (PAHs, a group of semi-volatile organic compounds emitted during combustion processes, many of which are known or suspected carcinogens), and a variety of allergens were examined in the dust samples.

- Metals
  - ✓ Elevated levels of lead were measured in some floor dust samples, most likely from tracked-in soil or paint chips from old paint indoors or outdoors.
  - ✓ Arsenic levels were slightly higher in portables, but more importantly, levels in both types of classrooms appeared to exceed typical levels found in California soils. Arsenic is a natural soil contaminant, and the primary source would be soil track-in. The elevated levels indicate possible additional school ground contamination from fertilizers and wood preservatives, some of which contain arsenic.

- Pesticides
  - ✓ Residues of both generally available and restricted-use pesticides were found in all floor dust samples, indicating the historical use of pesticides in and around schools.
  - ✓ Six pesticides were detected in over 80% of the samples: esfenvalerate, chlorpyrifos, *cis*- and *trans*-permethrin, *o*-phenylphenol, and piperonyl butoxide. Chlorpyrifos can last up to a year or more in the environment; the other five are shorter-lived, lasting just a few weeks. Thus, at most schools, pesticides appear to enter classrooms either during application or by being tracked in on shoes or clothing from the outdoors.
  - ✓ Children can be exposed to pesticides through inhalation, ingestion (hand-to-mouth activity), and dermal contact. Children in the lower grades tend to spend

a substantial amount of time sitting on the floor, bringing them into closer proximity to pesticides found in floor dust.
    - ✓ Further assessment of these pesticide results is underway.

- Polycyclic Aromatic Hydrocarbons
    - ✓ Most of the 16 PAHs studied also were found in over 80% of the classroom samples, but levels in the floor dust were relatively low.
    - ✓ Average levels were similar in portable and traditional classrooms, but portables had the highest levels. The reason for this is not known.

- Allergens
    - ✓ Cat and dog allergens were measured in more than half of the classroom samples, but the concentrations were generally below sensitization levels. Only two classrooms were above the sensitization level for dog allergens.
    - ✓ Cockroach and dust mite allergens were only infrequently found.

Moisture and Mold

- In the mail survey, 69% of the teachers reported smelling musty odors in their classroom, 43% reported current or previous floods or leaks, and 11% reported visible mold.
- Field observations by the study technician showed that:
    - ✓ 1% of all classrooms had visible mold inside the classroom, and 3% had visible mold on exterior walls.
    - ✓ 3% of portables and almost no traditionals had visible mold on the ceilings.
    - ✓ 21% of the portable classrooms and 35% of traditionals had visible water stains on the ceiling, and 13% of portables and only a few traditionals had visible water stains on the floor.
    - ✓ 17% of all classrooms (12% portables, 20% traditionals) had excess moisture measured in the walls, ceiling, or floor. Excess moisture was measured as material surface humidity above levels measured in comparable known dry material.
    - ✓ Water stains and measurements of excess moisture in building materials sometimes indicate hidden mold, and at a minimum indicate a moisture problem such as a leak that needs to be remedied.

Noise

- All classrooms exceeded the recently developed ANSI acoustic standard and WHO guideline of 35 decibels background noise for unoccupied classrooms.
- A substantial portion of unoccupied classrooms (50% portables, 38% traditionals) were measured with noise exceeding the outdoor nuisance standard of 55 decibels used by some California cities. It is excessive noise levels that leads some teachers to turn off the HVAC systems.
- Stakeholders have indicated that 45 decibels may be achievable with some associated costs and focused effort; 35 decibels appears technologically and financially unattainable at this time. California does not have a noise guideline or

standard for classrooms. CHPS has set a maximum level of 45 decibels as the goal for high performance schools.

Lighting

- About one-third of classrooms do not meet IESNA professional design guidelines of 50 foot-candles for low contrast materials, and a small percentage of classrooms do not meet the guideline of 30 foot-candles for high contrast materials.
- Portable classrooms had somewhat lower lighting levels than traditional classrooms.

RECOMMENDATIONS

Approaches to prevent and remedy most of the problems identified in this study are available, but may be subject to fiscal constraints. Actions are needed by all that are involved in providing classroom space conducive to effective learning for K-12 students. Many of the problems identified in this study can be addressed through meeting existing State standards and guidelines (primarily those of Cal-OSHA), through improved operation and maintenance programs, and through focused training efforts. Many also can be addressed at relatively low cost, although some remedies would incur significant costs. Reducing HVAC noise below 45 decibels, if deemed necessary, may require new technology.

The recommendations listed below are listed in three groups: 1) approaches that are relatively low-cost, short-term, and high priority, and are expected to yield major improvements in classrooms conditions; 2) actions that are a priority but may have more significant associated costs, and thus are subject to fiscal constraints and should be undertaken as resources allow; and 3) recommendations with a longer timeframe that are needed to assure healthful learning environments over the long-term.

GROUP 1: High Priority, High Benefit Actions with Relatively Low Cost

The Group 1 recommendations largely build on regulations, programs, and activities that are already in place but that are not being fully met or utilized. Additional resources, training, or incentives may be needed.

1. <u>Assure that all school buildings meet all relevant State regulations</u>. Unfortunately, some classrooms do not appear to meet various existing State standards, and meeting those regulations would go far to provide healthful conditions in classrooms. For example, operating HVAC systems as they were intended to be operated to assure adequate outdoor air ventilation; developing a health and safety program and training employees to implement that program, per requirements of the Injury and Illness Prevention Program regulation; and maintaining sanitary conditions and correcting water intrusion, leakage, and uncontrolled accumulation of water to reduce the potential for mold growth – all workplace requirements enforced by Cal-

OSHA – would correct several of the major problems seen in classrooms. Some remedies may not be low-cost, depending on the nature of the non-compliance.

2. Districts/schools should conduct "self-assessments" of basic safety and health conditions, similar to the self-inspection program undertaken by the LAUSD. In addition to assessing whether state regulations are being met, self-inspections can also be used to remedy obvious problems that are not necessarily regulated, and as a first step to begin to incorporate "Best Practices" into operation and maintenance functions. The LAUSD's basic checklist is provided in Appendix V; districts/schools can use all or part of it to conduct their own walk-throughs and identify key problems in the near term. Conditions that can be corrected with little or no cost should be remedied promptly and plans should be developed to obtain resources to address those that require additional funds to remedy.

3. Establish a State policy to incorporate "Best Practices" into the design and construction of new California schools, especially the measures developed by the California Collaborative for High Performance Schools (CHPS). Because of the large number of new construction and renovation projects statewide at this time, there is a unique opportunity to foster a new generation of classrooms that provide a healthful environment conducive to learning. The CHPS *Best Practices Manuals* provide an array of options and information that can be used in designing, constructing, and renovating school buildings. CHPS-based schools have a high potential for reduced energy consumption, and thus save energy dollars as well. The CHPS manuals and videos are available at http://www.chps.net/; manuals for school operation and maintenance are under development. Districts and schools should use CHPS Best Practices to the fullest extent feasible, at a minimum incorporating a few of the low-cost options that are suitable for their situation. Key examples are:

   A. Specify no- and low-emitting building materials and furnishings in construction contracts and solicitations. This should include using exterior grade wood products in wall & floor materials; no-formaldehyde insulation, ceiling tiles, and cabinetry; and other low- or no-emitting materials to avoid elevated formaldehyde and VOC levels.
   B. Specify HVAC systems that provide sufficient airflow at lower noise levels (45 dBA or lower).
   C. Design sprinklers and landscaping properly so water does not hit the building, and drains away from the structures.

4. Expand State-level design review for new buildings and major renovations. Review and approval of elements such as ventilation system design, building materials, and maintenance planning, could be added to the routine life/fire/safety plan-check function of the Division of the State Architect (DSA). The DSA is currently implementing a more proactive approach, but a more explicit mandate would assure a comprehensive state review of all plans.

5. Site portable classrooms appropriately. Classrooms should be located away from highways and busy roads, and proper grading assured. Individual portable classrooms should not be placed over low drainage areas that experience flooding. The foundation skirt should be at least 6 inches or more above ground level to prevent wicking of water up the wall, and adequate crawlspace ventilation should be specified. Some of these measures may not be low cost for some schools.

6. Train janitorial staff in proper vacuuming and cleaning procedures, and purchase efficient vacuums. Effective vacuuming of carpets requires a reasonable "residence time" of the vacuum on the carpet surface in order to effectively remove particles. This can effectively reduce persistent contaminants in carpeted classrooms. Vacuums do not need to be true HEPA, but do need to be efficient, and have virtually no particle leakage in the exhaust.

GROUP 2: Priority Approaches with Potentially Substantive Costs

7. Require districts and schools to develop an IEQ Management Plan. The U.S. EPA's *Tools for Schools Kit* provides guidance for developing such a plan: see http://www.epa.gov/iaq/schools/. Districts and schools should implement at least the core provisions in EPA's Tools for Schools (a new stream-lined, checklist version will be available in the future) and other preventive measures, including:
   A. Appoint an IEQ manager.
   B. Establish a regular inspection and maintenance schedule; ensure that HVAC systems are thoroughly cleaned and inspected at least annually.
   C. Use checklists for core inspection and preventive actions.
   D. Educate the building occupants.

8. Implement Integrated Pest Management Programs at all schools. The passage of the Healthy Schools Act of 2000 established requirements for schools to notify parents of pesticide use and to consider IPM. Successful application of IPM has been sufficiently widespread to support its implementation at all public schools, and to eliminate the use of pesticides with the greatest potential for toxic effects by school personnel. A program of preventive housekeeping practices and use of least-toxic pesticides when application is necessary has many benefits. See the Department of Pesticide Regulation website at http://www.cdpr.ca.gov/cfdocs/apps/schoolipm/main.cfm .

9. Develop and require full building commissioning procedures for new buildings and classrooms, including complete testing of HVAC, lighting, and other building systems under normal and high-capacity operational conditions.

10. Assure Preventive Maintenance. Greater incentives are needed to promote effective, routine maintenance of school facilities; the result would be both money saved (a stitch in time…) and improved learning conditions for students. Additionally, the existing Deferred Maintenance Program should be improved

through stable, consistent funding; the current year-to-year fluctuations do not permit appropriate long-term planning and preventive maintenance.

11. Develop State-level Chemical Exposure Guidelines or Standards for Classrooms. There is a lack of benchmarks for fully assessing and assuring healthful environmental conditions specific to classrooms and to the children and teachers who occupy them.

12. Increase the number of districts providing Lead-Safe Schools training for elementary school maintenance staff, and assure that they apply Lead-Safe practices during school modernization projects, e.g., use state-certified contractors when testing for, or abating, lead hazards.

GROUP 3: Future Priorities

13. Convene a task force to identify stable, long-term funding sources and approaches for school construction and maintenance for the long-term. Current funding programs are strained, fluctuating, and often function on a short timeframe.

14. Develop a Training and Certification Program for School Facility Managers. Success in operation and maintenance is often a function of the strength and knowledge of facilities directors, yet there are few credentials districts can apply in their selection of key facility department personnel. Districts should hire trained, certified facility managers.

15. Establish a state-level IEQ-in-Schools resource/outreach group to develop training materials and curricula, to coordinate training courses for school facilities personnel, and to implement an information clearinghouse.

16. Solicit teacher- and parent-organizations to provide additional support for improved operating and maintenance functions. Such groups might obtain funds for specific projects through fund-raisers, or they may provide in-kind services as "facility mentors" . For example, parents who are industrial hygienists, trained ventilation engineers, or have other skills useful in school operation may be willing to provide assistance with some of the more basic tasks.

17. Convene a task force of experts in audiology, medicine, education, and related fields to assess the impact of noise on children's learning performance and health, and to determine whether a California noise guideline or standard is needed for K-12 schools. If needed, develop and implement such a guideline or standard, and promote technology development accordingly.

18. Improve State school facility inventory and database. The State needs an effective system to inventory public school facilities. These represent among the State's greatest set of assets, yet there is no complete database on the condition, location, or even number of school buildings.

19. Re-design portable classrooms from the ground up. Most portable classrooms manufactured today are still based on designs and materials that have been available for 20-30 years or more, and on an assumption of a need for frequent relocation, which has not proven to be common. Southern California Edison, Lawrence Berkeley National Laboratory, and several portable classroom manufacturers have begun to develop very different styles of relocatable classrooms. These should be fully developed and used on a trial basis under different conditions to determine if these newer designs might better meet future classroom needs.

20. Retire older portable classrooms when they become relatively unserviceable or do not provide an adequate learning environment for children. Some older portables are well past the stage at which they should have been replaced with a new portable or a site-built classroom. New portable or site-built buildings will generally not only provide an improved environment but also will be more energy-efficient, with substantially reduced energy costs relative to the old buildings.

Implementation of some of the recommendations above will clearly incur costs to those involved, and will require fiscal planning to achieve. The Group 3 recommendations are not low priority: rather, they are actions needed to assure that healthful classrooms that facilitate learning are provided over the long-term, even in times of fiscal difficulty. The cost of not taking these actions appears high – harmful impacts on children's and teachers' health, reduced learning, reduced educational progress, and, in some cases, higher costs to fix facility problems when they become more serious. The LAUSD's self-inspection program has shown that much can be done at relatively low cost, and provides a good starting point. The CHPS *Best Practices Manuals* and U.S. EPA's *Tools for Schools Action Kits* provide ready-made guidance that can be used by districts and schools at varying levels, based on their individual resources and situations. And finally, State building, ventilation, and workplace regulations have been developed to assure safety and health, and should be met.

CONCLUSIONS

Environmental health conditions that warrant improvement were identified in this study. These included a variety of problems, such as inadequate design, operation, and maintenance of ventilation systems; contaminants present at undesirable levels in the air and floor dust; excessive noise levels; and mold and moisture problems. A number of programs initiated by the State, school districts, and others before or during the conduct of this study are already beginning to address some of these concerns. However, a more focused approach is needed to assure that existing problems are remedied and future problems prevented. The State, school districts and school administrators, school facility managers, teachers, manufacturers of portable classrooms, manufacturers of ventilation systems, and others who provide materials and supplies used by our schools all have an important role in improving the environmental health conditions of our schools. Most importantly, California needs to transition from remediation to a focus on prevention.

1. INTRODUCTION

The Air Resources Board (ARB) and the Department of Health Services (DHS) jointly conducted a study of environmental health conditions in California's portable classrooms from 2000-2003. This study, called the California Portable Classrooms Study, is the most comprehensive study of environmental conditions in kindergarten through 12th grade (K-12) classrooms to date, and provides important information for State and local decision makers working to assure a safe, healthful, and productive learning environment for California children. This report to the California Legislature provides an overview of the study, summarizes conditions identified in the study that need to be addressed at the State and local levels, and discusses options for assuring healthful conditions in both portable and traditional classrooms. The information presented in this report is based on the study results, as well as information provided by state agencies, school districts, consultants, and interested stakeholders.

1.1 Mandate and Need for the Study

The California Portable Classrooms Study was conducted at the request of Governor Gray Davis and the State Legislature (AB 2872 Shelley, 2000, California Health and Safety Code Section 39619.6; see Appendix I for full text), with an allocation of $1 million for the study. Their request was prompted by concerns that California's schools, especially portable classrooms, might not provide adequate environments for young students, and that they experienced unacceptable levels of problems such as mold contamination, inadequate ventilation, poor temperature control, elevated chemical contaminant levels, and excessive use of pesticides (Daisey and Angell, 1998; Ross and Walker, 1999; U.S. GAO 1995, 1996). Questions were raised regarding the true extent of these problems and whether they warranted state-level responses, school or school district level responses, or a combination of actions at all levels.

These questions and assertions posed a serious concern because portable classrooms have served an important need in California K-12 public schools. About one-third (30%, or 80,000) of the State's 268,000 K-12 public classrooms in the 2000-2001 school year were portable classrooms (DHS, 2003: see Appendix II). Portable classrooms are more quickly constructed and deployed to school sites. They have a lower initial cost than traditional, site-built buildings, and thus are often more affordable under the school budgeting processes in California. They can be obtained in a period of months rather than years, allowing schools to accommodate rapidly changing enrollment needs due to student population fluctuations. Their availability enabled the state to pursue class size reductions in the 1990s to help facilitate improved learning achievement.

Until 1998, the State required school districts requesting funding to design and construct schools with at least 30% of portable classrooms. This requirement was imposed as a cost-saving measure, with the expectation that districts would move classrooms rather than build new ones as student demographics changed. However, student growth continued and relatively few portables were being relocated. With the Leroy F. Green School Facilities Act of 1998 and passage of Proposition 1A, this restriction was lifted, and school districts were given greater flexibility in the design of their school, along with a revised formula for financing, based on per-pupil grants.

1.2 Definition of Portable Classrooms

The California Education Code (Section 17070.15 (k)) defines "portable classroom" as "a classroom building of one or more stories that is designed and constructed to be relocatable and transportable over public streets, and with respect to a single story portable classroom, is designed and constructed for relocation without the separation of the roof or floor from the building, and when measured at the most exterior walls, has a floor area not in excess of 2,000 square feet." Portable classrooms also are often referred to as relocatable classrooms, and occur in a variety of styles and forms. However, "modular" classrooms, which typically have some elements constructed off-site, may be either permanent structures or movable, and thus are not necessarily synonymous with the terms "portable" or "relocatable".

1.3 Purpose and Scope of the Study

The objectives of the California Portable Classrooms Study were to:

- Conduct a comprehensive study and review of the environmental health conditions in portable classrooms.
- Identify any potentially unhealthful environmental conditions, and their extent.
- In consultation with stakeholders, identify and recommend actions that can be taken to remedy and prevent such unhealthful conditions.

The Health and Safety Code directed that the study include review of design and construction specifications, ventilation systems, school maintenance practices, indoor air quality, and potential toxic contamination including mold and other biological contaminants. Recommendations were to be developed to address the need for modified design and construction standards, emission limits for building materials and furnishings, and other mitigation actions needed to assure protection of children's health.

