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Assessment of Organic Compound Exposures, Thermal Comfort Parameters, and HVAC System-Driven Air Exchange Rates in Public School Portable Classrooms in California

A dissertation submitted in partial satisfaction

of the requirements for the degree

Doctor of Environmental Science and Engineering

by

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This dissertation is dedicated to:

My hometown childhood peers, the public school children of Stamford, Connecticut, including my younger brother. Those public primary and secondary school experiences demonstrated how regardless of how socioeconomic background, culture, and family stability may vary among students, the school environment influences academic achievement as well as children's social, psychological, and physical development including respiratory health.

Specifically for the prospectus and its amendment, the efforts were dedicated to the memory of a friend, classmate, and colleague from the Yale University Department of Epidemiology and Public Health, Jaklen Muoi Tuyen, MA (UCLA 1996), MPH (Yale 1998). Ms. Tuyen passed away unexpectedly on December 6, 2000 at the age of 27. She was working as a public health prevention specialist with the U.S. Centers for Disease Control, stationed in Philadelphia, PA. Her main interests were international health, specifically infectious disease prevention and control, and improving and ensuring community environmental quality and health.

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

GLOSSARY OF TERMS, ABBREVIATIONS, AND SYMBOLS

AER	air exchange rate measurements
AM	morning
CH_3CHO	acetaldehyde
CAT	capillary absorption tube
CO	carbon monoxide
CO_2	carbon dioxide
COV	coefficient of variation
DNPH	dinitrophenyl hydrazine
DNSH PAKS	dansylhydrazine (5-(dimethylamino)naphthalene-1-sulfohydrazide) "Personal Aldehydes and Ketones Sampler"
GC/MS	gas chromatography/mass spectroscopy
HCHO	formaldehyde
HPLC	high performance liquid chromatography
HVAC	heating, ventilating, and air conditioning
IAQ	indoor air quality
IDEC	indirect-direct evaporative cooler
IEQ	indoor air and environmental quality
LOD	limit of detection
MDL	method detection limit
MTBE	methyl *tert*-butyl ether
O&M	operations and maintenance
OUPIA	overnight, unoccupied period integrated average
OVM	3M Organic Vapour Monitor
PFT	perfluorocarbon tracer gas source blocks
PM	afternoon
PMCH	perfluoromethyl cyclohexane, a perfluorocarbon tracer gas
RH	relative humidity, %
R_{perm}	permeation rate of PFT into a room, T dependent
SDA	school day average, integrated over 7-8 hours
SDIA	school day integrated average, daily school hours for week
SWIA	school week integrated average, Monday AM-Friday PM
SF_6	sulfur hexafluoride
T	air temperature, degrees Fahrenheit (°F) or Celsius (°C)
UV	ultraviolet
VOC	volatile organic compound, toxic and odorous
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
CalEPA	California Environmental Protection Agency
CARB	California Air Resources Board
CDHS	California Department of Health Services

CEC	California Energy Commission
DEG	Davis Energy Group
EOHSI	Environmental and Occupational Health Sciences Institute, UMDNJ/Rutgers University, New Jersey
LBNL	Lawrence Berkeley National Laboratory
LBNL RCS	LBNL/DEG/CEC field study of energy efficiency and IEQ
NCES	National Center for Education Statistics
OEHHA	Office of Environmental Health Hazard Assessment
RC	relocatable classroom, relocatables; RCS = RC Study
UCLA PCS	UCLA pilot "Portable Classrooms Study"
USEPA	United States Environmental Protection Agency
USGAO	United States General Accounting Office
hr^{-1}	per hour, e.g., air changes per hour (AER measurement)
ppm, ppb	parts-per-billion, parts-per-million, respectively, in air
REL	reference exposure level, acute or chronic non-cancer
$\mu g\ m^{-3}$	micrograms per cubic meter of air
SD	school district
BPUSD, SD 1, SD A	Baldwin Park Unified School District
LAUSD, SD 2, SD B	Los Angeles Unified School District, Region C
CUSD, SD 3	Cupertino Union School District
MCS, SD 4	Modesto City Schools

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ABSTRACT OF THE DISSERTATION

Assessment of Organic Compound Exposures, Thermal Comfort Parameters, and HVAC System-Driven Air Exchange Rates in Public School Portable Classrooms in California

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The prevalence of prefabricated, portable classrooms (portables, relocatables, RCs) has increased due to class size reduction initiatives and limited resources. Classroom mechanical wall-mount heating, ventilation, and air conditioning (HVAC) systems may function improperly or not be maintained; lower ventilation rates may impact indoor air and environmental quality (IEQ). Materials in portables may off-gas volatile organic compounds (VOCs), including formaldehyde, as a function of age, temperature, and humidity.

For a pilot study, public K-12 schools located in or serving target areas within five Los Angeles County communities were identified. In two communities where school districts (SD) consented, 1-3 randomly selected portables, one newer and one

older, and one main building control classroom from each participating school were included. Sampling was conducted over a five-day school week in the cooling and heating seasons, or repeated twice in the cooling season. Measurements included passive samplers for VOCs, formaldehyde and acetaldehyde, and air exchange rate (AER) calculation; indoor air temperature and humidity; technician walk-through surveys; an interview questionnaire about HVAC system operation and maintenance (O&M).

For an intervention study evaluating advanced HVAC technologies in comparison to the common conventional technology, and materials for source reduction of VOCs, four RC were manufactured and located in pairs at two schools in two recruited Northern California SD in different climate zones. RCs were built with the two HVAC systems, cabinetry and conduit for monitoring equipment, and standard or advanced interior finish materials. Each RC was its own control in a case-crossover design--HVAC systems alternately operated for 1-2 week intervals in the 2001-02 school year, with IEQ monitoring including aldehyde and indoor air temperature and humidity data.

Measured classroom AER were low, formaldehyde concentrations were below the state indoor air guideline "target level," and concentrations of most target VOCs were low. O&M questionnaire results suggested insufficient training and communication between custodians and SD offices concerning HVAC systems. Future studies should attempt larger sample sizes and cover larger geographical areas but continue to assess multiple IEQ parameters during occupied hours. Teachers, custodians, and SD staff must be educated on the importance of adequate ventilation with filtered outdoor air.

CHAPTER 1.-INTRODUCTION

1.1 Statement of the Problem

Recent state and federal policy initiatives to reduce public school class sizes in lower grade levels (K-3, ages 4-9) to a student-to-teacher ratio of 20 (Stone and Agee, 1996; State of California, 1998; CADE, 1999a), population growth and immigration, and severe resource restraints for capital projects, maintenance and modernization at aging schools have significantly increased the prevalence of prefabricated, portable classrooms (portables or relocatables) (Wyatt, 1997; Jacobson, 1998; Sturgeon, 1998; White, 1998; Kennedy, 1999; *SP&M*, 1999; Ross and Walker, 1999). The average American school as of the 2001-02 school year was 42 years old (Lyons, 2001). One source reported 33% of U.S. schools used prefabricated classrooms located away from the main building and restrooms (Lyons, 2001). The National Center for Education Statistics (NCES) Fast Response Survey System (NCES-FRSS) reported 36% of 903 schools surveyed used portables, 20% used temporary instructional space, and another 10% reported plans to install portables within two years (NCES, 2000). The modular manufacturing industry estimated a projected growth rate of 20% per year nationwide during this decade (Lyons, 2001). In 1991, the number of portables used in California was approximately 43,000 (Auditor General, 1991). A Pacific Gas and Electric Company study indicated an increase to approximately 45,000 portables (Davis Energy Group, 1997), while a more recent estimate reported 86,500 portables in 1997-98 school year (EdSource, 1998). At least 7,000 of those portables were from lease/purchase agreements between school districts (SDs) and the California Department of General Services, Division of the State

Architect, Office of Public School Construction (OPSC) State Relocatable Classroom Program (CAIWG-IAQ, 2000). Initiated in 1979, the program was initially designed for short-term emergency needs. As of the 2000-01 school year, the State had no more portables under this program to offer SDs (OPSC, 2000). The California School Facility Manufacturers Association has reported annual construction of 6000-8000 standard 960 ft^2 portables, each composed of two or three modules, in recent years and estimated the number demanded will increase to 10000 per year for the rest of this decade (Sarich, 2001).