The study was conducted in two phases. Phase I consisted of a mail survey of more than 1000 schools randomly selected statewide. For each school, the facility manager and three teachers (two from portable classrooms and one from a traditional classroom) were asked to complete detailed questionnaires on all aspects of the classrooms. Additionally, formaldehyde sampling tubes were sent to about two-thirds of the schools, for deployment in the three classrooms. In Phase II, a comprehensive chemical, biological, and environmental measurements were obtained in 201 classrooms at 67 schools randomly selected statewide. Similar to Phase I, two portable classrooms and one traditional classroom were studied.

The State contracted with Research Triangle Institute (RTI), a not-for-profit scientific research organization, through a competitively bid process to conduct the primary field work of the study for both Phase I and Phase II. For Phase I this included selecting and enrolling the sample of schools; formatting, mailing and analyzing the questionnaires; and analyzing the formaldehyde data. In Phase II, RTI planned the details of the field study; developed and refined sampling, analysis, and quality control protocols; handled the many contacts with schools and districts; conducted all on-site sampling and inspections; analyzed the samples collected; and prepared a final study report. ARB directed the field contract, air monitoring, and data analysis; obtained equipment used in the study; pre-tested the passive formaldehyde samplers used in Phase I; coordinated the stakeholder participation; and contributed funds for analysis of classroom carpet dust, a known reservoir for persistent contaminants such as pesticides and metals. DHS developed and administered a preliminary survey of districts to obtain key information on the numbers and ages of portables in each district; directed the school and classroom sampling approach and the assessment of ventilation systems; performed allergen analyses in the laboratory; and directed and reviewed the biological sampling conducted by RTI.

The study was endorsed by the Superintendent of Schools at the time, Ms. Delaine Eastin. The Superintendent's endorsement was a key factor in obtaining the cooperation of schools and school districts throughout the study.

ARB's Research Screening Committee, an external scientific peer review group that assures the quality of research funded by the ARB, reviewed and approved the Request for Proposals for the contractor, the proposals received, and the draft final report from RTI. Additionally, a small advisory panel was convened for review of the floor dust sample collection and analysis, because this is a relatively new area of investigation in the indoor air quality field.

The final report was due to the Legislature in June, 2002. However, completion was delayed for several reasons, including the September 11 attack, which delayed access to schools; the loss of some members of the study team; laboratory analysis delays for some environmental samples; and the organizational and practical difficulties associated with conducting, reporting, and reviewing such a comprehensive, statewide project.

A *Project Executive Summary* covering the key scientific results from the research study is attached as Appendix III. The two-volume Phase I and Phase II final reports from the field study are available on ARB's web site at http://www.arb.ca.gov/research/indoor/pcs/pcs.htm or upon request.

1.4 Stakeholder Participation

As directed in HSC § 39619.6, ARB and DHS consulted with relevant state agencies and stakeholders at key points in the study. A website and email distribution list were established to keep interested stakeholders up to date on the progress of the study.

ARB and DHS consulted with the Department of Education (CDE), the Department of General Services (DGS; primarily the Division of the State Architect [DSA] and the Office of Public School Construction [OPSC]), the Office of Environmental Health Hazard Assessment (OEHHA), and other interested state agencies prior to the study regarding the overall study design and detailed information to be obtained, and upon completion of the final research report from RTI.

Four public workshops were held at the beginning of the study—two each in northern and southern California—to obtain input from interested parties on the basic study design and specific information that should be obtained in the study. The information obtained resulted in some modifications to the study design and improvements in the questionnaires.

Four public workshops are planned during the review period for this draft document. For information on the review workshops scheduled for June 2003, please see the website above.

2. BACKGROUND

California public schools house more than six million children in kindergarten through 12th grade, close to 300,000 teachers, thousands of administrators and support staff, plus countless parent and community visitors on a daily basis. Many of these individuals spend a considerable portion of their time for years within the confines of school buildings. Because the key focus of school programs is the education of its pupils, it is important to note how school indoor environmental conditions – temperature, humidity, ventilation, lighting, noise, cleanliness, odor, and exposures to chemical contaminants and biological agents – can affect both the healthiness and productivity of the school environment, and thus support, or hinder, educational goals.

2.1 Indoor Environmental Conditions and Potential Health Effects

In recent years, concerns have risen among teachers, parents, and the public regarding potential health risks at schools, especially associated with portable classrooms. The concerns have focused on health complaints, similar to "sick building syndrome" or SBS (more currently called "building-related symptoms: allergies, eye or respiratory irritation , headache, lethargy, etc.), as well as the risks of chronic exposures to air toxics, such as formaldehyde, lead, mercury, and pesticides. The health impacts range from mild SBS symptoms and an array of respiratory symptoms , to the perception of poor indoor air quality, such as bothersome odors, to patent illness, such as increased rates of infectious diseases (e.g., influenza and the common cold), , asthma, and chronic sinusitis. Chemical toxins and biological agents, along with other indoor environmental problems in the classroom, are frequently the focus of concern.

Both students and school staff may suffer the detrimental effects of poor environmental conditions; however, children are far more vulnerable than adults to environmental contaminants and types of injury. Both their breathing rates and metabolic rates are significantly greater than adults relative to body mass. For example, in the same environment as adults, children will breathe in and absorb proportionally greater doses of airborne toxins. Because of their behavior, they also accidentally ingest more soil than adults. Their immune systems are less mature.

Asthma is among the most significant health problems associated with poor indoor environmental quality (IEQ) in schools. Asthma is a chronic disease of lung tissue involving inflamed airways and an increased sensitivity to contaminants in the air. Notably, the prevalence rate increased in the U.S. 74% from 1980 to 1995 (CDC, 2002). Disproportionately higher rates are found among low-income populations, minorities, and children living in inner cities. Schools with poor IEQ contain many known asthma triggers – airborne particles, chemicals, and allergens from dust mites, cockroaches, and mold spores. Asthma is the number one cause of chronic school absences, and it may account for as many as 3 million lost days of school missed by California students annually (Taylor 1992). Currently, about 10% of California's children suffer from asthma (CHIS,), with the highest prevalence found among 12-17 year olds.

Exposure to mold growth has been associated with worsening of asthma, allergies, and eye, nose or throat inflamation. However, health-based criteria for evaluating exposures to the spores, cell components, or chemical emissions from indoor mold growth are not currently available. Numerous studies have found that indicators of excess moisture such as musty odor and visible mold in buildings increase risk for respiratory symptoms such as cough and wheeze,and other health effects, and some studies have found correlations of health effects with elevated levels of mold spores in schools and other buildings (Meklin 2002, Bornehag 2001, Haverinen 1999, Verhoeff 1999).

2.2 Potential Economic and Performance Impacts

Just as poor environmental conditions in schools may directly cause occupants' ill health, it also affects school productivity and student performance (U.S. EPA, 2000). An extensive literature review was recently published, which identified limitations in conclusive data; the available evidence suggests that IEQ problems, such as low ventilation rate and less daylight or light, may reduce the performance of occupants, including students in schools (Heath & Mendell, 2002).

An economic analysis has not been done specifically for the educational sector; however, Fisk (2000) determined that the impacts of poor IEQ across the U.S. workforce are as much as $250 billion per year (1996 dollars). Fisk's results, scaled to California educators, projects that accrued benefits from improved IEQ in schools are as great as $600 million (California Sustainability Blueprint report, 2002)-- from reduced respiratory disease, reduced allergies and asthma, reduced SBS symptoms, and worker performance unrelated to health. This takes into consideration only the impacts on teachers and school staff; it omits analogous effects on productivity and performance that could be expected among the many more students sharing the school environment.

Improved IEQ in schools can reduce asthma-related medical cost (e.g., emergency room visits and hospitalization) for children and staff, but it can also improve the productivity and academic performance. Smedje et al. (2000) reported that the incidence of asthmatic symptoms was lower in pupils who attend schools (in Sweden) in which new ventilation systems have been installed. Students with exacerbated asthma suffer chronic school absences, which can cause delays in academic progress. At the same time, school districts suffer an economic loss, because revenues to California schools are determined by student attendance.

It can be expected that a more comfortable setting would be more productive, but there is limited data to quantify this. Among comfort parameters (temperature, relative humidity, light, noise, and odor), a study of school lighting has produced the most striking results. Researchers investigating lighting in an Orange County (CA) school district determined that increasing/greater daylighting (natural light, such as that through windows) improved learning rates (Heschong Mahone Group, 1999). The effect, as determined by standardized test scores among elementary school students, was as much as a 12% improvement over the school year.

In addition to the benefits of improved health and productivity, properly maintained buildings prove to be more cost-efficient, because fewer resources are needed under prevention-oriented programs than when neglect leads to costly repairs or untimely replacement for major facilities.

2.3 Indoor Environmental Regulations and Guidelines for Public Schools

While school design and construction are subject to codes and regulations (see next section), there are few specific standards or guidelines on environmental conditions specifically addressing schools. In fact, IEQ standards exist only for schools as workplaces, ostensibly to protect teachers and staff from potential health risks related to occupational exposure. Cal/OSHA (Department of Industrial Relations, Division of Occupational Safety & Health) sets and enforces the standards for workplaces in California, including General Industrial Safety Orders that buildings "… shall be kept clean, orderly and in a sanitary condition [and] maintained in such conditions as will not give rise to harmful exposure…" (CCR Title 8 Section 3362). Subsection (g) was recently added, requiring employers to correct exterior water intrusion, leakage from interior water sources, and other uncontrolled accumulation of water, in order to prevent mold growth. The State Education Code also establishes that it is the duty of the governing (school) board to furnish, maintain, and repair school facilities (Education Code Section 17565 et seq.).

Cal-OSHA also enforces Title 8 Section 3362(a),In addition, Cal/OSHA sets Permissible Exposure Limits (PELs), which are usually 8-hour time-weighted-average standards. These standards are developed for the protection of working adults, often for specific chemicals used in industrial processes/settings, and they are generally based only on acute or irritant effects, not to address the effects of chronic (long-term) exposures. .

Table 2.1 provides a summary listing of the standards and guidelines discussed below.

2.3.1 Environmental Contaminants

In general, PELs are usually much higher than indoor contaminant levels found in non-industrial settings, and Cal/OSHA rarely finds PEL violations in schools (an exception may be the occasional industrial arts classroom). However, these standards are likely insufficient to protect vulmerable school occupants such as pregnant teachers. School personnel include more vulnerable sub-populations than the "healthy worker", such as adults with chronic conditions, such as hypertention, and diabetes. Likewise, PEL standards are not designed to protect children (see Section 2.1).

For the general public, the National Ambient Air Quality Standards (NAAQS) are set by the U.S. EPA to regulate the outdoor concentrations of traditional pollutants to protect public health. These standards for outdoor air do not apply to indoor settings, but may serve as the minimum requrement for indoor air quality. California has its own state ambient standards set by the ARB that are equivalent to or more stringent than the federal NAAQS. With the California Senate Bill 25 (SB 25, the Children's Environmental Protection Act), existing California ambient air standards are being reviewed to ensure that children and infants are protected (ARB, 2000; ARB 2002). ARB also has developed indoor air quality guidelines for some pollutants in homes. National and state AAQS may be found at http://www.arb.ca.gov/aqs/aqs.htm, and ARB's indoor air quality guidelines are available at http://www.arb.ca.gov/research/indoor/guidelines1.htm.

OEHHA has developed and published Reference Exposure Limits (REL) as guidelines to prevent harm from air pollution. These non-regulatory health-based RELs were developed by reviewing available scientific evidence of toxic chemicals, considering both chronic and acute effects, to protect public health. In many cases, the REL is a factor of 100 to 1000 times less than the corresponding PEL. Acute RELS are usually applicable to exposures of about one hour, while chronic RELS address exposures that last many years. In the absence of indoor standards, OEHHA's RELs provide levels for comparison to assure a healthful environment. Some RELs have been specifically applied to indoor pollutants in non-industrial settings (Broadwin et al., 2000). For example, an 8-hour REL for formaldehyde, the most widespread of indoor pollutants, was set at 27 ppb to identify the level below which non-carcinogenic adverse health effects would not be expected to occur. OEHHA's RELs may be viewed at http://www.oehha.ca.gov/air/acute_rels/acuterel.html (acute) and http://www.oehha.ca.gov/air/chronic_rels/index.html (chronic).

Regulatory standards exist for lead and asbestos in schools, based on federal regulations (see Table 2.1). Lead is a toxin that can cause learning disabilities, decreased intelligence, kidney damage, and a host of other effects. U.S. EPA (2001a) set a limit on the maximum allowable amount of lead in surface dust, based on wet-wipe sampling. Children under 6 y are especially susceptible to its adverse impacts, and toddler-aged children are especially prone to ingesting lead through exposures to contaminated surface dust, as well as deteriorating lead-based paint surfaces.

In the absence of a regulatory standard for indoor radon, a voluntary guideline specifies concentrations of 4 pCi/l or more as an action level to trigger re-testing and remediation to reduce long-term indoor radon levels (U.S. EPA, 1993). Asbestos and radon were not measured in the Portable Classrooms Study because of cost considerations and because they are not expected to be a greater problem in portable classrooms relative to traditional classrooms. Furthermore, federal law requires the assessment of asbestos hazards in all schools (U.S. EPA ,1987), and a statewide investigation of radon in California schools is already available (Zhou et al., 1998).

2.3.2 Ventilation and Comfort

Requirements for heating, ventilation and air conditioning (HVAC) of schools are determined primarily by the California Energy Commission (CEC) and Cal-OSHA. Design requirements for outdoor air ventilation rates in public and commercial buildngs, including schools, are specified in the California Building Standards Code (CCR Title 24, §121). Although CEC's focus in regulating HVAC performance is on energy efficiency, minimum design levels are specified to assure sufficient *outdoor air* for specific indoor environments. For the typical classroom, 15 cubic feet per person is required; for special purpose classrooms such as laboratories or auto shops, higher rates may be required. While CEC's standards address equipment design, Cal-OSHA's HVAC Standard (CCR Title 8, §3142) addresses HVAC operation and maintenance in workplaces. The standard requires that ventilation systems supply at least the minimum amount of outside air as was required at the time the system was last permitted. It also requires that maintenance records of the HVAC system(s) be kept and be available during a Cal-OSHA inspection.

Non-regulatory guidelines exist for HVAC systems in school settings. The American Society of Heating, Refrigerating, and Air Conditioning Engineers' Standard 62, *Ventilation for Acceptable Indoor Air Quality*, sets professional standards for minimum outdoor air ventilation rates (ASHRAE, 2001), and Standard 55, *Thermal Environmental Conditions for Human Occupancy*, sets indoor comfort levels for temperature and humidity (ASHRAE 1992). While not intended as a health standard, ASHRAE Standard 62 has been historically adopted into state and local building codes, and continues to serve as a foundation for related elements of the California energy standard. With its continuous maintenance, addenda and appendices, Standard 62 continues to serve as the most explicit guideline available that address IAQ in schools and commercial buildings.

2.3.3 Noise and Lighting

Acceptable noise and lighting illumination levels for classrooms have been established by non-government organizations, similar to ASHRAE, and serve as target values in the absence of government standards. The American National Standards Institute (ANSI, a non-government standard-setting organization) and the World Health Organization (WHO) have established a standard and guideline, respectively, of 35 decibels (dBA) for background noise levels in (unoccupied) classrooms. This is a controversial noise limit, as it is not easily met in standard classroom construction. The Collaborative for High Performance Schools (CHPS), a California based non-profit organization, recommends a maximum unoccupied background noise level of 45dBA and a 0.6-second maximum (unoccupied) reverberation times. CHPS encourages designers to move beyond these minimum prerequisites and achieve background noise levels of 35 dBA for all classrooms. The ANSI and WHO recommendation for other indoor (non-school) settings is 45 dBA, and the outdoor community standard used in many cities is 55 dBA.

For lighting, the Illuminating Engineering Society of North America (IESNA) recommends lighting illumination levels for various kinds of visual tasks involving materials with different print sizes and of high or low contrast. The California Energy Code dictates the amount of lighting power (electricity) per classroom area that may be used, to require the use of efficient lighting equipment to meet IESNA recommended lighting illumination levels.

2.3.4 Mold

Floods, leaks, and water intrusion have long been concerns of school facility staff, because these problems can cause safety hazards, as well as degrade building structures and components. Recently, awareness has increased that dampness and indoor mold can cause a variety of health effects and symptoms, including allergic reactions, and can act as asthma triggers. Widespread publicity about "toxic mold" has served as stark encouragement to school facility staff to be especially vigilant in inspecting and repairing potential water intrusion problems quickly.

Unlike toxic chemicals, such as mercury or lead, there are no numeric standards to apply in situations where indoor mold contamination is found. Therefore, the results of this study cannot be compared to a standard. California recently passed legislation that directs DHS to consider the feasibility of adopting permissible exposure limits for indoor mold contamination (SB 732, Ortiz, Statutes of 2001). The form that SB 732 regulations might take remains uncertain, as a number of expert panels have stated that PELs are not appropriate for assessing mold exposure risk (ACGIH, 1999; NYC DOH, 2000). The current SB 732 implementation plan includes convening a task force to advise DHS on the development of practical guidelines to assess the health threat posed by the presence of mold and to establish guidelines for identification of mold, visible or hidden in an indoor environment, and for the remediation of mold. Despite the absence of PELs or numeric standards, practical guidance has been developed for assessment and clean-up procedures of indoor mold contamination (e.g., NYC DOH, 2000; U.S. EPA, 2001b).

Several guidance documents have been published specifically for school environments. DHS has produced "Mold in Your School," and the U.S. EPA released "Mold Remediation in Schools and Commercial Buildings" in March 2001. This document presents approaches for the assessment and remediation/cleanup of mold and moisture problems in schools, including measures designed to protect the health of building occupants and clean-up staff. It was designed primarily for building managers and custodians. Also published in 2001, the Minnesota Department of Health developed "Recommended Best Practices for Mold Investigations in Minnesota Schools". This guidance document was created to assist public school staff in investigating the causes of indoor mold concerns and in finding cost-effective solutions. This document is aimed at school staff, such as Indoor Air Quality Coordinators, facilities and maintenance personnel, health and safety staff, and other school officials. Both documents counsel school officials to make reasonable judgments as to whether their situation can be handled in-house and to recognize their limits in addressing more serious, widespread problems, when they should hire professional services.

2.4 Design and Construction of Portable Classrooms

Since the mid-1970s, the basic shape of portable classrooms used throughout California has remained mostly unchanged: 12x40 feet modular units fitting together in pairs (or more), with a metal roof, and a wall-mounted heat pump with air conditioning. Generally, the windows are relatively small, although they are often operable. Exteriors

Table 2-1 Selected Guidelines and Standards Relevant to Schools Environments.

COMPOUND/ PARAMETER	STANDARD, CODE or GUIDELINE	SOURCE
Ventilation	**Mechanical: outside air ventilation rate**: 15 cubic feet per minute (CFM) per person or 0.15 CFM per ft^2, whichever is greater. **Natural ventilation**: allowed when openable window area is 5% or more of floor area, space is within 20 ft, and airflow is unobstructed. **Demand control ventilation (not required):** CO_2 below 1000 ppm or CO_2[outside]+600 ppm (effective 2005) **Thermal comfort (guideline)**: Temperature and Relative humidity **Operation & maintenance**: annual inspection and written log	CCR Title 24, §121(b) CCR Title 24, §121(c) ASHRAE 55-1992 CCR Title 8, §5142
Noise	**Classroom standard (unoccupied):** 35 dBA (decibels) **Classroom guideline**: 45 dBA, **WHO guidelines**: Classroom: 35 dBA Indoor community: 45 dBA Playground guideline: 55 dBA **CHPS classroom guideline**: 45 dBA and 0.6 s reverberation time (Max) **Outdoor community standard**: 55 dBA	ANSI (2002) Crandell (1992) WHO (1999) CHPS (2003) City of Los Angeles
Lighting	**Large/high contrast**: 30 foot-candles **Small/high contrast or large/low contrast:** 50 foot-candles	IESNA (2000)
Formaldehyde	**Acute REL**: 76 ppb (1-hr average) **Interim REL**: 27 ppb (8-hr average) **Chronic REL**: 2.4 ppb (long-term average) REL= Reference Exposure Limit ppb=part per billion **Proposition 65 "Safe harbor"**: 1.3 ppb	OEHHA (1992) Broadwin (2000) OEHHA (2001) OEHHA (1992)
Lead dust	**Federal standards**: 40 micrograms of lead per square foot ($\mu g/ft^2$) on bare floor or carpet; 250 $\mu g/ft^2$ for interior window sills.	U.S. EPA (2001a)
Asbestos	Asbestos Hazard Emergency Response Act (**AHERA)** **PEL**: 0.1 fiber per cubic centimeter (cc) of air	U.S. EPA (1987) CCR Title 5, §5208(c)
Radon	**Voluntary Action Level**: 4 picoCurie (pCi) per liter of air	U.S. EPA (1993)
Molds	Voluntary guidance for assessment and remediation – no numerical standards of limits	U.S. EPA (2001) NYC DOH (2000)

and floors are usually plywood or composite wood siding, and interior walls are most often vinyl-covered tackboard. In recent years, designs with a concrete wall as well as two-stories have become more common. Most importantly, numerous improvements have been made in roofing, siding, windows, heating and air conditioning, lighting, and insulation.

General requirements for school facilities are given in regulations (CCR Title 5, Seciton 14001), which address educational goals, master planning and future needs, structural, fire and public safety requirements, siting to mitigate toxic hazards, " (d) designed for the environmental comfort and work efficiency of the occupants; (e) designed to require a practical minimum of maintenance." All public school facility construction within the State of California, including portable classrooms, must comply with the California Building Standards Code. This code is contained in Title 24 of the California Codes of Regulation (CCR). The State has among the nation's most stringent energy efficiency standards, which are contained in CCR Title 24 (Part 6) and include provisions on the building envelope, water-heating systems, lighting systems, and heating, ventilation and air conditioning (HVAC) systems. The Department of General Services (DGS) oversees the design and construction of educational facilities. The Office of Public School Construction (OPSC) within DGS administers the State funding of public school facilities construction and modernization, relocatable (portable) classrooms, and deferred maintenance.

The Division of the State Architect (DSA) within DGS is responsible for reviewing design plans and construction for new school facilities, additions, alterations, and modernization projects, including portable classrooms. Although the building design plans and the California Building Standards Code address all aspects of the school design and construction, the DSA plan check in the past has focused exclusively on three issues: the structural design (i.e., seismic safety), handicap accessibility (i.e., compliance with the Americans with Disability Act and related standards), and fire & life safety (e.g., sprinklers, fire alarms, etc.). Beginning in 2001, DSA has added compliance with the California Energy Code as an area of emphasis in plan check. In addition, throughout construction, school districts are required to retain a DSA-certified inspector to monitor all construction activities and to liaison between the building contractors and DSA regarding code compliance. In the case of portable classrooms, DSA offers an expedited review focused on the fire & life safety components, provided the classrooms will be duplicates of previously approved designs. Compliance with the California Energy Code is included in the review of relocatable school buildings.

2.4.1 State Relocatable Classroom Program

For the State Relocatable Classroom Program, the OPSC has purchased and maintains a set of approximately 6000 portable classroom units to make available to school districts on an as-needed/as-available basis. These classrooms are intended for districts impacted by excessive growth or for periods their facilities are closed during modernization or for unforeseen emergencies. The State purchases about 200 new portables per year, on average. Funding for portables comes primarily from lease revenues. Current costs range from about $25,000 to $47,000; districts lease them for $4000 per year. Districts are responsible for all maintenance of the leased units, which are retained by a district anywhere from less than one year to more than ten years. When a unit is returned to OPSC, they inspect the unit, make necessary repairs (charged to the former lessee), and generally deploy the unit to another district in need fairly quickly. In addition to the annual lease, school districts are responsible for the costs of installation, including site preparation and utility hook-up.

With DSA assistance, DGS issues bid specifications for contractors each time OPSC purchases units for the State program. Depending on funding, OPSC will issue a contract to build several hundred classrooms. The DGS specifications are for the "basic" classroom (DGS, 2000), and these often serve as the template for non-State program portable classroom purchases. Nonetheless, school districts may submit design plans of their own for approval when they are purchasing units for themselves.

The OPSC continually reviews the classroom specifications to assure that they meet or exceed Title 24 requirements. Current OPSC specifications exceed the minimum Title 24 standards in several areas, including:

- An interior moisture barrier is required at all metal roof structures to prevent moist interior air from contacting metal elements and producing condensation.
- Wall insulation requirements have been upgraded from R-11 to R-13, and ceiling insulation has been upgraded from R-19 to R-22.
- All windows are now dual glazed "low e".
- Lighting systems include T8 fluorescent type with photoelectric control.

OPSC also has taken and/or plans to take other steps to improve the state portable classroom specifications for their impact on indoor environmental quality. For example, all adhesives used for carpet or rubber baseboard installation must be water-based adhesives, and lighting systems are designed to provide 50 foot-candles at the desk level. OPSC's wallboard has been tested and contains no detectable formaldehyde residue. However, OPSC plans to require that tackboard wall material and fiberglass insulation contain no detectable formaldehyde. They are also considering several options for quieting noisy ventilation systems.

OPSC also administers the Deferred Maintenance Program (DMF), which provides funding to school districts for major repairs and upgrades, such as new roofs and plumbing. However, funding for the DMF is variable, fluctuating from year to year. Extreme Hardship Grants are available for urgent projects needed within one year for health and safety of structural reasons.

2.4.2 California Collaborative for High Performance Schools

The Collaborative for High Performance Schools (CHPS) is a California consortium of public agencies and energy utilities working to facilitate the design and construction of "high performance" schools. These are school facilities that aim to be models of energy and resource efficiency, as well as healthy and comfortable settings supporting quality education. CHPS uses a whole building design approach, as well as providing designers with specific guidance on component systems, that incorporates the best of current knowledge and technologies. The core of CHPS is a set of *Best Practices Manuals,* which address high performance school planning and design (CHPS, 2003). Recently, the U.S. Department of Energy adapted the CHPS Best Practices Manual Volume II (Design) for a national audience (U.S. DOE, 2003). In addition to its publications, CHPS provides ongoing training to school facility staff, architects, and engineers.

CHPS developed their own grading criteria using a point system, similar to the U.S. Green Building Council's Leadership in Energy & Environmental Design (LEED™) scoring (U.S. Green Building Council, 2003). This approach allows school boards to declare their intentions to build high performance schools, despite a lack of explicit knowledge of specify components. The CHPS scoring gives facility designers latitude to incorporate practices in the manner that best fits the district's application. CHPS has helped secure funding for a number of demonstration projects throughout the state. Several school districts, notably Los Angeles Unified, have established policies to require all new facilities to meet the CHPS criteria.

2.4.3 U.S. EPA *IAQ Design Tools for Schools*

The U.S. EPA is about to unveil a new on-line resource called *IAQ Design Tools for Schools* to help school districts with information resources for designing new school facilities and repairing existing facilities. Its primary focus is on IAQ, but it is also develops the concept of designing High Performance Schools, an integrated, "whole building" approach to addressing each of the important – and sometimes competing – priorities, such as energy efficiency, indoor air quality, day-lighting, materials efficiency, and safety, plus doing so in the context of tight budgets and limited staff. *IAQ Design Tools for Schools* builds largely on the CHPS program (see above), but it adds value by being web-based, having a national focus, and containing a broader array of resource materials on IAQ issues. The web site is still under construction, though it can be viewed at: http://www.epa.gov/iaq/schooldesign/.

2.4.4 State Workgroup on Relocatable Classrooms

An interagency workgroup was started recently to identify opportunities to implement Governor Davis' sustainable building goals with respect to portables. This subgroup is part of the interdepartmental Sustainable Building Task Force comprised of representatives from more than 40 state agencies with fiscal, construction, energy, health, and environmental policy expertise, which was formed after Governor Davis issued an executive order to direct state agencies to address sustainable buildings in the planning, design, and construction of state facilities (State of California, 2000). The workgroup is reviewing and revising the DGS building specification for relocatable classrooms with respect to sustainability goals, including enhanced IAQ. For more information, see www.governor.ca.gov/state/govsite/gov_homepage.jsp.

2.4.5 Innovative Design Initiatives

There have been on-going efforts to “rethink” the design of portable classrooms. In 1998, Southern California Edison (SCE) sponsored a workshop with architects, engineers, manufacturers, and school district officials, as well as outside consultants with expertise in energy analysis, modular buildings, and lighting design. SCE funded a demonstration project incorporating ideas from the 1998 workshop (SCE, 1998). A follow-up workshop was conducted in April 2003, and additional pilot portable classrooms are in development (SCE, 2003).

In 2000, the California Energy Commission funded a project with Lawrence Berkeley Laboratory investigating both low VOC-emitting materials and novel HVAC system design, to reduce chemical sources and increase classroom ventilation rates (Apte, 2002). Starting in mid-2003, CEC anticipates funding several projects on classroom ventilation technology for K-12 schools, including applications for portable classrooms (CEC, 2003).

2.4.6 Portable Classroom Manufacturers

The School Facility Manufacturers' Association (SFMA), formed in 1987, is a trade organization for the manufacturers of modular school buildings, architects, suppliers and others in related businesses, specific to California. Because portable classrooms require DSA approval, units are infrequently imported from out-of-state. Essentially all portable classrooms purchased or leased by California school districts are manufactured by one of about 10 companies. Portable classrooms are one application of factory-built modular building construction; consequently, many of these manufacturers also build products for a variety of commercial applications, e.g., offices, emergency rooms, airports, clinics, and retail centers. The Modular Building Institute (MBI) formed in 1983 is the national trade organization for manufacturers, dealers and material suppliers in both the portable classroom and commercial factory-built structure industry.

In 1999, California manufacturers of portable classrooms were sued under Proposition 65 by “As You Sow” for alleged exposures to formaldehyde above the “Safe Harbor” limits. The manufacturers disputed the claims of the lawsuit, but in 2002 the parties reached a settlement under the direction of the State Attorney General’s Office. The manufacturers agreed to minimize the use of particle board (a common construction material that contains formaldehyde). This product does not meet the structural requirements of DSA and therefore was infrequently used in portable classrooms except in cabinetry. Many manufacturers also have shifted to using insulation that emits no formaldehyde.

2.5 School Operation and Maintenance (O&M) Practices

Effective operations and maintenance (O&M) of school facilities are as essential as good design and construction to assure a safe and healthy learning environment. An effective maintenance plan requires adequate funding, properly trained facility maintenance staff, and administrative support to keep school facilities in good condition. The required activities include the daily janitorial services, routine inspection and maintenance of facilities including its subcomponents (e.g., HVAC systems, building envelope, landscaping, etc.), and planning for major repairs and modernization needs. Daily janitorial and routine maintenance services are funded from the general budget for school operations.

There is a relatively wide range in the services supported among districts, reflecting their relative wealth and commitment to O&M as a priority. Not surprisingly, budget cuts most often reduce facility maintenance programs as a way to “keep cuts out of the classroom”. Major repairs and modernization needs are funded separately from routine activities in most school districts. Districts apply to OPSC’s Deferred Maintenance Program for cost-sharing of major repairs, such as roof replacement, HVAC system upgrades, and other non-routine maintenance. However, funds are not always available in the Program.

2.5.1 LAUSD’s Facility Inspection Program

The Los Angeles Unified School District’s (LAUSD) Facility Inspection program is a comprehensive self-assessment of all district classrooms for basic health and safety conditions. After their first round of inspections, LAUSD officials determined that many of the basic problems found could be remedied by custodians or other school personnel, generally at less than $50 additional cost. Some of these basic problems included factors such as blocked fire extinguishers and unrestricted electrical cords, important safety items critical to school environments and child safety not studied in the Portable Classrooms Study. However, they also included items such as proper storage of chemicals and developing and implementing an Illness and Injury Prevention Plan, which also are handled by school personnel. Problems requiring experienced specialists from the main district office or from the private sector cost more to remedy. LAUSD has developed a detailed tracking system to assure that problems identified are addressed. LAUSD’s “Safe School Inspection Guidebook”, a set of checklists, are provided in Appendix V, and can serve as a good starting point for other districts and schools undertaking a self-inspection.

2.5.2 U.S. EPA’s Indoor Air Quality Tools For Schools Program

In 1995, the U.S. EPA launched their *IAQ Tools for Schools Program* (U.S. EPA, 1995). In the absence of federal legislation on IAQ, this voluntary program provides schools with information they need to understand IAQ issues and to solve or prevent IAQ problems. The program was developed to help school staff identify, diagnose, resolve and prevent IEQ problems related to the facilities and the occupants. It uses a team approach to school IEQ management and emphasizes the importance of staff training, communication, and routine maintenance for school facilities to establish priorities for their resources. The *IAQ Tools for Schools Action Kit* contains instructional materials with modular components for use in starting a program at a school or throughout a district. The self-contained IAQ management plan contains a set of activities, such as occupant checklists, evaluating this information and performing a building walk-through. U.S. EPA makes their kits available at no cost to schools across the U.S., and has funded numerous training workshops.

In California, U.S. EPA has trained more than 2000 individuals from districts throughout the state. Despite the outreach, awareness of the *IAQ Tools for Schools* program among California school facility staff is still relatively low: less than 35% of districts, based on PCS Phase I survey data. Nor is adoption of the program in California widespread: less than 10% of districts use all or part of the program. U.S. EPA attributes resistance among school decision-makers to the program to the following: (1) they are not adequately informed about the program; (2) they have the misconception that IAQ is strictly a facilities issue; (3) they fear that raising awareness of IAQ will open a “Pandora’s box” of complaints; (4) they do not recognize that many IAQ improvements can be made without additional costs. U.S. EPA is partnering with organizations of school officials (e.g., ACSA, the Association of California School Administrators, and CASBO, the California Association of School Business Officers) to overcome these misperceptions.

A pilot study was developed in the states of Washington and Idaho to create individualized, more streamlined *IAQ Tools for Schools* programs, with seemingly good results. School staff are assisted by an experienced IAQ/building science specialist to conduct walk-through assessments at each school, to identify actual problems plus provide as on-site training for staff. Schools use the assessment findings, along with guidance from the specialist, to adopt practices and procedures from a “menu” of options. The success of the modified program is ascribed to the following: (1) it is perceived as easy to understand, practical and action-oriented, (2) it is non-regulatory, and (3) an unbiased and qualified expert is made available to give on-site guidance, training, and resources (Prill et al., 2002).

Assembly Committee Resolution 75 (Chan), currently under consideration by the California Legislature, would encourage school districts to implement the program. U.S. EPA is currently developing a streamlined version of IAQ Tools for Schools, based in part on stream-lined checklists developed by the Los Angeles Unified School District, that would likely be more acceptable and useful to California districts.

2.5.3 Lead-Safe Schools

Lead exposure in the school environment is one of the few cases where an environmental toxin is regulated (see Section 2.3.1). In 1992, the Legislature directed DHS to conduct a study of lead hazards in the state’s public elementary schools and childcare facilities, as part of the *Lead-Safe Schools Protection Act*. The CLPPP study surveyed a random sample of 200 schools and daycare facilities, and identified the prevalence of lead hazards, including lead-based paint, contaminated soil, and drinking water with lead concentration above the federal action level in a report issued in 1998 (DHS, 1998). Most notably, some lead-based paints was found in close to 80% of schools and daycare centers, although only 38% of these also have paint that is deteriorated.