Use of portables has been especially prevalent in California's most populated counties such as Los Angeles, where children, including U.S. citizens of Spanish-speaking and Asian immigrants, started enrolling in the school system in large numbers. In the 1999-2000 and 2000-01 school years, the Los Angeles Unified School District, with about 710000 students and 655 schools, was the nation's second largest (NCES, 2001d, 2002). Approximately 1.2 million, or 27%, of California public school students were housed in portables in 1991 (Auditor General, 1991), increasing to nearly 2 million children by 1997-1998 (EdSource, 1998), i.e., one in three California students was taught in portables.

Public school elementary enrollment increased 5% nationwide between 1994 and 1999, and pre-K (3-5 year olds) enrollment increased 30% between 1989 and 1999 (NCES, 2001e), which indicated a present and future need for classroom space and thus portables. Between 1980 and 1995, California's student population growth was 34% (USDOEd, 1997a), between 1990 and 1999 21.7% (NEA, 2000), and was expected to grow 22% from 1995 to 2007 (USDOEd, 1997b) and by 4.6%, or about 278,000 students, from 2000 to 2010 (NEA, 2000). In the 1999-2000 school year, California ranked first with 8566 schools with approximately six million students (NCES, 2001c). From Fall 1996 to Fall 2001, one in eight American students and 12 of the largest 100 school districts were in California (NCES, 2001a-d, 2002). The 1999-2000 median public school pre-K-3rd grade student/teacher ratio in California was 19.9, the third highest in the nation (NCES, 2001c); the 2000-01 mean public school pre-K-12th grade student/teacher ratio in California was 20.8, the second highest in the nation (NCES, 2001a).

These trends were within a financial climate where California had a per student expenditure approximately 20% below the national mean, which ranked 35th among states and the District of Columbia for per-student state expenditure and an even worse 41st when including federal funding sources (USDOEd, 1997a). Approximately 35% of expenditures per student in 1998-99 were directed to support services including facility operations and maintenance (NCES, 2001b). Although some California SDs adopted year-round schedules to accommodate more children with existing facilities, this option may be undesirable and disruptive to lives of parents, teachers and staff, and will not be a long-term solution to class size reduction and facilities and personnel needs.

Teachers and parents in a number of California school systems have complained about health effects due to the use of portables (Ross and Walker, 1999).To date, these complaints are of unknown etiology, similar to occupational "sick building syndrome," such as asthmatic symptom prevalence and severity. Portables have a door, one or two windows which may not open easily or be inoperable, carpeted floors with small tiled areas, and wall-mounted heating, ventilation, and air conditioning (HVAC) systems. Although portables have been manufactured to regulated specifications (Brooks, 1999; CADE, 199b), HVAC systems may not function properly due to lack of maintenance, lack of understanding of operations instructions on the part of teachers and/or maintenance staffs, age, and vandalism. Thus, adverse thermal comfort conditions may develop, and lower ventilation rates may be detrimental to indoor air and environmental quality (IEQ) by allowing various pollutants to concentrate. Indeed, in United States General Accounting Office (USGAO) reports (USGAO, 1995; USGAO, 1996a; USGAO, 1996b) of school facilities nationwide, California ranked last: 71% of California schools reported at least one inadequate building feature; 41% reported inadequate HVAC systems; 40% reported roof problems; and, 22% reported indoor air quality (IAQ) problems. In an informal survey conducted by the California Coalition for Adequate School Housing, 40% of 144 SDs reported complaints of IAQ problems in portables (CASH, 1999). Anecdotal complaints about IEQ of prefabricated classrooms continued because though they were viewed as short-term solutions and not part of permanent facilities planning, in practice they have been sited permanently. As school facilities, portables have associated advantages, challenges, and required improvements (Moore, 1999; Godfry, 2000; Williams et al, 2000; Roman, 2001). Furthermore, initial capital costs, including site preparation, must be compared with operation and maintenance costs and a shorter life expectancy (Fickes, 1998).

The materials used to construct and furnish portables may off-gas toxic and odorous volatile organic compounds (VOCs) including formaldehyde (HCHO) as a function of age of materials, temperature (T), and relative humidity (RH) (Lewis, 1991; Hodgson et.al, 1993; Zhang et al, 1994; Kelly et al, 1999). Associations between emissions from such materials used in the home environment (EHP, 1999) and adverse respiratory outcomes among children have been investigated (Jaakkola, 1999; Jaakkola, 2000), including exposure to HCHO and risk of allergy (Wantke et al, 1996; Garrett et al, 1999).

Other characteristics of portables may be relevant to occupant health and productivity. Based on location on school grounds, weather, and local irrigation, portable classroom floors constructed of plywood, as well as roofs and exterior walls, may be subject to water condensation build-up then damage, providing a potential breeding ground for mold spores and bacteria (Moss, 2000). Portables usually have smaller interior volumes than permanent construction classrooms, and thus may not provide adequate space for teachers and students to move in, a consideration due to the ages of the students and their stage of social, educational, and physical development. California Title 24 (2001) specified the occupant density for school classrooms as 20 ft^2 per occupant; a typical 960 ft^2 portable classroom could have 24 occupants, i.e., a teacher and up to 23 students. Little information concerning relationships between IEQ and student health and productivity (Heath and Mendell, 2002) existed for schools and thus portables.

Energy efficiency can be gained through improved performance and/or selection of lighting fixtures and bulbs, HVAC units, the building envelope including insulation, and consumer education. Improvements in energy efficiency for portables would lead to lower energy bills for schools, providing a relatively larger percentage of tight budgets for other educational, facility, and teacher training priorities. SDs have chronically faced limited resources, short-term time frames, rapidly rising student populations, and class size reduction programs. Hence, the importance of energy efficient, comfortable, clean portables with low-VOC emitting construction, interior finish, and furnishing materials for schools is evident.

The bridge between energy efficiency and improved educational and human performance outcomes is IEQ; the most important factors are materials selection, moderated T and RH, and higher sustained ventilation rates to dilute concentrations of pollutants as well as bioeffluents like odors and carbon dioxide. Across California climate zones, portables constructed with more advanced energy efficiency measures showed higher annual cost savings, and savings were similar for a nine and twelve month school year (Davis Energy Group, 1997). Unfortunately, standardization of cost-effective features has failed; advanced HVAC technologies and materials have existed on the market, but were used in commercial office or residential site-built and modular buildings more than in schools (Davis Energy Group, 1997). Some SDs have requested specific materials or advanced HVAC systems, as a function of available money and historical preferences, but as individual options and not as part of a comprehensive package. There has been no federal guideline or program to promote pollution prevention with respect to school construction and interior finish materials, or classroom teaching and cleaning supplies (APHA, 2001). In California, however, there were regulations with respect to urea formaldehyde insulation, ventilation standards, and the consideration of IAQ in energy conservation efforts (Daisey and Angell, 1998).

1.2 Background

At present, limited quantitative or qualitative survey data exist for concentrations of airborne chemical compounds inside California or U.S. public schools; measurements have been limited, usually performed in complaint schools, and varied in sampling protocols and analysis methods (Weinstein, 1979; Educational Writer's Association, 1989; Daisey and Angell, 1998; CAIWG-IAQ, 2000; Daisey et al, 2002). Research in other countries specifically related to portables has also been limited. One example was the British Columbia Teacher's Federation Research Department survey mailed to teachers working in portables in seven school districts to address issues of access, quality of heating, lighting and furniture, ventilation and air quality, security, and teaching in portables versus the main building (Naylor, 1997). Other studies may be viewed as indirectly related as they focused on carpets as sources of and sinks for indoor pollutants (Hansen et al, 1987) or the relationship between subjective indices of IAQ and exposure (Smedje et al, 1997). Daisey and Angell (1998) stated though qualitative data on health complaints, ventilation, and perceived IAQ problems in complaint schools existed, three areas of research were needed:

1. A survey of California schools to know what fraction experience ventilation and IAQ problems, and health complaints, with quantitative data taken over a representative time period of occupancy;
2. Costs and efficacy of various interventions undertaken in specific schools;

3. Data on causal and dose-response relationships between IEQ and health symptoms, to establish protective standards in schools.

They also made specific recommendations. These included the development and testing of a standardized protocol to investigate complaints; means to identify potential environmental agents inside classrooms; and, low cost samplers to measure, during occupancy, full school-day exposures to VOCs and HCHO at or above 0.05 parts per million (ppm), the current California Environmental Protection Agency/Air Resources Board (CARB) "target" guideline for indoor HCHO (CARB, 1991). For SDs, they called for purchase specifications and a maintenance and repair commitment for portables. These recommendations were similar to two federal reports on environmental threats to children's health (USEPA, 1996; USEPA, 2000), which called for future research on toxic air contaminants in community-based field studies in urban areas in microenvironments where children spend time, including improved risk communication and environmental education. This dissertation incorporated studies whose designs, field testing of samplers and HVAC units, and development and field use of technician surveys and interview questionnaires responded to these scientific needs.