The *Lead-Safe Schools Project* was established in October 1998 jointly by U.C. Berkeley's Labor Occupational Health Program, CLPPP and the state Department of Education. The program provides training, focused documents, and a hotline aimed at school maintenance staff. The joint project has conducted 81 training programs around the state for school maintenance department staff (as of March 2003), with participants representing 425 of the targeted 882 school districts in California.

The Lead-Safe Schools Protection Act (SB 21, Escutia, Statutes of 2002) requires that, starting in 2004, schools shall certify they will follow all standards for the management lead hazards, when they apply for state modernization funding. The Act allows districts to use deferred maintenance funds for the assessment of lead-containing materials and the management of specific lead hazards.

2.5.4 Integrated Pest Management (IPM)

The Healthy Schools Act of 2000 (AB 2260, Shelley) mandated the Department of Pesticide Regulation (DPR) to promote school Integrated Pest Management (IPM) programs. IPM includes implementing non-chemical practices to reduce pest populations, using least toxic pesticides to treat infestations above designated thresholds, and training relevant individuals regarding IPM approaches. The Act also directed schools to comply with certain requirements to reduce exposures to pesticide at schools, such as parental notification of pesticide applications, warning signs, recordkeeping at schools, and pesticide use reporting by licensed pest control businesses that apply pesticides at schools. Meeting these requirements is the responsibility of individual school districts, and DPR does not enforce compliance. DPR started promoting school IPM earlier, but the Act lead to a more coordinated outreach program, production of guidance documents, formation of an advisory group, performance of baseline and follow-up surveys, and creation of a *California School IPM* web site (http://www.cdpr.ca.gov/cfdocs/apps/schoolipm/main.cfm)

According to the DPR’s 2002 survey (Geiger and Tootelian, 2002), 87% of districts were aware of the Healthy School Act, 71% reported themselves to be in compliance with at least three of the four Act’s requirements (posting, record keeping, annual notification, and maintaining lists for special notification), and 49% of school districts were fully compliant. Nonetheless, the Act does not explicitly require that schools alter their pest management program with respect to which pesticides are used. A survey by a public interest group identified that while district record keeping about pesticide use has improved under the Act, the use of pesticides with “very hazardous ingredients” has not decreased (McKendry, 2002).

2.5.5 School-based Asthma Management Program

As awareness of the increase of childhood asthma has also risen, a number of programs have been developed to target school environments, both to reduce children's exposures to asthma triggers, plus as a convenient contact point to provide information and aid in medical management for the disease. The U.S. EPA (2002) provides resources and information on their web site *Managing Asthma in the School Environment*. The American Lung Association has conducted its *Open Airways for Schools* program since 1992 to informs to educate and empower students to better manage their asthma with the assistance of parents, teachers, school nurses, and physicians, through in-class lessons taught by trained volunteers. Many local agencies and non-profit organizations are partnering to support school-based asthma management activities, such as the *California Asthma Among the School-Aged* (CAASA) program, funded by the California Endowment.

2.5.6 Statewide Organizations

Several statewide organizations are active in providing guidance to school officials regarding facility O&M. The Coalition for Adequate School Housing (CASH) is an association of school districts, architects, attorneys, facility manufacturers and planners, financial institutions, consultants, and vendors (http://www.cashnet.org/). CASH's Maintenance Network focuses on strengthening maintenance efforts statewide and increasing public and legislative awareness and funding for school maintenance issues. The California Association of School Business Officers (CASBO) represents the group of school officials most directly involved in making O&M policy decisions (http://www.casbo.org/). CASBO make recommendations about staff and budget needs for schools per their size (e.g., they publish manuals such as "Custodial Handbook" and "Maintenance Staffing Formula"). While committed individuals are working hard to promote these goals, there are no state regulations or guidelines on the O&M practices or minimum funding levels for school districts.

3. STUDY METHODS AND RESULTS

The study was conducted in two major phases, a mail survey followed by a field study. In the mail survey, Phase I, questionnaires for school facility managers and teachers and passive formaldehyde samplers were sent to randomly selected schools during April-June of 2001. In the field study, Phase II, field technicians inspected classrooms and obtained numerous environmental measurements from October 2001 through February 2002. In both phases, three classrooms (two portables and one traditional classroom) were randomly selected at each school to participate in the study. The following section summarizes the methods and results of the study. More detailed information is available in the final contractor reports for Phases I and II.

3.1 Methods

The sampling approach for this study was designed to be statistically representative of the “target” study population, which was defined as all public schools in California with at least one portable classroom in spring 2001. The sample of schools was drawn randomly from the California Public School Directory 2000 (CDE, 2002). A preliminary mail survey of all public K-12 school districts in 2000-2001 found that there were about 80,000 portable classrooms in California, or about 30% out of a total of 268,000 classrooms estimated to exist in California in 2001 (DHS, 2003).

To ensure that proportionate numbers of schools were selected among the school categories that might have different IEQ-related characteristics, the sample was also stratified by north-south regions of the state, by school type (elementary, middle, or high school), and by urbanization of the area (urban, suburban, or rural). The study data were weighted to adjust for this stratification, and for unequal response rates in certain categories, thereby providing a representative estimate for the target population. As shown in Table 3-1, Phase I included 1,133 classrooms across the state, and Phase II included 201 classrooms across the state.

Table 3-1. Study Design, Phases I and II.

Study Phase	Sampling Period	Sample Size	Question-naires	Building Inspection	Environmental Measurements
I: Mail Survey	April-July, 2001	1133 rooms; 384 schools	Teacher & Facilities	No	Formaldehyde only; 7-10 days
II: Field Study	Oct. 2001 – Feb. 2002	201 rooms; 67 schools	Teacher & Facilities	Yes	Numerous measurements; 6 hours (Table 3-2)

3.1.1 Phase I

Two questionnaires, a Facilities Questionnaire and a Teacher Questionnaire, were created collaboratively by ARB and DHS. The questionnaires were based on questionnaires from other studies, on guidance documents, and on information obtained during public workshops held across the state. The questionnaires were used during both study phases to obtain information from facility managers and teachers about classroom characteristics and the environmental quality conditions and complaints at the sampled schools. The Facility Questionnaire provided *school*-level and classrooms-level information on the physical conditions, operation, and maintenance of building facilities and grounds for 384 schools statewide. The Teacher Questionnaire provided *classroom*-level information, such as the presence of potential pollutant sources and observations of moisture, air quality, noise, and lighting problems.

In addition, airborne formaldehyde was measured in a sub-sample of the Phase I classrooms. ARB pre-tested the passive formaldehyde samplers (small glass tubes with a special adsorbent), and, in consultation with the manufacturer, developed protocols that achieved improved sensitivity and precision. These samplers have been widely used in previous mail survey studies, including those in a large study of manufactured homes conducted by DHS (Sexton et al., 1989; Liu et al., 1991). The samplers were mailed with the Phase I survey materials and placed in the classrooms by school or district personnel for approximately 10 days.

3.1.2 Phase II

Phase II was a field study of environmental conditions in classrooms from 67 schools in a stratified-random sample of all schools with at least one portable classroom both in the spring of 2001 and in the 2001-02 school year. Field technicians inspected the HVAC system and classroom interiors and exteriors, and recorded measurements of air flows, noise levels, lighting levels, and moisture content of the interior walls, floor, and ceiling. The field technicians also collected a wide array of environmental samples and measurements during one school day at each school, as summarized in Table 3-2. Indoor and outdoor data were collected for many of the measurements.

Most measurements were obtained across the six hours a day when the classrooms were typically occupied. HVAC testing, noise measurements, and sampling for culturable airborne molds and pollens were conducted during lunch breaks. Environmental samples were stored on ice and shipped weekly by overnight delivery. Quality control checks were performed for field and laboratory measurements, and for entry of questionnaire and inspection data. The measurements of air pollutants and dust contaminants showed good precision (an average of 10% or less across sample types). Only the measurements and data meeting acceptance criteria were used in the study.

Of the 67 schools studied in Phase II, 14 schools were specially selected into the Phase II sample based on their Phase I results (high complaints of environmental problems or high formaldehyde levels), to help determine whether classrooms with apparent or reported problems actually had serious environmental problems.

Table 3-2. Phase II, Summary of Environmental Measurements.

Sample	Classroom Air	Outdoor Air	Floor Dust	Comments
Airborne				
Aldehydes	X	X		13 aldehydes, including formaldehyde
VOCs (volatile organic compounds)	X Note: only sampled in half the schools	X		9 VOCs, including benzene, toluene, xylenes, chlorinated hydrocarbons
Mold Spores & Pollens	X	X		22 mold and pollen species
Culturable microorganisms	X	X		Specially selected schools only
Particle counts	X	X		Continuous. 2 cut points: <2.5 and <10 um
Floor Dust				
Pesticides			X	20 species studied
Metals			X	18 elements, including lead
PAHs (polycyclic aromatic hydrocarbons)			X	16 species studied
Allergens			X	5 types (cat, dog, 2 dust mite, cockroach)
Environmental				
CO_2 (carbon dioxide)	X	X		Continuous
Temperature, Relative Humidity	X	X		Continuous
Noise	X	X		Unoccupied classroom and outdoor measurements
Light	X			3 locations in room
Moisture	X			Walls, floor, and ceiling measured

3.2 Results

Results from Phase I and II are discussed below. When portable and traditional classrooms are compared, the results are given as "portable vs. traditional." When results are compared among portable, traditional, and all classrooms, the results are weighted to provide the statewide estimates. When the results are characterized as statistically significant, this reflects a 95% confidence level.

3.2.1 Classroom and School Characteristics

There was a substantial difference in the estimated age distributions for portable and traditional classrooms. For instance, 55% of the portables were 10 years old or less, whereas only 12% of the traditional classrooms were that new. This disparity is undoubtedly partly responsible for many other concomitant differences, e.g., differences in structural characteristics, HVAC characteristics, and types of environmental problems/complaints, all of which are discussed below.

Portable classrooms were more prevalent in elementary schools than in middle or high schools. Most of the portable classrooms (90%) were devoted to general instruction; a smaller fraction (75%) of the traditional classrooms were used this way.

The schools were mostly suburban schools (74%) and mostly elementary schools (59%). Only about 29% of the schools were less than 30 years old, and the majority (54%) of the schools have 10 or fewer portable classrooms. Nearly all portables had air-conditioning systems installed, but only about three-fourths of traditional classrooms had air-conditioning.

3.2.2 Building Materials and Other Pollutant Sources

As shown in Table 3-3**,** portable classrooms were reported more frequently than traditional classrooms to have carpeted floors, vinyl tackable wallboard, and pressed wood bookcases -- building features that are associated with indoor aldehyde, VOC, and/or particle emissions. Portables were also reported more often to have suspended ceilings and metal roofs–building features associated with indoor moisture-related problems. Similar results were found in Phase II.

Table 3-3. Percent of classrooms with certain building characteristics, Phase I.

Classroom Type	Carpeted floors	Vinyl tackable wallboard	Pressed wood bookcases	Suspended ceilings
Portable	71	79	55	87
Traditional	34	28	48	62
All	48	47	51	72

3.2.3 Environmental Problems

Most types of environmental complaints were reported more often for portable classrooms than for traditional classrooms (Table 3-4). Teacher complaints of air quality (stuffy air and musty odors) and noise were reported more frequently in portable classrooms (Table 3-4). Plumbing leaks and thermal (temperature) complaints were more prevalent in traditional classrooms. Pest-related problems (not shown in table) were reported about the same in both room types (over 30%).

The dominant thermal complaint in portable classrooms in Phase I was that they were too cool, but in traditional classrooms it was that they were too warm. This difference is consistent with the lower occurrence of air-conditioners in traditional classrooms.

Also, a large fraction of teachers in portable classrooms (60%) reported that they turn off the HVAC system due to high noise levels, an activity that had previously been reported anecdotally and in other studies. This behavior was reported significantly less often for traditional classrooms (23%).

Table 3-4. Percent of classrooms with environmental problems reported by teachers, Phase I.

Classroom Type	Stuffy Air	Musty Odor	Roof Leaks	Plumbing Leaks	Thermal	Noise	Lighting
Portable	45	69	27	8	22	53	27
Traditional	33	59	21	18	35	41	13

3.2.4 Building Operation and Maintenance

Facility management staff reported a program of routine HVAC maintenance at most schools (94%), although only two-thirds of the facility managers (67%) kept HVAC maintenance logs. However, some schools may rely on their HVAC contractors to maintain logs. Annual HVAC inspection, maintenance, and record-keeping are required by Cal OSHA regulations (CCR Title 8, Sec. 5142).

The majority of the schools conducted annual maintenance activities for the HVAC system (e.g., cleaning the coils, checking the condensate pan and heat exchanger), and most facility staff reported that the air filters were checked or replaced quarterly. About 5% of the facility managers reported never inspecting major components of the HVAC system, such as the outdoor air damper setting, condensate drain pan, and coils; it is not clear if this maintenance was done by contractors instead. About half of the schools (57%) swept, vacuumed, and dusted the classrooms five days a week; most other schools did so several times a week.

Over half of the school facility managers (52%) received some type of environmentally related complaint within the last year. About one third (35%) of the facility managers were aware of the U.S. EPA's program for managing indoor air quality in schools (*Tools for Schools*), but only 11% of the facility managers used the program.

3.2.5 Classroom Ventilation

3.2.5.1 Ventilation Systems

Phase I surveyed the characteristics of HVAC systems and the use of doors and windows for ventilation in portable and traditional classrooms. Results showed that portables had more modern HVAC equipment and controls than did traditionals, i.e., they more often had air conditioning (95% vs. 77%) and an adjustable thermostat in the room (77% vs. 50%) controllable by the teacher (45% vs. 27%). These factors may help explain why teachers in traditional classrooms more frequently complained that the rooms were too warm.

"Natural ventilation" from open doors and windows can sometimes help remove indoor pollutants from classrooms, if the wind speed, direction, temperature differences, and cross-flow patterns are sufficient. More portables than traditionals had windows that open (87% vs. 66%), but the fractions of teachers reporting they kept their windows open "frequently" were very similar for the two room types. More portable had doors that open to the outside (100% vs. 77%), but exterior doors to portables were reported to be kept open less often, likely because of outside noise.

Portables are more often equipped with packaged HVAC systems with heat pumps (81% vs. 63%), have wall air handling units (81% vs. 32%) and have automatic supply fan operation (87% vs. 65%). Ease of access is an important factor in how well HVAC systems are maintained over time. The much higher prevalence of wall units in portables may help explain why portable classroom HVAC systems have better access for maintenance compared to traditional classrooms, which often have roof top units.

3.2.5.2 Ventilation Inspection

Phase II provided detailed measurement and observational information. As shown in Table 3-5, poor HVAC conditions were found more often in portables. A significant number of outdoor air dampers were blocked in portables (11%), and over half of the portables failed the test for the HVAC condensate drain (59%). Nearly half of the portables had air filters with medium or heavy loading. These conditions can have negative impacts on indoor environmental quality, e.g.:

- Closed outdoor air dampers result in insufficient outdoor air ventilation.
- Malfunctioning or blocked condensate drains result in standing water, a potential source of mold and bacteria.
- Increased dust loading on filters result in decreased air flows and may become a breeding ground for mold.

- Many of these problems are indications of inadequate maintenance and/or poor design.

Table 3-5. HVAC Maintenance Characteristics, Phase II.

Classroom Type	Outdoor Air Damper Blocked (%)	Drain Test Failure (%)	Filter Loading: Medium or Heavy (%)
Portables	11	59	40
Traditionals	3	12	27

3.2.5.3 Ventilation and Thermal Comfort Measurements

CO_2 Levels. Carbon dioxide (CO_2) levels were measured continuously throughout the day as an indicator of building ventilation sufficiency. Indoor CO_2 levels reflect the CO_2 exhaled by building occupants and the outdoor air CO_2 levels. Indoor levels typically are higher than outdoor levels, but substantially elevated indoor levels result from insufficient outdoor air ventilation of the classroom. Groups such as ASHRAE and Health Canada have recommended that indoor CO_2 levels not exceed 800-1200 ppm, depending on outdoor CO_2 levels; the 2005 California Energy Code for certain types of ventilation systems requires that CO_2 levels not exceed 1000 ppm (CEC, 2003).

Average CO_2 levels in portable classrooms were 1064 ppm; traditional classrooms were not significantly different (Table 3-6). Outdoor CO_2 levels were typically about 425 ppm over the day, with short-term peaks over 650 ppm. Indoor CO_2 levels were elevated over 1000 and 2000 ppm for a substantial portion of the day, indicating that nearly half the classroom hours have inadequate or marginal ventilation, and that about 10% of the classroom hours clearly have inadequate ventilation.

Table 3-6. HVAC Operation Characteristics, Phase II.

Classroom Type	Mean Indoor CO_2 (ppm)	Mean Outdoor CO_2 (ppm)	Mean % of Class Hours @ CO_2 > 1000 ppm	Mean % of Class Hours @ CO_2 > 2000 ppm	Outdoor Air Flow (mean cfm/ft^2)
Portables	1064	425	42	9	0.95
Traditionals	1074	425	43	10	0.80

Outdoor Air Flow. Study technicians measured outdoor, return, and total supply air flow rates for a subset of classrooms while the HVAC system was operating. The State design standard for classroom ventilation is typically 15 cfm of outdoor air per person, or

0.15 cfm/ft^2. Nearly all classrooms had outdoor air flow capacities greater than 0.15 cfm/ft^2. When the air flow capacity was expressed in cfm per chair in the classroom (a surrogate for cfm/person), about 10-20% of the classrooms had HVAC systems with outdoor air flow capacities of less than 15 cfm/chair.

The air flow measurements were also expressed per square foot of floor area. The typical portable classroom is ~1000 ft^2 and houses between 20 and 35 persons. The standard of 15 cfm/person converts to a required outdoor air flow rate of 300 to 525 cfm (or 0.3 to 0.5 cfm/ft^2). Flow rate measurements indicated that all classrooms with operational HVAC units were capable of providing outdoor air above this minimum requirement. No significant differences were found between portable and traditional classrooms, except that portables had higher flow rates per square foot of floor area (see Table 3-6).