At the time of this study, assessments involving multiple parameters in portables were conducted and reported only by private consultants, trained in toxicology and microbiology, hired by one California SD between February and August of 1999. This included nurse epidemiological investigations (Anderson, 1999a; Anderson, 1999b) and biological and air quality testing during vacation periods (CDHS, 1999; Faeder, 1999). (For their reports and others, and a CDHS advisory on portable classrooms, see http://www.cal-iaq.org.) Their research provided no definitive conclusions on potential risks from biological or chemical contaminants inside portables since the exposure assessment was not comprehensive. Measurements were taken for one day, in uninhabited rooms during vacation periods, with no air exchange rate calculations and no questionnaires evaluating classroom characteristics, custodial supplies, and teacher and student activities.

NCES (2000) conducted the NCES-FRSS for national estimates representing United States regular public K-12 schools; data were collected on the physical and environmental condition of 903 schools. The NCES-FRSS collected data on school satisfaction with air conditioning, energy use, and six environmental conditions: lighting, heating, ventilation, IAQ, acoustics or noise control, and physical security of buildings. About 14% of K-12 schools had one, and about 30% of K-12 schools had 2-6, environmental conditions in unsatisfactory condition. Ventilation was the environmental condition most frequently reported as unsatisfactory-- 26% of K-12 schools, 25% of K-6 schools, and 37% of West region K-12 schools. The results for IAQ reported as unsatisfactory were 18%, 18%, and 22%, respectively, and for acoustics or noise control as unsatisfactory were 18%, 17%, and 20%, respectively. 29% of schools reported HVAC systems in less than adequate condition. About 33% of schools stated a lack of satisfaction with school energy efficiency. About 19% of schools with portables reported them to be in less than adequate condition.

Other field research responded to complaints received by local and county health departments in the U.S. and Europe; these assessments, not reported in the scientific literature, examined specific compounds instead of exploring the range of possible indoor sources and contaminants (Daisey and Angell, 1998). In portables, with only one to four classrooms assessed per study, four studies measured carbon dioxide as a proxy indicator for ventilation rate, two measured air exchange rate, one measured total VOC concentrations, and six measured HCHO concentrations; one summarized airborne bacteria counts in 150 classrooms of various types in 40 California schools (Daisey and Angell, 1998). Health Hazard Evaluation Reports by the National Institute of Occupational Safety and Health, conducted under mandate of the Occupational Safety and Health Act of 1970, and unpublished investigative reports in California made in response to complaints to local agencies, examined school-building factors potentially associated with poor IAQ and health symptoms (Angell and Daisey, 1997; Daisey and Angell, 1998). The major problems identified by complaint schools and SDs were inadequate ventilation with outdoor air to occupied spaces, poor HVAC system maintenance, and water damage resulting in mold and bacteria of an infectious or toxic nature. These were only indicators. The primary cause of the reported problems was most likely inadequate and/or deferred maintenance of HVAC systems (Daisey and Angell, 1998; CAIWG-IAQ, 2000), such as not changing the air filter at proper intervals and not mitigating or preventing the build-up of moisture.

An United States Environmental Protection Agency (USEPA) school evaluation program for radon reduction, including 26 schools in eight regions, found most schools did not meet current standards for school ventilation. Each school reported one or more ventilation problems, and the various ventilation systems were usually not designed or operated properly (Chmelynski and Leovic, 1992; Parker, 1992).

Questions concerning possible associations between types of ventilation, low air exchange rates, indoor air T and RH, and/or potential chemical, physical, and biological exposures with adverse learning or health outcomes have been investigated in traditional classrooms (Pepler, 1968; Green, 1974, 1985; Walinder et al, 1997, 1998; Meyer et al, 1999; Ahman et al, 2000; Heindel, 2000; Smedje and Norback, 2000, Sahlberg et al, 2002). Complete development of the human lung occurs through ages 6-8, i.e., 1^{st}-3^{rd} grades (Plopper and Fanucci, 2000; Perera et al, 2002). Furthermore, asthma has been the leading cause of school absenteeism due to chronic illness in the United States (Lyons, 2001; Mannino et al, 2002; USEPA, 2002a; USEPA, 2002b). This dissertation, however, was not an epidemiological study; no health data were collected, and only basic activities of entire classrooms were inventoried.

The United States Department of Energy estimated many SDs could save up to 25% of their utility bills through improved building designs, available energy efficiency technologies, renewable energy sources, and/or improved operations and maintenance practices (AASA, 2000). Products were on the market but not used specifically for school classrooms. Public and private sector experts believed any minor disadvantages; such as limitations in climate zone appropriateness, would be significantly outweighed by the advantages.

For the advanced technology under study in one project with specific components incorporated into this dissertation, the benefits reported by the manufacturer and supported by participating homes in a field test were numerous. These included up to 70-80% lower energy costs, 100% outdoor air supply, lower noise levels with the ducted system, no stratospheric ozone depleting substances, i.e., chlorofluorocarbons, reuse of the daily water discharge, and variable fan speeds (Davis Energy Group, 1998). The advanced technology, the two-stage indirect-direct evaporative cooler (IDEC) with continuous room ventilation coupled with a natural gas-fired water heater and hydronic loop for heating, exhibited declines in performance in lab and residential field tests only at outdoor RH levels above 60% (Davis Energy Group, 1998; Pacific Gas and Electric Company, 1998).

There were three broad questions of science integral to projects comprising this dissertation. They can be called "main hypotheses," but should not be considered specific null hypotheses subject to rigorous statistical tests.

- Teachers and students may be exposed to VOCs, including HCHO and acetaldehyde (CH_3CHO), due to building materials, cabinetry and furniture, teaching materials, cleaning products, and/or the influence of nearby outdoor sources such as traffic as a function of ventilation.
- Inadequate ventilation in portables was due to a lack of, or limited use of, windows and/or poorly maintained or poorly operated mechanical HVAC systems.
- Thermal comfort parameters (T, RH), and their seasonal variation, may influence potential chemical and biological exposures inside portable and main building classrooms. Biological exposures were not quantitatively assessed in this dissertation.

1.3 Overall Objectives

To address a school environment and children's health issue of present concern to parents, government agencies, education professionals, school nurses, scientists, and private sector interests, an assessment of existing public school portables and field tests of new, prototype relocatables were conducted in specific areas of Southern and Northern California, respectively. Ventilation-related characteristics, thermal comfort parameters, and target organic compound concentrations indoors were monitored and surveys, checklists, and questionnaires were designed and conducted. Classroom occupancy determined by attendance data and carbon dioxide monitors, window and door use sensors, sound level meters, numerous T and RH sensors, and energy monitoring equipment were built into the prototype relocatables to better understand the operation and efficiency of advanced and conventional HVAC systems.

At the time of this dissertation, the topic of portables was highly sensitized by media reports and concerns, sincere or unfounded, among multiple stakeholders. Monitoring of and critical thought about reports in the media, including the internet, concerning public school education in portables and associated issues of science, policy and law provided important information of context and about scientific data needs this dissertation addressed. For example, the California EPA, Office of Environmental Health Hazard Assessment (CalEPA/OEHHA) was planning a "Draft Reference Manual for Selected Indoor Air Contaminants: Inhalation Toxicity Criteria," which would include 'safe' concentration levels for acute exposures over eight and 24 hours for 64 toxic air contaminants (Broadwin, 2000). Overall, refinement of the risk communication strategy, i.e., summary of main results to participants, was the expected result.

As part of employment negotiations in fall 2000, Lawrence Berkeley National Laboratory (LBNL) agreed on at least two classes of data from their projects which could be incorporated in this dissertation: the aldehyde data, and the survey, checklist, and questionnaire data. Indoor air T and RH data collected with HOBO H8 family data loggers (Onset Corp, Bourne, MA) also used in the UCLA pilot "Portable Classrooms Study" (UCLA PCS) were available from the LBNL study (LBNL RCS) relocatables. Survey and checklist data collected during an epidemiological study of respiratory health of third-to-fifth graders and traffic density and emissions were also available for this dissertation. This project was conducted with CalEPA/OEHHA between December 2000 and June 2001. Ten schools participated, six in Hayward, three in San Leandro, and one in Oakland. LBNL completed air quality monitoring, and CalEPA/OEHHA and the UC-Berkeley Survey Research Center conducted the survey-based health assessment.

1.4 Specific Objectives

1.4.1 Los Angeles County Portion of Field Research (UCLA PCS)

- Recruit various stakeholders, which included SDs; schools principals and teachers; and collaborators for the chemical analyses.
- Develop a non-invasive, non-intrusive, non-disruptive quantitative exposure assessment methodology for public school portable and main building classrooms, as well as qualitative surveys and an interview questionnaire on the classroom environment and operations and maintenance of HVAC systems, respectively

- Develop a study design to conduct the methodology and collect data over an entire school week, including hours of school occupancy and HVAC system operation as well as the late afternoon/overnight period when HVAC units would likely be off and doors and windows closed and locked.
- Conduct field work to collect quantitative target pollutant concentration data inside portable and main building control classrooms in different seasons. The target pollutants were HCHO, CH_3CHO, and nineteen VOCs, including air and water toxic and odorous contaminants with indoor and outdoor sources.
- Conduct field work to collect continuous T and RH data inside portable and main building control classrooms in different seasons.
- Conduct field work to collect input data for air exchange rate measurements inside portable and main building control classrooms in different seasons.
- Conduct field work to conduct a checklist on the school and classroom physical environment in different seasons during each visit to the classrooms.
- Conduct field work to administer a qualitative person-to-person interview questionnaire on operations and maintenance of school facilities and HVAC systems with head custodians.

1.4.2 Northern California Field Study (LBNL RCS)

- Recruit various stakeholders, which included SDs and their facilities and construction offices; school principals, teachers and custodians; architects; and, manufacturers of portables, HVAC systems, construction and interior finish materials, and air pollution and thermal comfort monitoring equipment.

- Develop and use a non-invasive, non-intrusive, non-disruptive methodology to assess potential exposure to formaldehyde and acetaldehyde with active sampling equipment, and thermal comfort parameters with sensors and data loggers.
- Conduct field work to collect integrated school day HCHO and CH_3CHO concentration data in new prototype relocatables on public school campuses during eight and nine weeks of the cooling and heating seasons, respectively.
- Conduct field work to collect continuous T and RH data in new prototype relocatables on public school campuses during eight and nine weeks of the cooling and heating seasons, respectively.

1.4.3 For the UCLA PCS and the LBNL RCS

- Measure HCHO and CH_3CHO, two carbonyl compounds with known and/or suspected acute and chronic health effects, in older, newer, and brand new prototype portable classrooms sited at public elementary school campuses in California.
- Measure indoor air T and RH, two of the parameters comprising the ASHRAE 55 (1992) occupant thermal comfort standard, in older, newer, and brand new prototype portable classrooms sited at public elementary school campuses in California.

1.5 Hypotheses to be tested statistically

Overall, the UCLA PCS and the LBNL RCS were descriptive in nature. There were for this dissertation, however, select specific hypotheses for statistics, using mainly quantitative IEQ data. These hypotheses were as follows:

1.5.1 UCLA PCS

1. Concentrations of HCHO and CH_3CHO in portables from indoor and outdoor sources were higher than in main building control classrooms.

2. Concentrations of VOCs in portables, known to be from indoor, indoor and outdoor, or primarily outdoor sources because smoking is prohibited and space heaters were not present, were higher than in main building control classrooms.

Target compounds consistently above method detection limits (MDLs) would be tested

3. HVAC system-driven air exchange rates in portables were lower than in main building control classrooms.

1.5.2 LBNL RCS

The hypotheses for the LBNL RCS were similar.

1. Concentrations of HCHO and CH_3CHO in relocatables, regardless of the HVAC system in operation or materials composition, were higher in the fall cooling season than in the winter heating season. Higher concentrations were expected in the cooling season due to meteorological variables, i.e., T and RH, and relatively more off-gassing during initial months of classroom operation.

2. Concentrations of HCHO and CH_3CHO did not differ among relocatables with identical materials composition but different operating HVAC systems, i.e., advanced IDEC versus the conventional heat pump unit, due to teacher behaviors regarding HVAC system operation. If concentrations were different, then concentrations during IDEC operation were expected to be lower due to the increased percentage of continuous 100% outdoor air ventilation, versus a maximum of 25-50% intermittently.

3. Concentrations of HCHO and CH_3CHO did not differ among relocatables with identical operating HVAC systems but different materials composition, i.e., alternative versus industry standard selections. Higher concentrations were expected with industry standard selections.

1.6 Secondary Analyses Related to Study Hypotheses

1.6 UCLA PCS

Secondary analyses under the first hypothesis for these uncharacterized microenvironments included:

- Concentrations of HCHO and CH_3CHO in portables were higher in the cooling season than in the heating season due to T and RH.
- Concentrations of HCHO and CH_3CHO in portables were higher on Monday than on Friday, i.e., a typical weekday, due to a "weekend off-gassing build-up" effect.

Secondary analyses under the second hypothesis for these uncharacterized microenvironments included:

- Concentrations of VOCs in portables were higher in the cooling season than in the heating season due to T and RH.

Target compounds consistently above method detection limits would be tested.

Secondary analyses under the third hypothesis for these uncharacterized microenvironments included:

- Air exchange rates in neither portable classrooms nor main building control classrooms differed in the heating and cooling seasons.

• Air exchange rates and concentrations of HCHO and CH_3CHO in portables were inversely correlated.

• Air exchange rates and VOC concentrations in portables were inversely correlated. Target compounds above method detection limits would be tested.

Another related secondary analysis for these uncharacterized microenvironments was:

• Concentrations of carbon monoxide did not differ between relatively older and newer portable classrooms in SD 2 in the winter heating season.

Other related secondary analyses, to validate previous findings in homes and public and commercial office buildings, included:

• Indoor air T and RH values in portables and in main building control classrooms differed in the heating and cooling seasons.

• Indoor air T and RH values in portables differed from values in main building control classrooms.

• Indoor air T and RH values in portables and in main building control classrooms exhibited variation during school day hours, e.g., compare four-hour periods before and after lunch.

• Average morning and afternoon indoor air T from continuous measurements in portable and main building classrooms differed from morning (before lunch) and afternoon (after lunch) classroom thermostat readings as well as typical teacher thermostat set points reported by the head custodians.

1.6.2 LBNL RCS

Secondary analyses under the first hypothesis for these uncharacterized microenvironments included:

- Concentrations of HCHO and CH_3CHO in relocatables were highest with standard materials and the standard HVAC system but lowest with alternative materials and the advanced HVAC system.

Other related secondary analyses, to validate previous findings in homes and public and commercial office buildings, included:

- Indoor air T and RH values in relocatables differed in the heating and cooling seasons.
- Indoor air T and RH values in relocatables exhibited variation during school day hours, e.g., compare four-hour periods before and after lunch.
- Average morning and afternoon indoor air T from continuous measurements in relocatables were similar to recess and lunch time thermostat readings, but differed from early morning and end-of-school thermostat readings as well as typical teacher thermostat set points reported by the head custodians.

CHAPTER 2.-- EXPERIMENTAL

2.1 Selection and Recruitment of Targeted SDs, Schools, and Classrooms

2.1.1 UCLA PCS

For logistical convenience, and in recognition of the sensitivity of the school IAQ issue with the media and courts, K-12 schools serving the same target communities chosen for another UCLA study (Shendell et al, 2002a) were used. Baldwin Park, whose staff independently contacted UCLA with questions on HVAC systems, air filtration, and indoor air pollutants (Godfry, 2000a-b) was also included. The first seasonal sampling in Baldwin Park in June 2000 was treated as a pilot study. Geographic location and meteorology were considered in target area selection, and could be in analyses following field data collection. School grounds were determined to be, on average, upwind or downwind of a major freeway at varying distances. In each community, repeated efforts were required to successfully contact SD administrative offices, and then to contact individual schools, gain permission from principals, and establish the first seasonal sampling schedules.