Most HVAC systems were capable of delivering adequate outside air and total air flows when operated properly, but a small percentage of classrooms may have inadequate flow for maximum occupancies, due improper system design. The stuffy air complaints by teachers can result from inadequate outdoor air flow capacity, but they probably result most often from improper operation of the HVAC system. This occurs primarily for three reasons:

- the outdoor air dampers are closed or blocked;
- either the thermostat control is limiting the amount of time the system fan is operating (i.e., the fan operates only when the system needs to heat or cool the classroom); or
- the teacher simply turns off the system because the noise is disruptive to class activities.

Thermal Comfort. HVAC systems should not only provide healthful indoor air quality but also provide a comfortable thermal environment. Temperature levels were significantly different, with 27% portable and 17% traditional classrooms experiencing levels cooler than ASHRAE thermal comfort standards for the heating season. Both classroom types experienced temperatures notably warmer than the ASHRAE standard levels for a large percentage of the day, even though the weather was generally cool during sampling. About 14% of all classrooms had relative humidity (RH) measurements above 60% for a substantial part of the day; such levels are not only uncomfortable, but can lead to increased moisture and mold problems, increased dust mite populations (allergy and asthma triggers), and other problems. About 11% of both types of classrooms had RH levels below 30%, which can lead to dry mucous membranes and increased susceptibility to respiratory infections.

3.2.6 Air Pollutant Measurements

Some classrooms had air pollutant levels that exceed levels of health concern. To assess the level of health concern, measured levels are compared to available guidelines and standards based on health and comfort. The cancer guidelines used here for comparison are based on unit risk estimates for pollutants that are carcinogens.

These cancer unit risk estimates assume a *lifetime exposure* to the pollutant at a concentration of 1 µg/m^3. Clearly students and teachers do not spend their entire life in classrooms, but the concentrations of these pollutants in other indoor environments such as homes and office buildings where they spend most of their time are often similar to those concentrations in schools, or even higher. The combined lifetime exposures to carcinogens in indoor and outdoor environments are of concern, but the cancer risks from indoor exposures may be somewhat lessened for those pollutants that off-gas from building materials over time. The measured levels of pollutants and the level of health concern are discussed below.

3.2.6.1 Aldehydes

Of the 13 specific aldehydes measured in the study, only two–formaldehyde and acetaldehyde–were detected in more than 75% of the samples. Five other aldehydes were measurable in at least 25% of the samples. For virtually all of the aldehydes, the indoor levels were higher than the outdoor levels, indicating the presence of indoor sources.

Formaldehyde. ARB (1992) has identified formaldehyde as a Toxic Air Contaminant, based on its potential to cause cancer. Formaldehyde can also irritate the eyes and respiratory system, and affect the immune system. For these non-cancer effects, OEHHA has established an Acute REL of 76 ppb for 1-hour exposure, and a Chronic REL of 2 ppb for long-term exposure (Table 2-1). OEHHA has also extrapolated an 8-hour Interim Reference Exposure Level (IREL) of 27 ppb for 8-hour exposure to formaldehyde (Broadwin, 2000), which is the most directly relevant guideline for assessing Phase II results.

Indoor concentrations were routinely elevated over outdoor concentrations (measured in Phase II), as shown in Table 3-7. This is consistent with the findings of previous studies, indicating that indoor sources of formaldehyde emissions are ubiquitous and sizable. Modeling results showed that several factors were associated with indoor formaldehyde levels, including the following:

- Composite wood products in building materials or furnishings, including plywood and particleboard, vinyl tackboard, and pressed wood bookcases and cabinets, which can all emit large amounts of formaldehyde.
- Temperature and humidity, which affect the emission rate of formaldehyde.
- Classroom age, which reflects the off-gassing of formaldehyde sources over time.

Indoor formaldehyde air concentrations in portables averaged 32 ppb in Phase I, and 15 ppb in Phase II. Traditional classrooms were lower, averaging 24 ppb in Phase I and 12 ppb in Phase II. Both the means and 95th percentile concentrations were notably higher in Phase I, and higher for portables compared to traditional classrooms in both Phase I and II. The higher indoor levels in Phase I were expected because the Phase I sampling was conducted during warmer weather when indoor formaldehyde levels are

Table 3-7. Indoor Formaldehyde Concentrations, Phase I and II.

Location	Sample size (n)		Mean (ppb)		95th Percentile (ppb)		% Exceeding 27 ppb, IREL Health Guideline*	
	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
Outdoor	NA	62	NA	3	0	0	NA	0
Portable	644	135	32	15	72	26	50	4
Traditional	267	64	24	12	55	22	29	3
All Classrooms	911	199	27	13	62	24	37	~ 3-4

*IREL (Indoor Reference Exposure Level) for formaldehyde: 27 ppb, 8-hr average. Established by OEHHA, based on eye irritation and effects of the respiratory and immune system (Broadwin, 2000).

usually higher, and because the sample size was substantially larger, increasing the probability of including classrooms with more extreme levels in the sample. Phase I also included nights and one or two weekends in the sampling period, during which the classrooms were probably poorly ventilated. Also, in Phase II sampling, technicians operated the ventilation system to make flow measurements, which might have reduced formaldehyde levels relative to what they might have been under normal operation conditions. Average school-year levels of indoor formaldehyde are likely to fall between the Phase I and II measurements.

Using Phase II measurements over 6 hours during cooler weather as a very conservative estimate, a minimum of 4% of the portables, and more likely a higher percentage, had indoor formaldehyde levels above the IREL of 27 ppb. All of the classrooms exceeded the Chronic REL. Also, as in most homes and offices, all classrooms greatly exceeded 0.13 ppb of formaldehyde, the level equivalent to a risk of one excess cancer case per million persons (ARB, 2002). These results indicate that a small but substantial percentage of classrooms have formaldehyde levels that may cause short-term irritant effects, and that nearly all classrooms have formaldehyde levels that may cause long-term irritation and contribute to cancer risk.

Acetaldehyde. ARB (1993) has identified acetaldehyde as a Toxic Air Contaminant, based on its potential to cause cancer. Additionally, short-term exposure to acetaldehyde can cause eye, skin, and respiratory tract irritation, while long-term exposure can affect the upper airway, red blood cells, kidneys, and growth (ARB, 1993). OEHHA (2000) has established a chronic REL for acetaldehyde of 5.0 ppb. Outdoor sources of acetaldehyde include combustion sources such as tailpipe exhaust, stacks, and fires, as well photochemical oxidation of hydrocarbons (smog). Indoor sources of acetaldehyde include combustion sources such as cigarettes, fireplaces, woodstoves, gas appliances, and cooking activities. Acetaldehyde can also be emitted from some building materials such as composite wood products, rigid polyurethane foams, and some consumer products such as adhesives, coatings, lubricants, inks, and nail polish remover (Kelly, 1996[i]; ARB, 1997).

Acetaldehyde levels in portable classrooms in Phase II averaged 6.6 ppb. Outdoor levels averaged slightly less (4.4 ppb), and may be higher during warmer seasons due to increased photochemical production. Traditional classrooms had slightly lower indoor levels of acetaldehyde. Factors contributing to indoor levels included those identified for formaldehyde, except that outdoor air concentration was significantly correlated and classroom age was not.

About 75% of the portable and traditional classrooms exceeded the chronic REL, and about 25% of the outdoor measurements exceeded this guideline. Nearly all classrooms and outdoor concentrations exceeded 0.21 ppb, the concentration that poses a risk of one excess cancer case per million persons (OEHHA, 2002). These results also suggest that a large portion of the classrooms have indoor acetaldehyde levels that can cause chronic irritation and perhaps other health effects, especially when considering the concurrent exposures to formaldehyde and other aldehydes and irritants also found in the classrooms and other buildings.

3.2.6.2 Volatile Organic Compounds (VOCs)

Seven of the nine measured VOCs were measured above their detection limits in 80% of the samples. The other two were detected in at least 50% of the samples. As in most indoor air quality studies, the measured indoor VOC concentrations were higher than those observed outdoors. Average indoor classroom concentrations ranged from a high of 6 μg/m^3 for toluene (slightly less for *m,p*-xylene) to less than 0.5 μg/m^3 for chloroform. For all others, the averages were in the range of 1 to 2 μg/m^3.

Benzene. Benzene is a carcinogen; ARB (1984) has identified it as a Toxic Air Contaminant. Short-term exposure to benzene can cause mild irritation. Long-term exposure can reduce the numbers of blood cells, platelets, and immune system components in the blood. OEHHA (2000; 2002) has established an Acute REL of 1300 μg/m^3 for 6-hour exposures, and a Chronic REL of 60 μg/m^3.

Indoor benzene concentrations in portable classrooms averaged 1.3 μg/m^3, with a 95th percentile value of 3 μg/m^3. Outdoor levels of benzene averaged 1.0 ppb, while the 95th percentile value was 3 μg/m^3. In traditional classrooms, the mean was similar to that of portables, but the 95th percentile value was higher at 4.6 μg/m^3. Modeling results showed that indoor air benzene concentrations were associated with outdoor concentrations, and suggested that the presence of carpet and outdoor activities such as construction might contribute.

These results indicate that classroom levels of benzene are well below the RELs, and, hence, do not pose a risk of non-cancer hazards. However, both the outdoor and indoor concentrations of benzene exceeded by two orders of magnitude the level of 0.03 μg/m^3, the concentration that poses a risk of one excess cancer case per million persons (OEHHA, 2002). The results suggest that, because outdoor sources of benzene are the primary sources for both indoor and outdoor levels, schools should be carefully sited and operated to minimize exposure to vehicle and equipment emissions. Building materials and other products should be screened to assure they do not contain benzene.

Chloroform. Chloroform is a carcinogen; ARB (1990) has identified it as a Toxic Air Contaminant. Chloroform is released into indoor air by vaporization from a number of sources including: chlorinated tap water, pools, and spas; household bleach products; and office and household products manufactured using chloroform as a solvent. Short-term exposure to chloroform can affect the nasal lining, reproductive system, and development. Long-term exposure can affect the liver and kidneys. OEHHA (2000, 2002) has established an Acute REL of 150 µg/m^3 for a 7-hour exposure, and a Chronic REL of 300 µg/m^3.

Indoor chloroform concentrations in portable classrooms averaged 0.30 µg/m^3 in portables and 0.48 µg/m^3 in traditional classrooms. The 90th percentile values were lower in portables (0.42 vs. 0.91 µg/m^3). Outdoor levels of chloroform averaged 0.45 µg/m^3, while the 90th percentile value was over 1.12 µg/m^3. Modeling results showed that indoor air chloroform concentrations were associated primarily with outdoor concentrations, and to some extent with temperature, classroom age, school type, room age, ventilation, and outdoor activities such as construction.

These results indicate that classroom levels of chloroform are well below the RELs, and, hence, do not pose a risk of non-cancer hazards. However, about 75% of the outdoor and indoor concentrations were above 0.19 µg/m^3, the concentration that poses a risk of one excess cancer case per million persons (OEHHA, 2002). The results suggest that outdoor sources of chloroform are the primary source of indoor chloroform levels; thus, schools should be carefully sited and operated to minimize exposure to outdoor emissions of chloroform. In addition, use of cleaning products containing bleach should be minimized, and indoor areas of heavy tap water use should be well ventilated.

3.2.6.3 Particle Counts

Real time counts of particles were measured in each classroom and outdoors. It should be noted that particle counts cannot be directly associated with mass concentration standards. However, the measurements provide a relative indication of mass for comparison purposes.

The mean counts for the two particle sizes of interest, <2.5 microns and <10 microns, were about the same, but portable classrooms showed higher counts at the upper percentile levels, especially for the smaller size range. One possible explanation for the increased particle counts in the portables is that, as mentioned before under the characteristics of the classrooms, carpets and rugs were more often found in the portable classrooms, and could be a source of the particles, either due to resuspension of previously deposited particles or by chemical reactions at the carpet surface (Fan et al., 2003). Another possible source of particles, as well as of benzene and acetaldehyde, is vehicle traffic and portable equipment used for landscape maintenance. Over 50% of portable and traditional classrooms were within 50 feet of parking lots and roadways, and portables are sometimes sited with their air handling units near roadways and parking lots for security reasons. Recent research (Sioutas et al., 2003) has shown dramatically higher levels of fine particles very near roadways. Additionally, most schools maintain their landscaping and grounds with blowers and other equipment that are notorious dust producers. Further analysis is needed to confirm the relationships of potential indoor and outdoor particle sources, and examine the particle count patterns throughout the day.

3.2.7 Floor Dust Contaminants

Some persistent (long-lived) environmental contaminants can accumulate in floor dust over time. This is especially a concern for younger children who spend time on the floor and can be exposed to the dust contaminants by hand-to-mouth contact and skin contact, and by inhalation of resuspended floor dust by walking, vacuuming and other activities.

Floor dust was collected because it provides useful information on the deposition of persistent contaminants in the past. Floor dust was collected in this study by using a special vacuuming protocol – a measured area of the floor in the rooms' main foot traffic area was vacuumed with a hand-held vacuum containing a filter. Dust contaminants were expressed as concentrations (:g/g, microgram per gram of dust) and as loading (:g per cm^2 of sampled floor area). Contaminant levels in floor dust and soil can be indicators of *potential exposures in the past and present*. The estimated health risks from exposures to these pollutants depend in part on the age, toxicological vulnerability, and activity of the populations exposed.

Concentrations of some pollutants in the floor dust can be compared to the Preliminary Remediation Guidelines (PRGs) for residential soil concentrations developed by U.S. EPA Region 9 (EPA, 2002a) for screening carcinogenic and non-carcinogenic health hazards at hazardous waste sites. The PRGs for carcinogens are based on a risk of one excess cancer case in a million persons exposed for a lifetime. California State agency risk estimates are also used when available.

3.2.7.1 Pesticides in Floor Dust

Exposure to pesticides in sufficient quantities may affect the nervous system or the immune system. Some pesticides are also known to cause cancer, and some are suspected of being endocrine disruptors, i.e., they affect hormonal function. Selected pesticides of several types were measured: organochlorine, organophosphate, pyrethroid, carbamate, and synergist (DPR, 2003). Some of the pesticides have been banned or restricted in use.

Floor dust samples from the two portable classrooms at each school were combined for analysis due to cost constraints. Thus, there were two samples from each school, one containing dust from two portables and one containing dust from a single traditional. Pesticide residues were found in all floor dust samples, indicating the widespread use of a variety of different products in or near classrooms. Six of the 20 pesticides measured were detected in over 80% of the samples: esfenvalerate, chlorpyrifos, *cis*- and *trans*-permethrin, o-phenylphenol, and piperonyl butoxide. Three others–diazinon, 4,4,'DDE, and propoxur–were measured in over 50% of the samples.

At the 95th percentile, nine of the pesticides were measured at concentrations above 1.0 :g/g, although several of these had few measurable samples. There were no significant differences in the mean levels in portable and traditional samples. Many of the pesticides had median loading levels less than 0.01 ng/cm^2, nanograms per square centimeter of sampled floor surface). Esfenvalerate, a commonly used insecticide, had the highest dust concentration and the highest median loading level (0.34 ng/cm^2). No statistically significant differences between the means for the portable samples and traditional classrooms were found for either the concentration results or the loading results. Because some of the pesticides have an environmental half-life of a few weeks, some of the pesticides were likely applied within a few months before the sampling period at some schools in 2001-2002.

As expected, some very persistent pesticides that have been banned for some time were found in the floor dust – chlorpyrifos, DDE, and dieldrin. It is likely that dust levels of these pesticides in schools may be slowly decreasing after the bans, because the pesticides can persist in soils and dust for several years.

- Chlorpyrifos is an organophosphate insecticide once used regularly on school grounds. Before June 2000, when EPA issued its ruling to ban chlorpyrifos in non-agricultural settings including schools, chlorpyrifos was found in over 800 insecticide products; it was an ingredient in many lawn-care pesticides and in common household insecticide products.

- DDE is a break-down product of DDT, a widely used insecticide that was banned in 1972 (EPA, 2000a). Environmental sources of DDE include soil, atmospheric dispersion, sediment runoff, contaminated plants and animals, and improper use and disposal. Measurable levels of DDE (4,4'-DDE) in the floor dust were found in 48% of portable samples and 58% of traditional classroom samples.

- Dieldrin, an insecticide and a by-product of the pesticide Aldrin, was widely used from 1950 to 1974 to control insects on cotton, corn and citrus crops (EPA, 2000b). Also, dieldrin was used as to preserve wood, control termites, and control locusts and mosquitoes. Most uses of dieldrin were banned in 1987. Environmental sources of dieldrin include soil surrounding wooden structures treated for termites; soil or sediment; improper use or disposal; contaminated fish and shellfish; and contaminated dairy products and meat.

Since the discontinuation of chlorpyrifos, a class of insecticides called pyrethroids, which includes esfenvalerate and *cis*- and *trans*- permethrins, has been widely used as a substitute for chlorpyrifos and other organophosphate pesticides. Permethrin acts on a broad spectrum of insects, and is less persistent than chlorpyrifos in dust and soils with a half-life of 30 to 38 days. Esfenvalerate is equally short-lived in the environment. Many of the pyrethroid-containing insecticides are more effective with the addition of piperonyl butoxide (PBO) as a synergist. PBO is used in indoor fogging and termite control, and on gardens, lawns, and indoor plants. Like the pyrethroids, PBO is not a long-lasting contaminant of dust and soils.

Lindane, an organochlorine pesticide, was used on a wide variety of food crops, ornamentals, livestock, homeowner, and other sites until about 1985 (EPA, 2002c). Lindane is still used to treat head lice and scabies, and to treat seeds for six crops (barley, corn, oats, rye, sorghum, and wheat). Measurable levels of lindane in the floor dust were found in 6% of the portables samples and none of the traditional classroom samples. The highest lindane levels measured were at least two orders of magnitude less than the PRG of 0.44 ppm for cancer effects.