Permission from the Baldwin Park Unified SD (BPUSD) Superintendent's office was facilitated by their Director of Facilities, who also helped with classroom inventory and selection of schools for inclusion in the study. In addition to BPUSD, the final study population consists of K-12 public schools serving the West Los Angeles area of the Los Angeles Unified SD (LAUSD) Region C. The other three target SDs declined to participate, due to the sensitivity of the issue in the media as well as among parents and teachers. These LAUSD Region C elementary schools were within the 90064 and 90066 zip codes and about 0.5-1.0 kilometers away from the I-405 and I-10 freeway intersection. A list of schools and their facilities was developed based on phone conversations conducted with assistant principals, secretaries, and other school administrative staff members in December 1999; this had been done for SDs in target communities. The numbers of portables and main building classrooms were determined. Schools with no portables, or temporary ones only for main building repairs, were excluded. Results directed recruitment of up to six elementary schools and one senior high school; the high school provided nighttime adult continuing education classes held in portables. There were no junior high schools with portables in the target areas.

Following a letter to the Office of the Superintendent (see Appendix A.1.2.1), the project required formal approval with a comprehensive application (see Appendix A.1.4.1) to the LAUSD Program Evaluation and Research branch. The application's instructions included complete descriptions of the study goals, hypotheses, methodology, the current version of the survey instruments, samplers to be used, and ethical considerations. After official approval was granted (see Appendix A.1.4.2), introductory letters were sent to the principals of the seven schools including notice of the proposal's acceptance by LAUSD (see Appendix A.1.3 and A.1.4.3). Among consenting schools, three or four were to be selected at random, however since only four agreed to participate, each was included in the first seasonal sampling. In the second sampling, to maximize the limited resources available for the UCLA PCS, only the three elementary schools were included. In BPUSD, two elementary and one junior high school were selected and sampled twice in the cooling season.

Across SD, in general, two portables, one newer and one older, and one main building control classroom were selected randomly at each school. The library at one elementary school, located in a large, older portable, was also selected since it was used throughout each school day. At one elementary school, only one portable was assessed since portables were recognized to be of similar age, from the same manufacturer, and sited side-by-side behind the main buildings. By chance, the random selection of classrooms included a newer portable at the junior high school with an advanced filtration technology incorporated into the HVAC system (see Appendix 12). BPUSD was interested to know if the use of this HVAC technology resulted in lower measured concentrations of gaseous organic compounds as compared to the other portables assessed. Overall, 13 portables and seven main building classrooms were assessed.

2.1.2 LBNL RCS

LBNL obtained funding from the California Energy Commission Public Interest Research Program, as Element Six of the High Performance Commercial Buildings Systems Program, to construct and modify four relocatables (RCs) with upgrades to energy efficient technologies. Two RCs, one of each pair, were constructed with alternative, advanced finish materials for tackable wall panels, ceiling tiles, cabinetry, roof coating paints, and carpets and adhesives. These RCs, the most common 24' by 40' (960 ft^2) size as selected by the participating SDs, were sited by the start of the 2001-02 school year in side-by-side pairs on the campuses of two recruited Northern California SDs in different climate zones. The SDs were located in cities which met climate criteria, to test the performance of the advanced HVAC technology, IDEC (see Appendix

A.4.2.2). The IDEC, based on environmental chamber and residential field tests (Davis Energy Group, 1997; Davis Energy Group, 1998), operated best in environments with hot, dry summers, mild winters, and no pervasive year-round morning and afternoon fog, e.g., San Francisco and other California coastal areas. Therefore, LBNL targeted the Sacramento and inland San Jose metropolitan areas, the northern Central Valley, and the foothills east of Berkeley starting with Walnut Creek (Shendell et al, 2002b). Energy modeling done in collaboration with Davis Energy Group (DEG, Davis, CA) confirmed choices (Apte et al, 2001).

In November and December 2000, three manufacturers were recruited in Northern California, as well as one in Southern California with clients in the northern part of the state, with repeated phone conversations. Meetings at their offices, coupled with tours of their production facilities, product prototypes, finished buildings storage lots, and means to transport RCs were conducted.

The process of recruiting SDs began with a one-page formal cover letter accompanied by a one-page description of the LBNL RCS including goals and activities. LBNL solicited 12 SDs in three groups, two, four, then six, who were proven repeat customers of the potential collaborating manufacturers. Some of these 12 targeted SDs even placed orders for new RCs by December 2000 for delivery in 2001. LBNL required working with SDs ordering RCs for elementary schools, with construction in late spring or summer 2001 and delivery to school campuses in late summer 2001 for use beginning in late August or early September 2001. Meetings were scheduled at the administrative offices of three interested SDs in January 2001. By February 2001, one northern Central

Valley SD declined due to Board of Education liability concerns, while Cupertino Union SD (CUSD) near San Jose and Modesto City Schools (MCS) in the northern Central Valley confirmed their interest and participation.

LBNL selected one manufacturer, American Modular Systems (AMS) of Manteca, for RC construction by the end of February 2001, based on information learned during phone conversations and visits as well as the preferences and historical experiences of recruited SDs. Indeed, SD property management and facilities and construction offices had classroom, furniture, and/or carpet manufacturer preferences.

Discussions between LBNL, DEG, AMS, and architects of participating SDs were initiated in late February and early March 2001. These collaborative efforts were conducted by multiple means of communication. The overall goal was to modify existing drawings for RCs, mechanical HVAC systems, and site preparation specifications according to the needs of the project, while respecting SD preferences and adhering to relevant state codes and guidelines. The iterative process was dynamic and challenging, but ultimately rewarding. LBNL purchased monitoring equipment, HVAC system installation hardware and distribution system components, and three classes of alternative interior finish materials from among eight categories inventoried and evaluated (Hodgson et al, 2001; Hodgson et al, 2002) in spring 2001. SDs received final responsibility for purchasing approval and color selections. Schedules for RC construction, delivery and siting, final LBNL IEQ and energy monitoring equipment set-up and testing, and DEG IDEC commissioning, although subject to numerous delays for various reasons, were agreed upon and realized, with work completed before inauguration of the school year.

2.2 Study Design: Monitoring of Classrooms and School Environment: Samplers, Checklist, Survey, and Questionnaire

2.2.1 UCLA PCS

2.2.1.1 Overview of Samplers for Quantitative Measurements

Four samplers were used in the IEQ assessment (Table 2.2.1.1.1).

Table 2.2.1.1.1: Samplers and instruments to be used in measurements

Apparatus	Compounds Assessed	Attributes of Sampler
3M 3500 organic vapor monitor (OVM) badge	volatile organic compounds (VOCs); 19 target compounds	small, orange plastic clip-on badge with adsorbing surface and protective white film
DNSH treated passive cartridge/badge	aldehydes, e.g., HCHO and CH_3CHO	small, white and clear colored cartridge placed in clip-on badge
perfluorocarbon tracers (PFTs) and capillary absorption tube (CAT) system, 2:1 ratio used	air exchange rate (hr^{-1}), i.e., amount of outdoor air ventilation provided primarily by mechanical HVAC system	PFTs emitted non-toxic gas, equilibrated in 24-48 hours, which CAT (activated charcoal) collected passively
HOBO data loggers	T, RH	small, durable grey case enclosed sensors; download data to PC; five or six minute samples

HCHO and CH_3CHO were sampled with a passive clip-on cartridge (Environmental and Occupational Health Sciences Institute (EOHSI), UMDNJ/Rutgers University); the common chemical name is dansylhydrazine (DNSH), and the sampler was designated as the "DNSH Passive Aldehydes and Ketones Sampler (PAKS)" (see Figures 2.2.1.1.1-2.2.1.1.2, and Appendix A.2.1 and A.2.6.1). This cartridge was a modified solid phase extraction tube coated with the DNSH. Aldehyde samples were extracted and analyzed using a high performance liquid chromatography (HPLC) with fluorescence detection method at EOHSI.

Nineteen VOCs were sampled with the clip-on passive 3M OVM 3500 badge (see Appendix A.2.1). Analyses of the VOC samples were conducted by extraction in carbon disulfide followed by gas chromatography/mass spectrometry (GC/MS) at the University of Texas-Houston School of Public Health.

The Harvard University School of Public Health (HSPH) methodology for measuring air exchange rate was used. The system included tubes (PFTs) emitting the non-toxic tracer gas perfluoromethyl cyclohexane (PMCH), which equilibrated for 64-88 hours in the classroom's volume, and a capillary absorption tube (CAT) packed with an adsorbent (Ambersorb XE-347, Rohm and Haas) with properties similar to activated charcoal (see Appendix A.2.1).

Indoor air T and RH data were collected continuously by battery-operated HOBO data loggers (Onset Corporation, Bourne, MA, see Appendix A.2.1). Data were downloaded from the instrument (BoxCar Pro, v. 3.5/4.0) and then exported to Microsoft Excel for data management and descriptive statistics.

An idea raised during discussions with outside peers was to include continuous monitoring for carbon monoxide (CO) inside the portables during the heating season, the second seasonal sampling in February 2001 in LAUSD. Natural gas fired heat pumps coupled to the HVAC units in some newer portables or wall heaters in some older portables from the 1950s-1960s may be indoor sources of CO if not maintained for efficient operation. Nearby freeways and primary arterials, due to meteorology and especially wintertime atmospheric conditions, i.e., stability and lower inversion layer ceilings, may impact indoor CO concentrations. HVAC air intakes adjacent to areas where delivery trucks or buses may stand in idle may result in increased CO concentrations as well.

Figure 2.2.1.1.1: Diagram depicting chemical reaction in use of DNSH PAKS

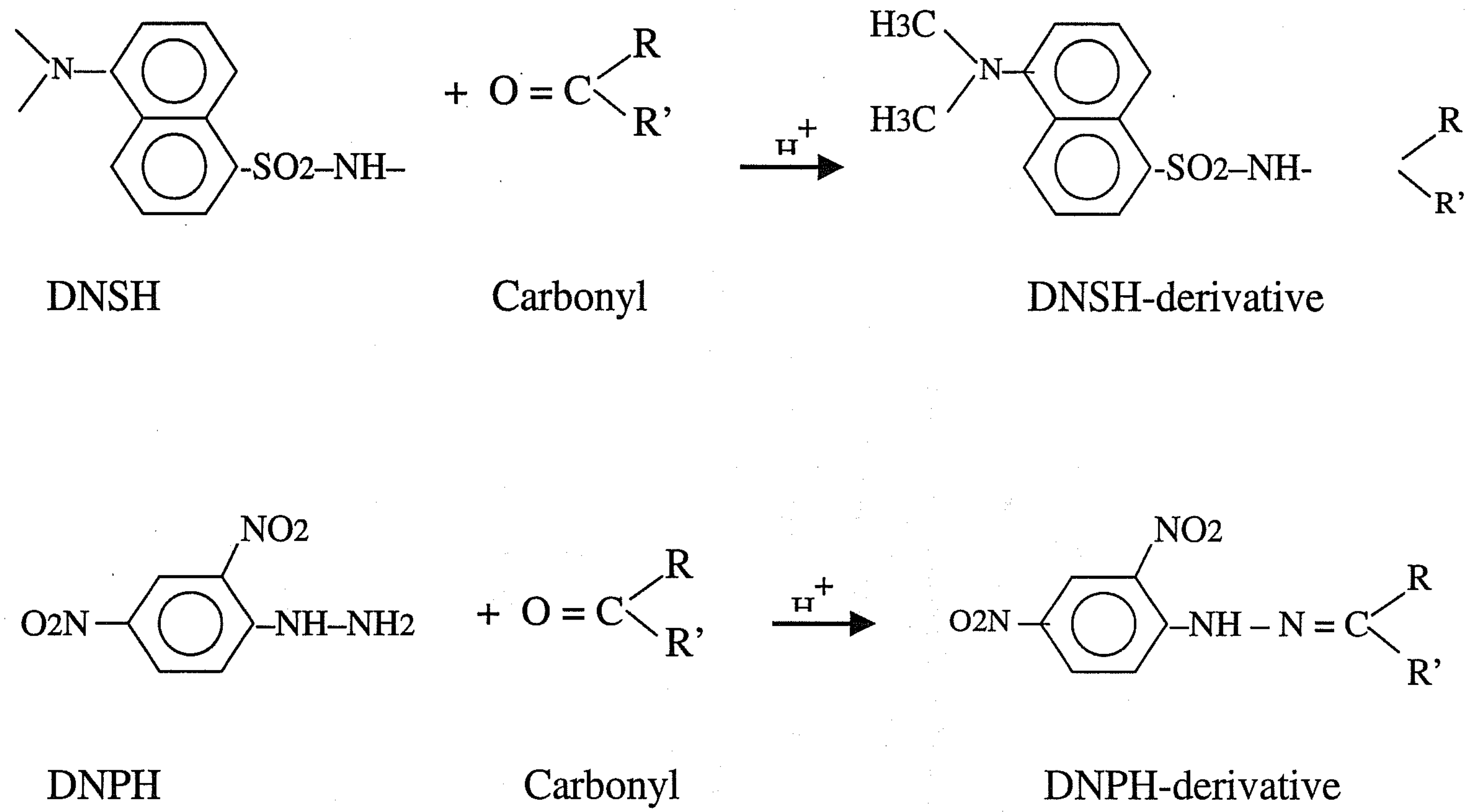
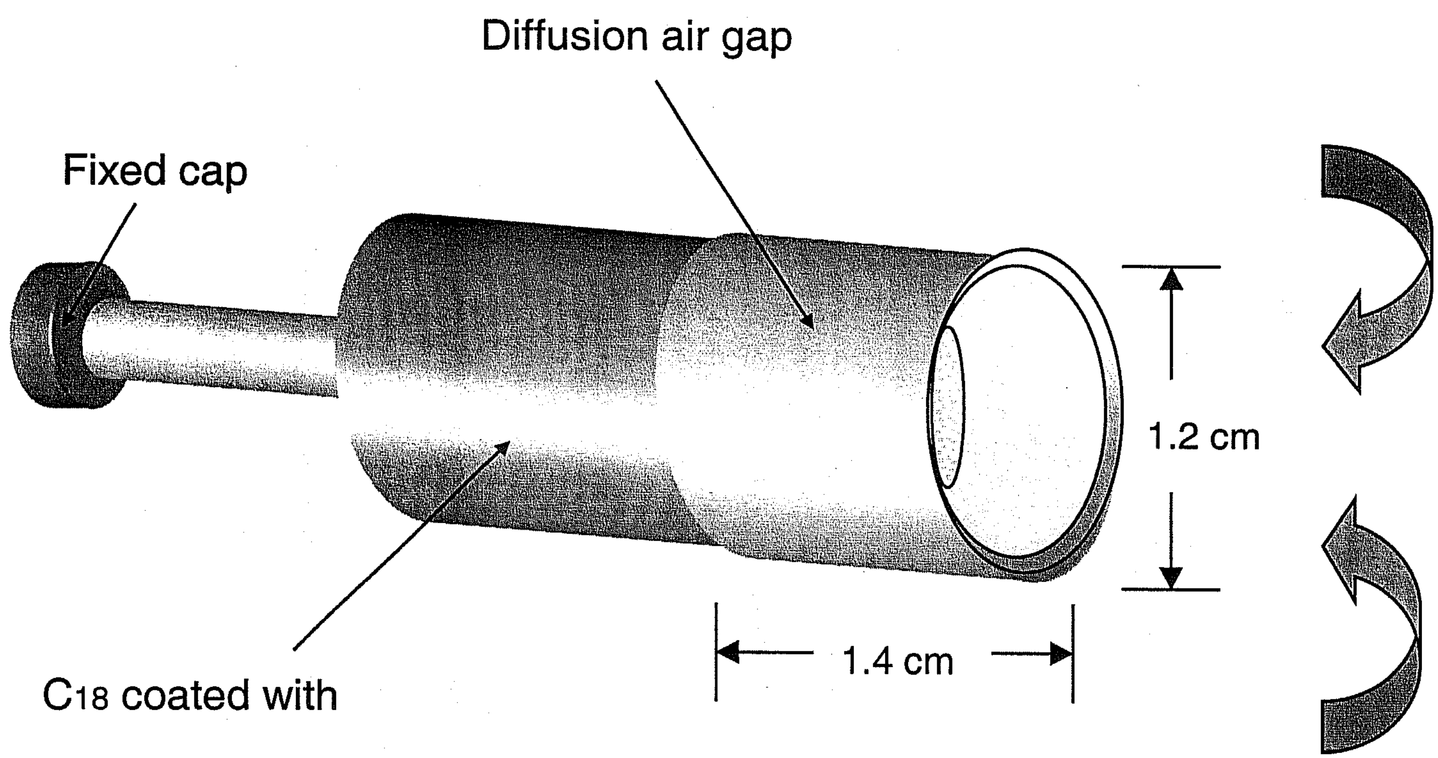


Figure 2.2.1.1.2: Diagram of the DNSH PAKS passive aldehydes sampler



2.2.1.2 Sampling Systems: Further Background and Specifications

2.2.1.2.1 3M 3500 Passive Badges for Volatile Organic Compounds (VOCs)