O-phenylphenol was the only fungicide measured in the study. *O*-phenylphenol's use in commercial disinfectants such as Lysol and in some common insecticides makes it an easily accessible and highly prevalent pesticide in school classrooms. Data were not available on its persistence in the environment.

Dieldrin was the only pesticide measured in floor dust that exceeded or nearly exceeded a PRG for cancer or non-cancer effects. It was found in measurable levels in 13% of the portables and 30% of the traditional classrooms. Compared to the PRG of 0.03 :g/g for cancer effects, less than 10% of portable samples but about 25% of traditional classroom samples had dieldrin levels above the PRG. This result suggests that, based on the conservative assumptions in the cancer risk calculations, the cancer risk from dieldrin is a potential health concern, especially in older classrooms.

3.2.7.2 Metals in Floor Dust

Some of the metals measured in this study are known to have neurological or carcinogenic effects. Fifteen of the 18 metals analyzed were detected in the floor dust samples. Some metals, such as lead, had higher median dust concentrations in samples from traditional classrooms; arsenic tended to have higher median dust concentrations in the portables samples.

Because the floor dust samples for the portable classrooms were combined before laboratory analysis in order to screen samples that would merit further analyses, only limited statistical comparison of floor dust results was conducted. Significant room-type differences at or near the 10% level were found for a few metals: aluminum, magnesium, and strontium concentrations in floor dust were significantly greater in traditional classrooms, but at levels not expected to be of health concern.

When comparing dust loading (:g/cm^2, micrograms per square centimeter of floor area sampled), all metals had higher dust loadings in portables samples than in traditional samples. This may be due to the higher frequency of carpeted floors and elementary school locations. However, only arsenic loadings showed a significant difference – portables were significantly higher. This difference may be due to the presence of arsenic-treated structural wood and playground equipment, as well as natural-occurring soil concentrations and arsenic in fertilizers.

<u>Lead.</u> Samples from portables averaged 67 :g/g (micrograms per gram; also equal to ppm) of lead with a 95^{th} percentile value of 152 :g/g, while traditional classrooms averaged 95 :g/g and showed a 95^{th} percentile value of 201 :g/g. Although these differences were not statistically significant, it is possible that the higher levels in traditionals are in part due to the presence of old paint.

Classroom dust samples in the PCS are not directly comparable to those used for compliance testing for the federal lead standard (U.S. EPA, 2001c), which use wet-wipes rather than vacuuming. The vacuum sampling in carpeted classrooms may tend to overestimate the lead accessible to children because it may include lead buried in the carpet fibers. The vacuum sampling of hard floors, which is more common in traditional classrooms, would have this problem to a lesser degree. Furthermore, the federal standard was established to protect children under six years of age who are most susceptible to lead toxicity, and especially infants and toddlers, who are most likely to ingest lead from surface dust exposures. Although PCS results cannot be compared against any state or federal standards, the amount of lead collected from the carpets does indicate the presence of lead-containing dust.

A DHS (1998) study of lead in California’s public elementary schools found that 7% of schools had lead levels in soil exceeding the U.S. EPA hazard standard of 400 ppm. Lead paint and some paint deterioration were found in 37% of the schools. The frequency of elevated soil lead in the DHS study is similar to that for elevated levels of floor dust lead in this study. Recent inspections in the Los Angeles Unified School District have found that 34% of pre-1993 schools had environmental lead deficiencies, i.e., peeling or chalking exterior paint (Brakensiek, 2003).

One possible source of lead contamination in floor dust is lead-based paint, which is very common in older buildings. Lead from outdoor paint can contaminate soil that is tracked into classrooms, and it can be released and spread in older buildings during repairs and remodeling. However, because carpets are often fairly old, it is not possible to determine whether lead found in dust samples was recently or historically introduced into the classroom. These results suggest that some portable and traditional classrooms may require remediation to remove lead, especially where younger students or women of childbearing age are present.

<u>Arsenic.</u> Sources of arsenic include naturally occurring arsenic in soil, which can be significant in some areas, as well as certain pesticides and contaminated fertilizer and perhaps treated wood. The California Department of Food and Agriculture (CDFA ,

2002), has proposed standards for arsenic, lead, mercury, and cadmium levels in fertilizers.

Arsenic concentrations in floor dust in portables averaged 13 ppm, while traditional classrooms averaged 11 ppm. The 95%ile value was 19 ppm for portables, and 15 ppm for traditional classrooms. In comparison, median levels of arsenic in California agricultural soils (Bradford et al., 1996) are about one-third the mean floor dust concentrations measured in the classrooms, while 95th percentile values for arsenic in agricultural soils are about two-thirds of the values for floor dust in this study. Nearly all samples of floor dust had arsenic levels above 0.39 ppm, the estimated level in the PRG for residential soil that is equivalent to a risk of one excess cancer case in a million persons exposed.

3.2.7.3 Polycyclic Aromatic Hydrocarbons (PAHs) in Floor Dust

PAHs are ubiquitous products of combustion (e.g., wood smoke, diesel and gasoline exhaust, tobacco smoke, cooking). They are found in measurable quantities in the air, especially in urban areas. They are semivolatile compounds and therefore accumulate in soil and dust. Most of the 16 PAHs studied (some of which are also known or suspected carcinogens) also were found in over 80% of the classrooms, but the loading levels were relatively low. The mean concentrations of most PAHs in the portables sample were similar to those in traditional classroom sample, but the portable samples had much higher 95th percentile values for nearly all PAHs measured. These differences between room types may be due to the higher prevalence of carpeted floors and nearby vehicle traffic in portables. The indoor PAH levels results were similar to those reported surface wipe loadings for the homes of 102 children in Minnesota (Clayton et al., 2002), and lower than those reported for floor vacuum samples in children’s homes in North Carolina (Chuang, et al., 1999).

3.2.7.4 Allergens in Floor Dust

Varying amounts of allergen levels were measured in floor dust samples. Dog and cat allergens (*Can f*1 and *Fel d*1) were detected most frequently: they were found in more than half of the classroom dust samples. However, their concentrations were generally below sensitization levels. Dust mite allergens (*Der f1* and *Der* p1) were detected in only 6-7% of dust samples. Levels of cat, dog, or mite allergens showed moderate concentrations in a small subset of classrooms, but only two classrooms had any allergen (dog) above an established sensitization level (IOM, 1993, 2000). This finding is consistent with previous studies indicating that allergens from pets can be carried into schools and other buildings on the clothes of pet owners, but that the concentrations of these allergens are seldom enough to cause sensitization (IOM, 1993, 2000). However, concentrations of these allergens as found in both traditional and portable classrooms may be sufficient to cause allergic responses in those with pre-existing allergies to dogs, cats or dust mites. Cockroach allergen was detected in only two samples (1%), in part because the detection limit was higher for this type of assay.

3.2.8 Moisture and Mold

The episodic and infrequent nature of roof leaks, plumbing leaks, floods, etc., the dependence of mold growth on temperature and humidity, and the influences of ventilation patterns and indoor activity on particle generation and distribution determine the likelihood of mold growth and concentration of spores in indoor air. Spot measurements of airborne mold spores provide limited information on the presence of mold growth in indoor environments. Therefore, we did not expect to measure elevated levels of airborne mold spores in classrooms during a one-day building inspection unless mold contamination was severe. In addition to sampling for culturable and non-culturable bacteria and fungi, the field technicians also inspected the classrooms for signs of mold growth or its predecessor (water damage), by searching for water stains, condensation, visible mold, and poor site drainage, and by measuring the moisture content of interior building surfaces.

3.2.8.1 Moisture-related Indicators

As discussed above, Phase I questionnaire data showed that teachers frequently observed signs of excess moisture and mold contamination. In Phase II, field technicians measured moisture content at one location in each wall, floor, and ceiling; preferred measurement locations were near water stains or other signs of water damage, or under windows. Because the large majority of the moisture readings were 0% and the rest were nearly all between 10-20%, excess moisture was defined operationally as at least 10% moisture. Observations of the field technicians sometimes confirmed the presence of leaks or spills nearby when moisture levels were in this range. The results of building inspections for moisture indicators in Phase II are summarized in Table 3-7.

Water stains on the ceiling were found in 21% of the portable classrooms, indicating current or previous roof leaks. This frequency seems high given that most portable classrooms are relatively new, but portable classrooms often have a full-length joint between modules that can leak at the roof level. Traditional classrooms had a higher frequency of water stain on the ceiling (35%), which may reflect their greater age. Water stains on the floor were observed in 13% of the portable classrooms, but very rarely in traditional classrooms, possibly due to the lower frequency of carpeted floors in traditional classrooms. This may also be due to poor performance of flashing and caulking used in the modular construction of portable classrooms.

Excess moisture in the walls, floors, or ceilings was found in 12% of the portable and 20% of traditional classrooms. This is consistent with the higher rate of ceiling stains and standing surface water near traditional classrooms. Visible mold was not commonly observed, but was seen on the ceiling in 3% of portable and 0.1% of traditional classrooms.

Other indicators of potential moisture problems were also examined. Mold was observed on HVAC filters infrequently (1.3% of portable and none in traditional

Table 3-7. Percent of Classrooms with Moisture Indicators, Phase II.

Classroom Type	Water Stains on Ceiling	Water Stains on Floor	Excess Moisture in Walls, Floor or Ceiling*	Visible Mold on Ceiling	Standing Water within 50 ft.
Portable	21	13	12	3	32
Traditional	35	2	20	0	43

* Operationally defined as a moisture meter reading of at least 10%.

classrooms). Many portable classrooms (43%) had foundation skirts less than two inches from the ground, which can lead to moisture problems with the walls and subfloor due to wicking action and/or poor crawlspace ventilation.

3.2.8.2 Mold Measurements

In the Phase II study, air samples for *non-culturable* mold spores and pollen grains were collected indoors and outdoors with the Allergenco sampler at all classrooms. In almost all cases, outdoor concentrations of mold and pollen were higher than indoor levels in both portable and traditional classrooms. The only exceptions were species of the mold *Botrytis* (higher in portable classrooms than outdoors) and *Curvularia* (higher in traditional classrooms than portable ones), although the differences were relatively small. Overall portable and traditional classrooms were very similar in the types and concentrations of mold spores and total pollen in indoor and outdoor air. *Stachybotrys* is a mold that has gained recent public attention as it may be associated with health effects other than allergies. Airborne *Stachybotrys* spores, were identified in 2 of 185 classrooms (1%) and 2 of 62 of the outdoor samples (3%); the portable-traditional classroom difference was not statistically significant. The two positive indoor air samples contained very few *Stachybotrys* spores. When very low airborne spore concentrations are found in rooms in which a thorough inspection has identified no water leakage, moldy odor or visible mold growth, it is likely that these spores have been brought indoors through open doorways or windows and no further action is needed.

Concentrations of total *mold spores* found in portable and traditional classrooms ranged from about 30 to approximately 2000 spores/m^3 (5^{th} to 95^{th} percentiles). Geometric mean values were about 290 spores/m^3. Compared to the interpretation guidelines for total outdoor mold spores (AAAI, 2003) shown in Table 3-8, the concentrations of total mold spores were in the Low Category, suggesting that only extremely sensitive persons may experience symptoms. While these guidelines were developed for the interpretation of outdoor air samples, the responses of mold-allergic persons to indoor exposures is likely to be similar.

Table 3-8. National Concentration Guidelines for Outdoor Airborne Mold Spores and Plant Pollen.*

Category (%ile of total distribution)	Persons who may experience allergy or asthma symptoms	Concentration (pollen grains/m^3 or mold spores/m^3)			
		Weed Pollen	Grass Pollen	Tree Pollen	Total Mold Spores
Absent (not detected)	None	Below detection	Below detection	Below detection	Below detection
Low (<50%)	Extremely sensitive persons only	0–9	0–4	0–14	0–6499
Moderate (50–90%)	Many sensitive persons	10–49	5–19	15–89	6500–12,999
High (90-99%)	Most sensitive persons	500–499	20–199	90–1499	13,000–49,999
Very high (>99%)	Almost all sensitive persons (extremely sensitive persons may experience severe symptoms)	>500	>200	>1500	>50,000

*Source: AAAAI (American Academy of Allergy & Asthma & Immunology), 2003. National Allergy Board, Reading the Charts. Available at http://www.aaaai.org/nab/index.cfm?p=reading_charts

Additional air samples of *culturable mold spores* were collected indoors and outdoors with the Mattson-Garvin sampler during lunch breaks in a subset of 14 schools. Airborne concentrations of five mold groups were reported in culturable samples: *Cladosporium* species, *Penicillium* species, *Aspergillus* species, Other and Unknown fungi. The results from these supplemental samples agreed with the findings from the Allergenco samples, that is, outdoor concentrations of mold spores were higher than indoor levels for both portable and traditional classrooms, except for the genus *Aspergillus*. This group was not observed in any outdoor samples, but was found at low concentrations in most indoor samples from both portable and traditional classrooms. This finding is probably due to the small number of outdoor samples (n=10) and detection limit of the measurement method.

3.2.9 Pollen

Airborne pollen grains were also collected in the Phase II study, using the Allergenco sampler indoors and outdoors at all classrooms. Total pollen concentrations were almost always lower indoors than outdoors. For example, the mean outdoor pollen level was 21 grains/m^3 while the indoor mean was 8 grains/m^3 for both portable and traditional classrooms. The 95th percentile values were 19 grains/m^3 for portable and 78 grains/m^3 for traditional classrooms, versus 276 grains/m^3 for outdoor air. This indicates that most classrooms were in the “Low” categories established by AAAI for different types of pollen (Table 3-8). Less than five percent of the portable classrooms were in the “Moderate” category, while traditional classrooms had somewhat higher extreme concentrations – less than five percent were in the “High” category, depending on the type of pollen. Differences between room types may be due to more mature and intensive landscaping near the traditional school buildings, which were more likely part of the original school construction. Alternatively, it may indicate cases where there was greater infiltration of outdoor air and pollen into traditional classrooms.

Because the AAAI sensitization classifications depend on pollen type and pollen type was not characterized in this study, it is difficult to assess the significance of these pollen results with respect to health impacts on students and teachers. Nonetheless, because few indoor pollen-producing plants were observed in classrooms, it is unlikely that children’s pollen exposures were higher in class than outside in the schoolyard or elsewhere in the community.

3.2.10 Noise

All classrooms exceeded the new ANSI acoustic standard for classroom noise levels -- 35 decibels A-weighted, or dBA. A substantial percentage of both portable and traditional classrooms exceeded outdoor noise limits of 55 dBA set by some California communities (see Table 3-9). Noise levels measured in both types of classrooms were not statistically different. However, the teachers in portable classrooms were much more likely to turn off the HVAC unit due to noise (68% versus 42% in traditional classrooms).

Table 3-9. Classroom Noise and Lighting Conditions Exceeding Standards, Phase II

Classroom Type	Noise Level Near HVAC > 55 dBA (%)	Mean Light Intensity < 30 Foot-candles (%)	Mean Light Intensity < 50 Foot-candles (%)
Portable	50	9	38
Traditional	38	4	27

3.2.11 Lighting

The mean light intensity measured in the traditional classrooms was significantly higher than that measured in the portable classrooms. However, a small percentage of both portable and traditional classrooms did not meet professional design guidelines (IESNA, 2000) of 30 foot-candles (f-c) for high-contrast materials. In addition, approximately one-third of both portables and traditional classrooms did not meet the IESNA light guidelines of 50 f-c for low-contrast materials, indicating inadequate lighting in both types of classrooms (see Table 3-9).

3.2.12 Specially Selected Classrooms

The specially selected classrooms at the 14 schools that were identified in Phase I were included in Phase II. Their environmental measurements and building characteristics were compared to the target population. The specially selected classrooms had much more moisture–related problems reported, such as musty odors and visible mold areas, when compared to target population. However, these classrooms had similar formaldehyde concentrations, and lower mean percentages of time when indoor CO_2 levels exceeded 1000 ppm.

Surface swab samples were also collected in the specially selected classrooms. Four mold groups were reported: *Aureobasidium* species, other Yeasts, *Cladosporium* species, and Other. Concentrations of surface microbes ranged from non-detectable to 4 million, depending on sampling sites (e.g., desk, window sill or ceiling). The highest values suggest some areas of patent mold contamination, as would be expected since some of the swab samples were taken in areas that visibly appeared moldy during the inspection process.

3.3 Summary

This study provides the first and only comprehensive investigation of classroom indoor environmental quality, ventilation, and HVAC system conditions for California's K-12 schools. The findings were drawn from both remote assessments (mailed questionnaires completed by the local facility staff in Phases I and II) and on-site assessments (inspections and measurements by PCS staff in Phase II). A summary of the results from measurements of contaminant levels in classroom air are shown in Table 3-10.

Both portable and traditional classrooms had indoor pollutant levels that exceeded those outdoors, and the indoor pollutant levels exceeded available environmental standards and guidelines in some cases. Building materials, classroom age, ventilation conditions, outdoor air, and other factors were associated with elevated pollutant levels. There were significant differences between portable and traditional classrooms in many of their environmental conditions and the associated factors.

The Phase II study was successful in generating a massive amount of information about California schools and classrooms. Further analyses of this very rich data base will likely reveal other factors that could prove useful for further understanding the IEQ problems in schools and the measures to be taken to reduce their potential effects.

Table 3-10. Summary of Contaminant Levels in Air and Floor Dust, Phase II.

Pollutant Type	Summary Statistics & Comparisons of Pollutant Levels			Modeling Results -- *For Selected Species and Selected Predictors*	
	Indoor Levels Vs. Outdoor Levels	**Exceeds health or comfort guideline/ standard**	**Portable V. Traditional Mean Test**	**Portable Vs. Traditional Test**	**Other Significant Predictors**
Formaldehyde (air)	Indoors much higher	YES OEHHA draft Interim REL , CREL	Portables higher	Portables higher (most models)	RH, temperature, room age, school type, genl. instruction classroom, others related to materials in room
Other aldehydes (air)	Indoor generally higher	Possibly acetaldehyde. Others detected.	About the same	Depends on outdoor level (acetald.)	Room age, school type; genl. instruction classroom, outdoor air (acetaldehyde)
VOCs (air)	Indoor higher	Possibly benzene and chloroform	About the same	About the same, some depend on outdoor level	Outdoor air, depending on room type; a few others that vary by analyte
Particle Counts (air)	Indoor generally higher	NA	About the same	About the same	Frequency of vacuuming/ sweeping/dusting; outdoor air, depending on room type
Pesticides (dust)	NA	Possibly dieldrin; many detected	About the same	NA**	NA
Metals (dust)	NA*	Possibly lead, arsenic	Lead higher in T; Arsenic higher in P	NA**	NA
PAHs (dust)	NA	Many detected	Some loadings higher in P	NA**	NA
Allergens (dust)	NA	Cat and dog dander in most	Traditional slightly higher	NA**	NA
Mold and Pollen (air)	Outdoor generally higher	Mold spores and pollens at low-moderate thresholds	About the same	About the same	Open windows

NA Data not available.

* Outdoor soil samples were collected and analyzed for metals under funding from OEHHA. Those results will be incorporated as an addendum to this report.

** Modeling has not yet been conducted for dust analytes, but may be pursued under separate funding.

4. RELATED STUDIES OF ENVIRONMENTAL CONDITIONS IN CALIFORNIA SCHOOLS

Previous to the PCS, there had been no comprehensive study of environmental conditions in California public schools. Various investigations had been conducted over the past decade that addressed specific components or looked at a limited subset of school facilities. These are summarized below:

- A nationwide survey of school facilities was last conducted by the federal General Accounting Office in 1995 (GAO, 1995). At that time, California was ranked last, having more unsatisfactory environmental conditions in schools than any other state. Seventy-one percent of California schools reported at least one inadequate building feature (HVAC, plumbing, roof, framing, floor, foundation, wall, window, door, interior and exterior finish), 41% of schools reported inadequate HVAC systems, and 40% reported roof problems. These surveys are summarized in a series of published reports. In the GAO studies, center-city schools and those with higher proportions of minority and poor students reported needing extensive repair or replacement at least 30% more than non-center-city/minority schools.

- Researchers at Lawrence Berkeley National Laboratory (LBNL) reviewed the available literature in 1997 on general school IAQ (Daisey and Angell, 1998). The report, contracted by OEHHA, was largely based on records of school investigations by NIOSH. They found that the most common building-related problem was inadequate ventilation with outside air. The second most common problem was water damage to building elements, leading to mold contamination and growth. The report also pointed out that measurements of indoor air pollutants were very limited, and quantitative analyses of their impacts on health were therefore difficult. However, respiratory and central nervous system symptoms were the most common health complaints. A similar analysis done for Oak Ridge National Laboratory highlighted the need for pollutant source control, proper ventilation, and humidity control to prevent IAQ problems in schools.

- The California Energy Commission investigated ventilation in California schools and other non-residential buildings. Their report found that schools consistently had lower ventilation rates than required and that one-third of the classrooms they tested had air exchange rates less than 50% of the level required by State regulations and industry standards (CEC, 1995).

- DHS conducted a survey of lead hazards from paint, soil and water in a representative sample of 200 elementary schools and child care facilities in California (DHS, 1998). The study found that nearly all schools had some lead-containing paint, and the lead content of paint is inversely related to school age (much less post-1979). Almost 40% of facilities had some paint that is deteriorated. Lead levels exceeding the U.S. EPA reference value (400 ppm) were found in 6% of surveyed schools, and, an estimated 18% of schools had lead in drinking water at or above the U.S. EPA action level (15 ppb).

- A California non-profit, public interest group published a survey of pesticide use information for 46 school districts (representing ~25% of state students) that documented the widespread use of pesticides in public schools (Kaplan et al., 1998). It found that 87% of the districts reported using one or more of 27 particularly hazardous pesticides (i.e., known or suspected to cause cancer, affect the reproductive system, mimic the hormone system, or act as nerve toxins).

- DHS estimated approximately 5% of California schools have one or more classrooms with long-term radon concentrations above the U.S. EPA's recommended *action level*, and for some regions (e.g., Santa Barbara County), the rate is as high as 16% (Zhou et al., 1998). An estimated 1% of classrooms statewide exceed the U.S. EPA limit.

- Another non-profit, public interest group released a critical report about the rising use of classroom portables, and their concerns received substantial media coverage (Ross and Walker 1999). The report postulates that the IEQ problems for portables, especially elevated exposures to VOCs, are more serious than for permanent buildings, and that children are adversely affected by being housed in them. Incidents of *sick-building syndrome* complaints among teachers and students were described.

- A small study of portables in Los Angeles was conducted by UCLA in 1999-2000 (Shendell *et al*, 2003). Overall, the results found low concentrations of target toxic and odorous VOCs. The four most prevalent VOCs measured were toluene, *m-p-*xylene, *a*-pinene, and *d*-limonene, and their likely indoor sources in the school classroom environment were commercially available personal, teaching, and cleaning products. No daily-integrated samples of formaldehyde concentrations exceeded 33 $\mu g/m^3$. Weekly-integrated and daily-integrated acetaldehyde concentrations were higher in portables than in main building classrooms. These data suggested the main sources of aldehydes were interior finish materials and furnishings made of particleboard without lamination, though other non-material sources likely influenced high values in specific portables, e.g., outdoor sources such as vehicles as a function of ventilation.

- LBNL recently conducted a study of four brand-new relocatable classrooms installed at two separate locations (one coastal and one inland). Apte *et al* (2003) designed and constructed four energy-efficient relocatable classrooms for this study to demonstrate technologies with the potential to simultaneously improve energy efficiency and indoor environmental quality (IEQ). Two were installed at each of two school districts, and energy use and IEQ parameters were monitored during occupancy. Two portables (one per school) were finished with materials selected for reduced emissions of toxic and odorous volatile organic compounds (VOCs). Each had two HVAC systems, operated on alternate weeks, consisting of a standard heat-pump system and an indirect-direct evaporative cooling (IDEC) system with gas-fired hydronic heating. The IDEC system provides continuous outdoor air ventilation at 15 CFM per person or more, providing efficient particle filtration while using significantly less energy for cooling. School year-long measurements included: carbon dioxide (CO_2), particles, VOCs, temperature, humidity, thermal comfort, noise, meteorology, and energy use. IEQ monitoring results indicate that important ventilation-relevant indoor CO_2 and health-relevant VOC concentration reductions were achieved while average cooling and heating energy costs were simultaneously reduced by 50% and 30%, respectively.

- The selection of “low-emitting” building products is being encouraged for school construction. At the same time, the California Integrated Waste Management Board (CIWMB) promotes the use of recycled-content products, an essential component of California efforts to meet its waste reduction mandates. While recycled content products have been promoted for use, little is known regarding emissions from such products.

The CIWMB funded a laboratory study to measure emissions from commonly used and alternative building products, including those most commonly used for school construction, to obtain data on whether or not alternative products with high recycled content adversely impact indoor air quality. DHS conducted the study (DHS et al., 2003). The testing protocol was designed to simulate volatile organic compound (VOC) emissions during the early stage of building occupancy. Over 70 products in material categories were tested for their emissions of 75 target chemicals. Predicted concentrations were calculated from laboratory emissions data and using typical dimensions, ventilation rates and material use scenarios (referred to as the “Section 01350 protocol”).

The study concluded that safe, sustainable building materials are available for all categories of materials tested, although many of the tested products emitted chemicals at rates that result in calculated concentrations that exceed the concentration limits and screening criteria used in this study. The researchers found that emission limits were exceeded more or less equally by both standard and alternative products under the Section 01350 protocol as well as more stringent IAQ criteria. The majority of the products that exceeded the IAQ concentration limits did so by exceeding the limits of only one chemical, which suggests that product reformulation could readily improve performance. The one exception was rubber-based resilient products, such as used for flooring. These products emit substantially greater amounts of VOCs, and further refinement and testing of these products is necessary before they can be used safely in most indoor environments. Moreover, the investigators recommended that building product manufacturers should be encouraged specifically to reduce emissions of naphthalene, formaldehyde, and acetaldehyde from their products. Industry-supported product certification programs or product labels claiming low-or zero VOCs may not sufficiently protect building occupants. These concerns warrant frequent product testing through independent certified laboratories. A copy of the study may be found at
http://www.ciwmb.ca.gov/GreenBuilding/Specs/Section01350.

5. INFORMATION FROM OTHER STATES

The most comprehensive, previous statewide study of classrooms was conducted in Texas, including an assessment of environmental conditions in 115 classrooms. The investigators found that the use of chemical cleaning compounds and air fresheners, especially during after-hours custodial cleaning when there was likely inadequate ventilation, led to elevated VOC concentrations of several target compounds including *d*-limonene and *p*-dichlorobenzene (Torres *et al,* 2002). The Texas study found no statistically significant differences for mean school-day and peak carbon dioxide (CO_2) concentrations between portable and main building classrooms, or when data were separated by teacher responses to questions regarding classroom odors. About 2/3 of the classrooms had school-day averaged CO_2 concentrations above 1000 ppm (per ASHRAE 62), reflecting a prevalence of inadequate ventilation (Corsi et al, 2002).

In an IAQ assessment at a Texas public high school (Petronella et al, 2002), formaldehyde concentrations were measured above federal occupational guidelines in classrooms where the HVAC systems ran on normal daily cycles, and windows and doors were closed. Inspections, however, found 16 of 19 classrooms had ventilation rates below the ASHRAE 62 recommendation.

Several states have undertaken mandated or voluntary efforts to improve IEQ in public school buildings. Maryland's Department of Education (1987) established a program on IAQ in public schools in 1987, and it developed a seminal set of guidance documents on related school facility issues (such as ventilation systems, carpets, interior painting, and science laboratories) (Maryland, 1996). The State of Washington developed their "best management practices" for IAQ in 1994 (Washington DOH, 1995), and the Texas Health Department recently issued "voluntary guidelines" for IAQ in schools (Texas DOH 1998), under mandate from their legislature. The Minnesota Department of Health has developed extensive training and guidance for schools, including a streamlined inspection package, an IAQ Management Plan Development Package, and website links to funding source information (Minnesota, 2003).

Others states have conducted comprehensive review or evaluation of school IEQ to develop programs to solve noted problems, including Vermont (1999) and Delaware ((1998). Similar efforts have been successful even at the local level; the County of Montgomery (MD) (1998) developed its own IAQ Action Team and report with guidance and specific recommendations for achieving good IAQ in public schools. Healthy School Networks in Massachusetts, and New York were established to press for improvement in their state's facilities. These are coalitions of teacher, parent, and non-profit organizations. In New York, they successfully pressed their State Regents to sponsor an Advisory Committee on Environmental Quality in Schools. In contrast, there is no established *healthy schools* stakeholder group or advisory board in California, similar to those in other states.

6. SUMMARY OF STAKEHOLDER INPUT

As mentioned above, ARB and DHS consulted with other interested state agencies and stakeholders. Interested stakeholders included portable classroom manufacturers, environmental and health organizations, school district administrators and facility managers, teachers, school nurses, indoor air quality consultants, and ventilation companies.

6.1 Pre-Study Workshops

The first set of workshops were conducted in February and March, 2001, in Sacramento, Oakland, El Monte (Los Angeles), and San Diego. ARB and DHS staff presented information on the overall study design, as well as details regarding the intended schedule and scope of the project. The workshops were well-attended. Participants asked a variety of questions regarding the study, and also provided comments or suggestions regarding the planned study design, questions to include in the questionnaires, plans for external notice and review, and other topics. The following is a brief listing of some of the comments received during the initial workshops:

- Some schools wanted their results prior to the end of the study, others did not want them. (Results were provided by RTI directly to schools that requested them).

- Portable classroom manufacturers concerned regarding premature press and media coverage of results…wanted assurance they would be able to review the report ahead of time (report to be released to everyone at once).

- Requested on-line resources for parents and teachers regarding indoor air quality (DHS provided this online feature subsequent to the workshops).

- Would like to review detailed study protocols (general protocols could be reviewed, but detailed protocols not available for review prior to study due to tight study schedule).

- Be sure to consider age of the classrooms…old and new portables are very different (age was recorded for all classrooms and used regularly in analysis of the data).

- Please consider the type of installation and foundation…some portables have had mold and other problems because of improper installation, foundation skirts too close to the ground, etc. (Foundation skirt and installation information was included on the technician inspection checklist).

- Concerns were raised over how appropriate health thresholds would be selected and discussed in the final report. (OEHHA’s acute and chronic Reference Exposure Levels were used, along with other health and comfort standards and guidelines that are available, such as those of IESNA, ASHRAE, and others.)

6.2 Post-Study Workshops

TO BE ADDED AFTER WORKSHOPS

7. RECOMMENDATIONS AND DISCUSSION

The results of this study do not support fears that severe environmental health problems are widespread in California schools. However, they demonstrate that many schools are not models of hygiene or healthfulness, and that there is a need for improvement in some areas. The study demonstrated that most districts do an adequate job of operating and maintaining school facilities (at least when funding has been available to support core operation and maintenance programs). Where found, environmental problems generally fall into one of these key areas: (a) inadequate classroom fresh-air ventilation (many causes); (b) unnecessary or uncontrolled sources of chemicals, particles, or other contaminants; (c) unchecked moisture intrusion; and (d) ineffective cleaning, maintenance, or repair practices.

For virtually all of the problems identified in the study, both broad-scale and immediate school-level remedies can be identified. The most effective solutions require addressing the underlying causes of the problems, and promoting those systems that appear to be functioning well. In most cases, problems need to be prevented and solved at the classroom and school level. At this level, the most common problems can be resolved with minimal cost, as illustrated by the LAUSD's inspection and remediation program. However, the catalysts, oversight, and guidance for effective solutions must come from the district and State levels.

The recommendations listed below are listed in three groups: 1) approaches that are relatively low-cost that can be done in the near-term, are high priority, and are expected to yield major benefits in terms of improvements in classrooms conditions; 2) actions that are a priority but may have more significant costs associated with them, and thus are subject to fiscal constraints and should be undertaken as resources allow; and 3) recommendations with a longer timeframe that are needed to assure healthful learning environments over the long-term.

Because traditional classrooms had many of the same problems found in portable classrooms and a portion of both types of classrooms exceeded applicable guidelines for health and comfort, the recommendations below are directed toward preventing and resolving problems in all classrooms, unless otherwise noted.

GROUP 1: High Priority, High Benefit Actions with Relatively Low Cost

The Group 1 recommendations largely build on regulations, programs, and activities that are already in place but that are not being fully met or utilized. Additional resources, training, or incentives may be needed.

1. <u>Assure that all school buildings meet all relevant State regulations</u>. Unfortunately, a substantial number of classrooms do not meet various existing State standards, and meeting those regulations would go far to provide healthful conditions in classrooms. For example, operating HVAC systems as they were intended to be operated to assure adequate outdoor air ventilation; developing a health and safety program and

training employees to implement that program, per requirements of the Injury and Illness Prevention Program regulation; and maintaining sanitary conditions and correcting water intrusion, leakage, and uncontrolled accumulation of water to reduce the potential for mold growth – all workplace requirements enforced by Cal-OSHA – would correct several of the major problems seen in classrooms. Some remedies may not be low-cost, depending on the nature of the non-compliance.

2. Districts/schools should conduct “self-assessments” of basic safety and health conditions, similar to the program of self-inspections undertaken by the LAUSD. In addition to assessing whether state regulations are being met, self-inspections can also be used to remedy obvious problems that are not necessarily regulated, and as a first step to begin to incorporate “Best Practices” into operation and maintenance functions. The LAUSD’s basic checklist is provided in Appendix V; districts/schools can use all or part of these to conduct their own walk-throughs and identify key problems in the near term. Conditions that can be corrected with little cost should be remedied promptly, and plans should be developed to obtain resources to address those that require additional funds to remedy.

3. Establish a State policy to incorporate “Best Practices” into the design and construction of new California schools, especially the measures developed by the California Collaborative for High Performance Schools (CHPS). Because of the large number of new construction and renovation projects statewide at this time, there is a unique opportunity to foster a new generation of classrooms that provide a healthful and environmentally preferable learning environment. The CHPS *Best Practices Manuals* provide an array of options and information that can be used in designing, constructing, and renovating school buildings. The CHPS manuals and videos are available at http://www.chps.net/; manuals for school operation and maintenance are under development. Districts and schools should use CHPS Best Practices to the fullest extent feasible, at a minimum incorporating a few of the low-cost options that are suitable for their situation. Key examples are:

   A. Specify no- and low-emitting building materials and furnishings in construction contracts and solicitations. This should include using exterior grade wood products in wall & floor materials; no-formaldehyde insulation, ceiling tiles, and cabinetry; and other low- or no-emitting materials to avoid elevated formaldehyde and VOC levels.
   B. Especially for portable classrooms, specify HVAC systems that provide sufficient airflow at lower noise levels (45 dBA or lower).
   C. Design sprinklers and landscaping properly so water does not hit the building, and drains away from the structures.

4. Expand State-level design review for new buildings and major renovations. Review and approval of elements such as ventilation system design, building materials, and maintenance planning, should be explicitly added to the routine life/fire/safety plan-check function of the Division of the State Architect (DSA). The DSA is currently implementing a more proactive approach, but a more explicit mandate and

commensurate resources are needed to allow a comprehensive state review of all plans.

5. Site portable classrooms appropriately. Classrooms should be located away from highways, and proper grading assured. Individual portable classrooms should not be placed over low drainage areas that experience flooding. The foundation skirt should be at least 6 inches or more above ground level to prevent wicking of water up the wall, and adequate crawlspace ventilation should be specified.