The 3M Company (St. Paul, MN) OVM was manufactured in two versions, the 3500 and the 3520. The 3520 had two adsorbing charcoal pads, one in each of the front and back sections of the passive dosimeter, while the 3500 contained only one adsorbing charcoal pad. The extra "back" pad of the 3520 was designed as a backup when the capacity of the front pad may be exceeded, e.g., industrial exposures or measurements in high T/high RH climates, to confirm sample validity (Chung et al, 1999b). Chung et al (1999a-b) conducted an evaluation of the 3520 under specific controlled conditions in a dynamic exposure chamber. Concentrations of target compounds (10, 20 and 100 $\mu g/m^3$), T (controlled within +/- 1°C), and RH (12% +/- 1.5%, 50% +/- 2%, and 90% +/- 3%) were chosen to represent the range of community indoor and outdoor air microenvironments. Extraction efficiencies, method detection limits, percent recoveries with respect to delivered concentrations, and the effects of varying T and RH across the established range for target compounds were investigated using a exposure chamber. The UCLA PCS used the same laboratory for chemical analyses of 3M 3500 OVMs. Results indicated there was only a limited advantage to using the 3520 over the 3500 OVM for these target compounds under a range of typical conditions, which included target compounds in the UCLA PCS, and the entire sampled mass was almost always found on the front charcoal pad. Thus, the 3500 OVM was judged to be sufficient for the UCLA PCS. Furthermore, though charcoal tube and OVM measurements were similar in magnitude, OVMs provided higher precision. Discussion of the validity and precision of laboratory analysis procedures and results, including for the UCLA PCS, will follow.

In a study of 20 homes of randomly selected adults in Erfurt, Eastern Germany (Schneider et al, 1999), 3M OVM 3500 passive samplers exposed seven days for VOC concentrations indoors and outdoors were placed at multiple heights in the main living room (0.7 m, 1.2 m, and 2.0 m). No vertical variability was observed, i.e., there were no significant differences between the median values of the weekly average air concentrations at different heights, supporting the design of the present study, which focused on keeping the samplers safe and unobstructed, out of sight and reach of students, and out of the teacher's organizational and instructional space.

2.2.1.2.2 DNSH-PAKS Passive System for Aldehydes

The passive sampler and chemistry used for monitoring HCHO and CH_3CHO in Los Angeles County classrooms were previously named and described. A few additional specific details from the sampling and handling protocols developed by EOHSI (Zhang et al, 1999) will now be highlighted.

Dansylhydrazine (DNSH) was reagent grade 5-(dimethylamino)naphthalene-1-sulfohydrazide. The cartridge serving as the sampling medium for carbonyls was a 6 ml., 0.5g. Supelclean LC-18 Syringe Cartridge (Supelco Corporation). The caps used to seal the sampler were polyethylene cap plugs. During handling and transport between UCLA and schools, the East Bay and the Los Angeles area, and UCLA and EOHSI, capped samples were wrapped in aluminum foil and placed in plastic bags in cooler packs. Ice packs were used in the cooler packs to maintain T at or below 4°C (39.2°F) as long as possible. Sample shipment was by overnight express carriers.

2.2.1.2.3 PFTs and CATs System, Air Exchange Rate (AER) Calculations

Total ventilation, a combination of unintentional air infiltration through the building envelope, natural ventilation through open doors and windows, and mechanical ventilation using HVAC systems, provides a means for removing and/or diluting concentrations of indoor air pollutants but requires a potentially significant energy load on a building (Sherman and Wilson, 1986; Sherman, 1989; Sherman, 1990). The only method for direct measurement of air infiltration, i.e., ventilation rate or air exchange rate (AER), during normal occupancy and averaged over an appropriate time period was with a tracer gas technique (Dietz and Cote, 1982; Leaderer et al, 1985; Sherman, 1985; Sherman and Wilson, 1986). The two most common techniques were tracer gas decay, e.g., using carbon dioxide (CO_2) or sulfur hexafluoride (SF_6), and the steady-state tracer gas method, e.g. using a perfluorocarbon tracer (PFT) gas collected by capillary absorption tubes (CAT). The appropriate time period for measuring average AER depends on the type of building, operating and occupancy schedules, and the number and types of pollutants of concern (Sherman and Wilson, 1986). This dissertation used PFTs and CATs in elementary school portable and main building classrooms to calculate AER averaged over an entire school week (SWIA), during only school hours averaged for an entire school week (SDIA), and during late afternoon and overnight periods averaged for an entire school week (OUPIA). The latter value was determined from direct measures of the first two values. Further details on handling, transport, and shipment of samples, composition of the PFTs and CATs, the analysis, and practical issues are now provided.

The PFT used was PMCH. The background environmental concentration of PMCH was measured as 0.003 pl/L, and was shown at concentrations in the percent range, e.g., 30 ppb, to be nontoxic by inhalation or ingestion (Dietz and Cote, 1982; Dietz, 1992). The PFT source used was a liquid permeation tube source, with PFT liquid contained in a small aluminum shell plugged with a silicone rubber cylinder and crimped; the original diffusion plug source had been an elastomer containing the dissolved PFT compound which emitted vapors (Dietz and Cote, 1982). The liquid PMCH, 0.4 ml, was placed in the 22 cm aluminum metal shell before the elastomer plug was crimped in place (Dietz and Cote, 1982; Weker, 1999). The quantified liquid permeation source PFT emission rate was constant while liquid remained, about 4-5 years, had a small, quantifiable T dependence but negligible age effects, and achieved a steady-state concentration in the room or zone under study (Dietz and Cote, 1982; Dietz et al, 1986; D'Ottavio et al, 1988; Weker, 1999). The source was in an insulating polyurethane or polystyrene sponge of dimensions 2 cm long by 3 cm wide by 5 cm height, which further reduced the aforementioned affect of T variation during sampling (Wilson et al, 1996; Weker, 1999). Once the PFTs were placed in a room and PMCH emitted, uniform mixing began rapidly (Dietz and Cote, 1982). The diffusion coefficient of PMCH was empirically determined to be 0.0505 cm^2/sec (Dietz and Cote, 1982).

PMCH appeared to meet criteria for an ideal tracer gas (Sherman, 1990): safe, non-flammable, non-toxic, and non-allergenic; no chemical or physical reaction or interference with the system under study; quantifiable; and, not a normal constituent of air.

Physical dimensions of the passive CAT were 6.35 cm in length, 6 mm in outer diameter, and 4 mm in inner diameter (Weker, 1999). At each open end, the PMCH tracer gas diffusing section was about 2.5 cm long and 1 mm in diameter (Dietz and Cote, 1982); the CAT was symmetrical, and both ends could opened (Weker, 1999 and 2000). 50 mg of a carbonaceous adsorbent were packed in the middle of the CAT, and held in place by stainless steel screens and also glass wool (Dietz and Cote, 1982; Weker, 1999).

For this study, the T dependence correction was 3% for each 1°C the average indoor T of the monitoring period deviated from the T of the HSPH Environmental Laboratory, 24°C (Weker, 1999). Wilson et al (1986, 1996) also used empirical multipliers, but found the change to be 4.6%/1°C in the earlier study and 3.8%/1°C in the later study. One possible explanation for the discrepancy may have been the authors estimated average indoor T for the defined monitoring periods from four readings (initial, final, maximum, minimum), instead of calculating the arithmetic mean from continuous data taken at a defined sampling interval, e.g., 5-6 minutes, as done in this dissertation. Dietz and Cote (1982) found an 8% change in AER for a 3°C change, and Leaderer et al (1985) found the time-weighted average T for the sampling period could determine estimated source strengths and produce no bias in calculation of AER if T fluctuations from laboratory room T were less than 8°C (14°F), which was true in the UCLA PCS.

Other potential sources of error in the calculated AER related to the PMCH source emission rate and thus measured tracer concentrations, but can be controlled and made negligible. PFTs used in this study were returned to HSPH after each season of sampling, i.e., every 3-4 months, to reweigh PFTs to calibrate the PMCH emission rate (Weker, 1999). A batch of PFTs prepared with the same materials at the same time had an associated relative standard deviation less than 3% (Weker, 1999). The single, well-mixed zone assumption could fail at night at the boundaries of the classrooms (D'Ottavio et al, 1988), since doors and most if not all windows were closed and the HVAC unit was off. The improved study design for the second seasonal sampling in LAUSD and second late spring sampling for BPUSD allowed separation of school day hours from late afternoon and overnight periods for integrated AER calculations and statistics.