6. Train janitorial staff in proper vacuuming and cleaning procedures, and purchase efficient vacuums. Effective vacuuming of carpets requires a reasonable "residence time" of the vacuum on the carpet surface in order to effectively remove particles. This can effectively reduce persistent contaminants in carpeted classrooms. Vacuums do not need to be true HEPA, but do need to be efficient, and have little particle leakage in the exhaust.

GROUP 2: Priority Approaches with Potentially Substantive Costs

7. Require districts and schools to develop an IEQ Management Plan. The U.S. EPA's *Tools for Schools Kit* provides guidance for developing such a plan: see http://www.epa.gov/iaq/schools/. Districts and schools should implement at least the core provisions in EPA's Tools for Schools (a new stream-lined, checklist version will be available in the future) and other preventive measures, including:
   A. Appoint an IEQ manager.
   B. Establish a regular inspection and maintenance schedule; ensure that HVAC systems are thoroughly cleaned and inspected at least annually.
   C. Use checklists for core inspection and preventive actions.
   D. Educate the building occupants.

8. Implement Integrated Pest Management Programs at all schools. The passage of AB 2260 (Shelly) established requirements for schools to notify parents of pesticide use and to consider IPM. Successful application of IPM has been sufficiently widespread to support its implementation at all public schools, and to eliminate the use of pesticides with the greatest potential for toxic effects by school personnel. A program of preventive housekeeping practices and use of least-toxic pesticides when application is necessary has many benefits. See the Department of Pesticide Regulation website at http://www.cdpr.ca.gov/cfdocs/apps/schoolipm/main.cfm .

9. Develop and require full building commissioning procedures for new buildings and classrooms, including complete testing of HVAC, lighting, and other building systems under normal and high-capacity operational conditions.

10. Assure Preventive Maintenance. Greater incentives are needed to promote effective, routine maintenance of school facilities; the result would be both money saved ("A stitch in time saves nine…") and improved learning conditions for students. Additionally, the existing Deferred Maintenance Program should be

improved through stable, consistent funding; the current year-to-year fluctuations do not permit appropriate long-term planning and preventive maintenance. Preventive maintenance of physical plant and capital items is clearly cost effective; however, the funding systems for California public schools effectively de-couple the capital budgets from savings generated by effective operation and maintenance. Possible revisions might include augmenting eligibility of funds to promote proper routine maintenance.

11. Develop State-level Chemical Exposure Guidelines or Standards for Classrooms. There is a lack of benchmarks for fully assessing and assuring healthful environmental conditions specific to classrooms and to the children and teachers who occupy them. The state should provide explicit guidance on acceptable chemical exposure limits for children and standards for emissions from sources of indoor pollution at school facilities, such as building materials, furnishings, and products used in instruction and maintenance. The state should also provide guidance on environmental factors such as temperature, lighting, and noise that specifically consider the needs of children in a learning environment.

12. Increase the number of districts providing Lead-Safe Schools training for elementary school maintenance staff, and assure that they apply Lead-Safe practices during school modernization projects, e.g., use state-certified contractors when testing for, or abating, lead hazards.

GROUP 3: Future Priorities

13. Convene a task force to identify stable, long-term funding sources and approaches for school construction and maintenance for the long-term. Current funding programs are strained, fluctuating, and often function on a short timeframe.

14. Develop a Training and Certification Program for School Facility Managers. Success in operation and maintenance is often a function of the strength and knowledge of facilities directors, yet there are few credentials districts can apply in their selection of key facility department personnel. The complexity of modern school facilities continues to increase, as do the demands on staff hired to operate and maintain school campuses. Training requirements of staff are uneven (e.g., lead and asbestos) and it would be more efficient if such programs were comprehensive and coordinated. Districts should hire trained, certified facility managers.

15. Establish a state-level IEQ-in-Schools resource/outreach group to develop training materials and curricula, to coordinate training courses for school facilities personnel, and to implement an information clearinghouse.

16. Solicit teacher- and parent-organizations to provide additional support for improved operating and maintenance functions. Such groups might obtain funds for specific projects through fund-raisers, or they may provide in-kind services as “facility

mentors" . For example, parents who are industrial hygienists, trained ventilation engineers, or have other skills useful in school operation may be willing to provide assistance with some of the more basic tasks.

17. Convene a task force of experts in audiology, medicine, education, and related fields to assess the impact of noise on children's learning performance and health, and to determine whether a California noise guideline or standard is needed for K-12 schools. If needed, develop and implement such a guideline or standard, and promote technology development accordingly.

18. Improve State school facility inventory and database. The State needs an effective system to inventory public school facilities. These represent among the State's greatest set of assets, yet there is no complete database on the condition, location, or even number of school buildings.

19. Re-design portable classrooms from the ground up. Most portable classrooms manufactured today are still based on designs and materials that have been available for 20-30 years or more, and on an assumption of a need for frequent relocation, which has not proven to be common. Southern California Edison, Lawrence Berkeley National Laboratory, and several portable classroom manufacturers have begun to develop very different styles of portable classrooms that should be fully developed and used on a trial basis under different conditions to determine if these newer designs might better meet future classroom needs.

20. Retire older portable classrooms when they become relatively unserviceable or do not provide an adequate learning environment for children. Some older portables are well past the stage at which they should have been replaced with a new portable or a site-built classroom. New portable or site-built buildings will generally not only provide an improved environment but also will be more energy-efficient, with substantially reduced energy costs relative to the old buildings.

While some cost is involved with most of the recommendations discussed above for the State and for districts and schools, the cost of not taking these actions may be much higher – harmful impacts on children's and teachers' health, reduced learning, and reduced educational progress, as well as higher costs to fix facility problems that are not addressed at an early stage. Recent studies have shown links between learning performance and physical surroundings and health and comfort factors. Children cannot learn efficiently or effectively if they are uncomfortable, in a noisy or poorly lighted environment, or absent due to asthma or other illness. Cooperative actions are needed by the State, the districts, individual schools, manufacturers, teachers, and others to effectively remedy these problems.

8. SUMMARY AND CONCLUSIONS

The California Portable Classrooms Study (PCS) was conducted to address concerns raised regarding environmental conditions in California's portable classrooms. The objective of the study was to examine environmental health conditions, especially those related to indoor air quality and health risks, in K-12 portable classrooms in California. These environmental conditions included levels of airborne chemicals; the presence of potential pollutant sources; the performance of heating, ventilating, and air-conditioning systems; factors such as light, noise, temperature, and relative humidity; the presence of mold and other biological contaminants; and pollutant and allergen levels in floor dust.

A preliminary mail survey to all school districts conducted by DHS in Fall, 2000 indicated that 85 percent of K-12 public schools had at least one portable classroom at that time, and that about 80,000 portable classrooms were in use statewide, totaling about one-third of all California classrooms. These portable classrooms ranged in age from less than one year old to over 40 years old.

The study was conducted in two phases: Phase I was a mailed survey in which questionnaires and passive formaldehyde monitors were sent to over 1000 randomly selected public schools with at least one portable classroom in the spring of 2001. Phase II was a field study of a wide array of environmental measurements obtained in 201 classrooms at 67 schools statewide, from October 2001 through February 2002. At each school, two portable classrooms and one traditional classroom were studied.

8.1 Results

Both portable and traditional classrooms were found to have some environmental conditions that require improvement. However, the picture is not dire: most school buildings and grounds are operated and maintained adequately, and the most serious problems occur only at a small percentage of schools. Remedies to address the problems identified are generally available, although some will incur more than minimal costs and/or require new technology. The solutions require a combination of actions by the State, districts, schools, manufacturers, facility managers, teachers, and others. Adherence to state regulations and improved operation and maintenance, including training of school personnel, can go a long way to address many, but not all, of the problems identified.

The primary problem areas identified include the following:

1. Ventilation
    - Inadequate at times in about 40% of the classrooms, and seriously deficient in about 10% of classrooms.
    - A majority of teachers in portables have turned off the ventilation system at times due to excess noise.

- Portables had more instances of dirty HVAC filters, closed dampers, and air-conditioner condensate drainage problems.
- Overall, the HVAC systems deliver adequate flow, so sizing is not an issue.
- Noise is the primary issue that needs to be addressed by HVAC manufacturers, and lower noise levels (45 decibels or less) should be specified by schools.

2. Temperature and Humidity
   - A small percentage of portable classrooms had temperatures above or below the ASHRAE standard for acceptable indoor temperature, and about 11%-14% of classrooms had relative humidity levels outside the ASHRAE standard range for comfort.
   - Properly operating and maintaining HVAC systems should remedy these problems in most classrooms.

3. Air Pollutants
   - <u>Indoor formaldehyde concentrations</u> were elevated above OEHHA health guideline levels. Highest levels occurred primarily in the warmer seasons, as expected, and primarily in portable classrooms. Alternative low-emitting materials are available and should be used in constructing new portable classrooms
   - <u>VOCs</u> were present indoors at levels similar to other indoor environments. Levels were below acute (immediate effects) risk levels; although some classrooms exceeded the one in a million cancer risk level for a few VOCs, this is not a major concern because outdoor levels likely contributed most to these levels.
   - Real-time <u>particle counts</u> were somewhat higher in portable classrooms for PM10 and PM2.5 size ranges, likely due to the greater use of carpets in portables, and the proximity to vehicle traffic.

4. Floor Dust Contaminants
   - <u>Metals</u>: Levels of lead measured in floor dust in some classrooms were elevated. Arsenic levels were slightly higher in portables, and above the one in a million cancer risk level in most classrooms.
   - <u>Pesticides:</u> Residues of both generally available and restricted pesticides were found in all floor dust samples, and six pesticides were detected in over 80% of the samples: esfenvalerate, chlorpyrifos, *cis-* and *trans*-permethrin, *o*-phenylphenol, and piperonyl butoxide. Chlorpyrifos can last up to a year or more in the environment; the other five are shorter-lived, lasting just a few weeks. Children can be exposed to pesticides through inhalation, ingestion (fingers in the mouth), and dermal contact, and children in the lower grades tend to spend a substantial amount of time sitting on the floor; therefore the number of pesticides found in the floor dust are of concern, although it is not yet known whether levels are above exposure and risk levels of concern
   - <u>PAHs</u> also were found in over 80% of the classrooms. However, levels in the dust were relatively low.

- Allergens: Cat and dog allergens were measured in more than half of the samples, but the concentrations were generally below sensitization levels. Cockroach and dust mite allergens were only infrequently found.

5. Moisture and Mold
    - In the mail survey, a large percentage of teachers reported smelling musty odors in their classroom, or current or previous floods or leaks, and 11% reported visible mold.
    - The field study found that showed that 1-3% of classrooms had visible mold, and at least 21% had visible water stains on the ceiling and/or floor. About 17% of all classrooms had excess moisture measured in the walls, ceiling, or floor. Water stains and measurements of excess moisture in building materials sometimes indicate hidden mold, and at a minimum indicate a moisture problem that needs to be resolved.

6. Noise
    - All classrooms exceeded the recently developed acoustic standards of 35 decibels background noise for unoccupied classrooms, and many exceeded outdoor nuisance standards of 55 decibels used by some California cities.
    - Stakeholders have indicated that 45 decibels, the level recommended by CHPS, may be achievable, but that 35 decibels appears technologically and financially unattainable at this time. California does not have a noise guideline or standard for classrooms.
7. Lighting
    - About one-third of classrooms do not meet IESNA professional design guidelines.
    - Portable classrooms had somewhat lower lighting levels than traditional classrooms

8.2 Recommendations

Approaches to remedy and prevent most of the problems identified in this study are available. Both state-level and district/school level actions need to be taken. Most of the problems can be addressed through meeting existing State level standards and guidelines (primarily those of Cal-OSHA), through improved operation and maintenance programs, and through focused training efforts. Most also can be addressed at relatively low cost, although some remedies will incur significant costs. A few, such as reducing the noise levels in HVAC systems below 45 decibels, may also require new technology.

Recommendations are offered in three groups as a means to direct actions that might be most effective in preventing and addressing the problems identified in this study, with consideration of notable budget constraints currently experienced by the state, by districts, and by schools as well.

GROUP 1: High Priority, High Benefit Actions with Relatively Low Cost

Group 1 recommended actions should be undertaken within the next year or two. The highest priority recommendation is that all school buildings need to be brought into compliance with existing state regulations. Unfortunately, a substantial number of classrooms do not meet various existing State standards (primarily Cal-OSHA's workplace standards), and meeting those regulations would go far to assure healthful conditions in classrooms. A second key priority recommendation is that districts and schools should conduct "self-assessments" of basic safety and health conditions, similar to the program of self-inspections undertaken by the LAUSD. In addition to assessing whether state regulations are being met, self-inspections can also be used to remedy obvious problems that are not necessarily regulated, and as a first step to begin to incorporate "Best Practices" into operation and maintenance functions.

Another priority is that the State should establish a State policy to incorporate "Best Practices" into the design and construction of new California schools, especially the measures developed by the California Collaborative for High Performance Schools (CHPS). Because of the large number of new construction and renovation projects statewide at this time, there is a unique opportunity to foster a new generation of classrooms that provide a healthful learning environment. The CHPS *Best Practices Manuals* provide an array of options and information that can be used in designing, constructing, and renovating school buildings in all areas of the state.

State-level design review for new buildings and major renovations should be expanded. Review and approval of elements such as ventilation system design, building materials, and maintenance planning, should be explicitly added to the routine life/fire/safety plan-check function of the Division of the State Architect (DSA). Additionally, portable classrooms should be sited appropriately, away from highways, with proper grading, and away from low drainage areas that experience flooding. Finally, janitorial staff should be trained in proper vacuuming and cleaning procedures, and allowed sufficient time to perfume their tasks properly. Schools should purchase efficient vacuums (cost about $300-$500) to assure effective cleaning.

GROUP 2: Priority Approaches with Potentially Substantive Costs

Group 2 recommendations are a priority but may incur substantial costs to implement. Their implementation should be delayed only as long as is required to identify resources needed to implement them, which is likely to vary across districts and schools. Of great importance is the need for districts and schools to develop an IEQ Management Plan, such as that in the U.S. EPA's *Tools for Schools Kit,* http://www.epa.gov/iaq/schools/. Districts and schools should implement at least the core provisions in EPA's Tools for Schools (a new stream-lined, checklist version will be available in the future). Districts and schools also should implement Integrated Pest Management Programs as soon as feasible. A program of preventive housekeeping practices and use of least-toxic pesticides when application is necessary has many benefits. See the Department of Pesticide Regulation website at http://www.cdpr.ca.gov/cfdocs/apps/schoolipm/main.cfm . The State should develop, and districts and schools follow, full building commissioning procedures for new buildings and classrooms, including complete testing of HVAC, lighting, and other building systems under normal and high-capacity operational conditions. Additionally, the State and districts need to assure preventive maintenance, which not only saves dollars in the long term but also protects school occupants health and safety and assures a better learning environment.

The State and districts should take necessary actions to increase the number of districts providing Lead-Safe Schools training for elementary school maintenance staff, and assure that they apply Lead-Safe practices during school modernization projects. The State also should develop State-level chemical exposure guidelines or standards for classrooms. There is a lack of benchmarks for fully assessing and assuring healthful environmental conditions specific to classrooms and to the children and teachers who occupy them.

GROUP 3: Future Priorities

There are many actions needed in the future to assure that California's schools provide a safe environment conducive to learning over the long-term. First and foremost, the state should convene a task force to identify stable, long-term funding sources and approaches for school construction and maintenance for the long-term. Current funding programs are strained, fluctuating, and often function on a short timeframe. Insufficient funding was repeatedly noted as the primary reason for many schools not taking actions known to be needed. Schools operate on many fewer dollars per square foot for operation and maintenance than do offices and commercial buildings.

Other actions needed include development of a Training and Certification Program for school facility managers, and use of certified individuals by districts and schools. The State also should establish an IEQ-in-Schools resource/outreach group to develop training materials and curricula, to coordinate training courses for school facilities personnel, and to implement an information clearinghouse. The State should also convene a task force of experts in audiology, medicine, and related fields to assess the impact of noise on children's learning performance and health, and determine whether a California noise guideline or standard is needed for K-12 schools. The State should also improve the State school facility inventory and database; currently there is no complete database on the condition, location, or even number of school buildings. Districts and schools should solicit teacher- and parent-organizations to serve as facility mentors, to provide additional financial support or to assist with some of the more basic functions.

Finally, manufacturers, the State and districts should consider the potential wisdom of, and need to, re-design portable classrooms from the ground up. Most portable classrooms manufactured today are based on designs and materials that have been available for 20-30 years. Several groups have begun to develop very different styles of portable classrooms that should be fully developed and used on a trial basis under different conditions to determine if these newer designs might better meet future classroom needs. Older portable classrooms should be retired when they become unserviceable or are no longer able to provide an adequate learning environment for children; the energy savings of the newer replacement buildings will be an added plus.

Some cost is involved with the recommendations discussed above for the State and for districts and schools: many are relatively low-cost, but some have substantial costs and require focused fiscal planning to address. However, the cost of not taking these actions may be much higher—harmful impacts on children's and teachers' health, reduced learning, reduced educational progress, and, in some cases, higher costs to fix facility problems when they become more serious. The LAUSD's self-inspection program provides a good starting point for districts, and the CHPS Best Practices Manuals and U.S. EPA's new Tools for Schools provide valuable tools for designing, operating, and maintaining "high performance" schools.

CONCLUSIONS

The environmental health problems identified in this study ranged across several areas, including inadequate operation and maintenance of ventilation systems, contaminants present at undesirable levels in the air and floor dust, excessive noise levels, and mold and moisture problems. A number of programs initiated by the State, districts, and others before or during the conduct of this study are already beginning to address some of these concerns. However, a more focused approach is needed to assure that existing problems are remedied and future problems prevented. The State, district and school administrators, school facility managers, teachers, manufacturers of portable classrooms, manufacturers of ventilation systems, and others who provide materials and supplies used by our schools all have an important role in improving the environmental health conditions of our schools. Most importantly, California must transition to true prevention programs that have stable funding.

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