2.2.1.2.4 HOBOs for Indoor Air Temperature (T) and Relative Humidity (RH)

The HOBO data loggers with T and RH sensors, including the sampling interval and the software and method of interfacing with PC Windows computers, were previously described. The accuracy, resolution, and precision of the sensors (Onset Computer Corporation, 1997-99) are now presented.

The operating range of the HOBO H8 Family loggers was -4° F to 158° F (-20° C to 70° C), and from zero to 95% RH non-condensing. The replaceable lithium battery (part number CR-2032) could operate the logger for approximately one year under continuous use or longer with delayed start times and thus specified use intervals as in this dissertation. The time accuracy of the logger was +/- one minute per week for the maximum ambient and indoor T ranges expected in this study, 40° F to 100° F (4° C to 38° C), which was sufficient given the 5-6 minute sampling interval chosen. The internal T sensor measured ambient or indoor air over the logger's operating range. Over the aforementioned expected T ranges for this study, the accuracy of the T sensor was 1.3 +/- 0.2° F (0.7 +/- 0.1° C) with a resolution of 0.8 +/- 0.2° F (0.4 +/- 0.1° C). The internal RH sensor was T compensated, and its operating ranges at 60° F (16° C) and at 80° F (27° C) were 30-90% and 25-95%, respectively. The accuracy over a 41° F to 122° F (5° C to 50° C) operating range for sampling intervals greater than or equal to ten seconds was +/- 5%.

2.2.1.2.5 Langan T15 DataBear and Software for Carbon Monoxide (CO)

Electrochemical cell-based Langan T15 DataBears (Langan Instruments, Inc., San Francisco, CA; see Appendix A.2.1) purchased and used for another UCLA human exposure study were borrowed and deployed to measure CO concentrations in LAUSD portables in the winter heating season. They were calibrated weekly with zero gas and 20 ppm gas cylinders (Draeger, Pittsburgh, PA) according to the manufacturer's protocol. CO was measured inside each portable at three different schools over six school days and a weekend; each classroom was represented by 1.5-2.5 days of data. These data logging instruments were co-located with the other samplers. Hourly averages, daily averages, school week averages, and minimum and maximum readings were calculated.

2.2.2 LBNL RCS, Quantitative Measurements, Specifications and Background

2.2.2.1 DNPH-based Active System for Aldehydes

Programmable timer-controlled active sampling systems were used in the environmental chamber tests of emission rates from different interior finish materials in relocatables (Hodgson et al, 2001; Hodgson et al, 2002) as well as for the measurement of concentrations of aldehydes indoors and outdoors during the field study. The samples were silica cartridges (XpoSure Aldehyde Sampler, part number WAT047205, Waters Corporation, Milford, MA) based on dinitrophenyl hydrazine (DNPH) chemistry (see Figure 2.2.1.1.1). DNPH coated cartridges reacted with target compounds in the air; reaction products, i.e., derivatives, specific to each target parent compound, stabilized or sorbed on to the sampling surface until extraction with an appropriate solvent, e.g., acetonitrile, during sample processing and analysis. The target compounds were HCHO and CH_3CHO; low molecular weight acid aldehydes and certain reaction by-products may also be detectable. The active sampling system was based on Masterflex No. 16 tubing and peristaltic pumps (Masterflex 115 V Standard pump drive, P/N H-07543-60, with Standard pump head, P/N 07016-21; Cole Parmer Instrument Company, Vernon Hills, IL) operated at 60 revolutions per minute. The system was also constructed with Fischer Scientific programmable date and time timers, 1/8" diameter copper tubing, male and female leur fittings and connectors, and the removable DNPH cartridges. The target flow rate provided by the air sampling pumps was between 130-160 cc/min, with variability driven by T. The pump selected was durable, stable at low flow rates, and relatively small and quiet compared to competing products. The pump could be programmed to sample during specific hours of the day, one day per week, i.e., when LBNL visited schools during eight and nine weeks of the fall 2001 cooling and winter 2002 heating seasons, respectively. The sampling period for integrated average concentration measurements captured hours of classroom occupancy by teachers and/or students.

Flow rates of the active sampling system were calibrated within half an hour after the start and before the end of the sampling period. The BIOS International DryCal DC Lite-1 flow meter with low flow cell was used (available through SKC Inc., part number 717-01). The average of ten individual flow rate measurements was recorded on field data sheets (see Appendix A.2.2.2). The instrument provided flow cell volume and a crystal timing mechanism certified NIST-traceable, and single point calibration to verify flow before and after sampling at a fixed rate with a rated accuracy of +/- 1% (SKC Inc., 2001). For further details, refer to Shendell et al (2002b).

2.2.2.2 HOBOs for Indoor Air T and RH

The HOBO data loggers with T and RH sensors were the same as used in the UCLA PCS, except the sampling interval was changed from five minutes to six minutes to allow compatibility with the entire LBNL central data acquisition system (Shendell et al, 2002b) if data were combined for a future analysis for the CEC.

In conclusion, the study designs and selection of samplers were dependent on available resources, travel and schedule logistics, and a specific objective of this dissertation to create sampling methodologies which did not invade, intrude or disrupt public elementary school students and teachers.

2.2.3 UCLA PCS and LBNL studies: Qualitative Assessments

Table 2.2.3.1 gives the contents of pages 1-3 and 5 of the "Technician Walk-Through" survey (Appendix A.2.3.2). Page four was a blank piece of graph paper used to sketch the classroom interior. Potential indoor pollutant sources were recorded, e.g., rugs or carpets, trash, cleaning agents. The location of lighting fixtures, HVAC system components, the thermostat, and doors and windows were drawn (see Figure 2.2.3.1 for example). Measurements of classroom dimensions were taken to calculate interior volume. Table 2.2.3.2 summarizes the contents of the three page "Operations and Maintenance (O&M)" questionnaire (Appendix A.2.3.3) conducted by the technician with the school's head custodian or plant manager. This questionnaire assessed HVAC system function, operation parameters and maintenance, the ages of the main buildings and portables, and the level of staff training. There was also a qualitative IEQ "Classroom Checklist" (see Appendix A.2.3.1) completed by the technician at each visit to the study classrooms. The parameters assessed included thermostat readings, lighting, windows, HVAC system functioning, doors, the technician's perception of odors, and observations of evidence of moisture incursion-induced water damage and mold growth.

Survey and checklist data were also collected during an epidemiological study of respiratory health of third-to-fifth graders and traffic density and emissions, the East Bay Children's Respiratory Health Study (OEHHA study). This project was conducted with the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (CalEPA/OEHHA) between December 2000 and June 2001. Ten schools participated, six in Hayward USD, three in San Leandro USD, and one in Oakland USD; 65 classrooms were included.

Table 2.2.3.1: Summary of the contents of the "Technician Walk-Through" survey, by category and parameters assessed.

Category	Parameter
Identifying information	Name and title of interviewer and interviewee Name of school, address and contact information Dates of sampling Room number; in main building or portable classroom Name of teacher, grade level and subjects instructed
Physical characteristics of the classroom	Number of rooms within the (portable) classroom Number of partitions in the classroom; were partitions permanent walls or temporary (retractable, sliding) Number of student desks or tables Was the portable classroom raised above ground-level; if so, by approximately how many feet (technician noted if concrete steps or metal ramp led up to doorway) Kind of surface, i.e., foundation, classroom was sited upon Approximate volume, based on technician measurements in inches, of length, height and width
Physical characteristics of the environment surrounding the school campus	Stationary sources of toxic air contaminants within 50 yards and/or 0.5 km, e.g., dry cleaners, gas station, industrial facility, other (specified) Approximate horizontal distance, in yards or miles, to nearest major thoroughfare (freeway, primary road); shipping facility, i.e., truck loading and unloading area; bus depot; train depot; other (specify) Approximate horizontal distance, in feet, to other portable classrooms; main building classrooms; fields, including asphalt playgrounds; parking lots; loading and unloading area for trucks; boarding area for school buses; nothing Location and general type of vegetation inside and immediately outside the classroom (potential sources of biogenic hydrocarbon emissions)
Weekly activities of teacher and students	Hours in a typical school day Average length of time spent in, and location of, the following scheduled activities outside the classroom: lunch; recess; classes for other subjects; school assemblies

Figure 2.2.3.1: Typical classroom sketch drawn on page four of the UCLA PCS "Technician Walk-Through" survey.

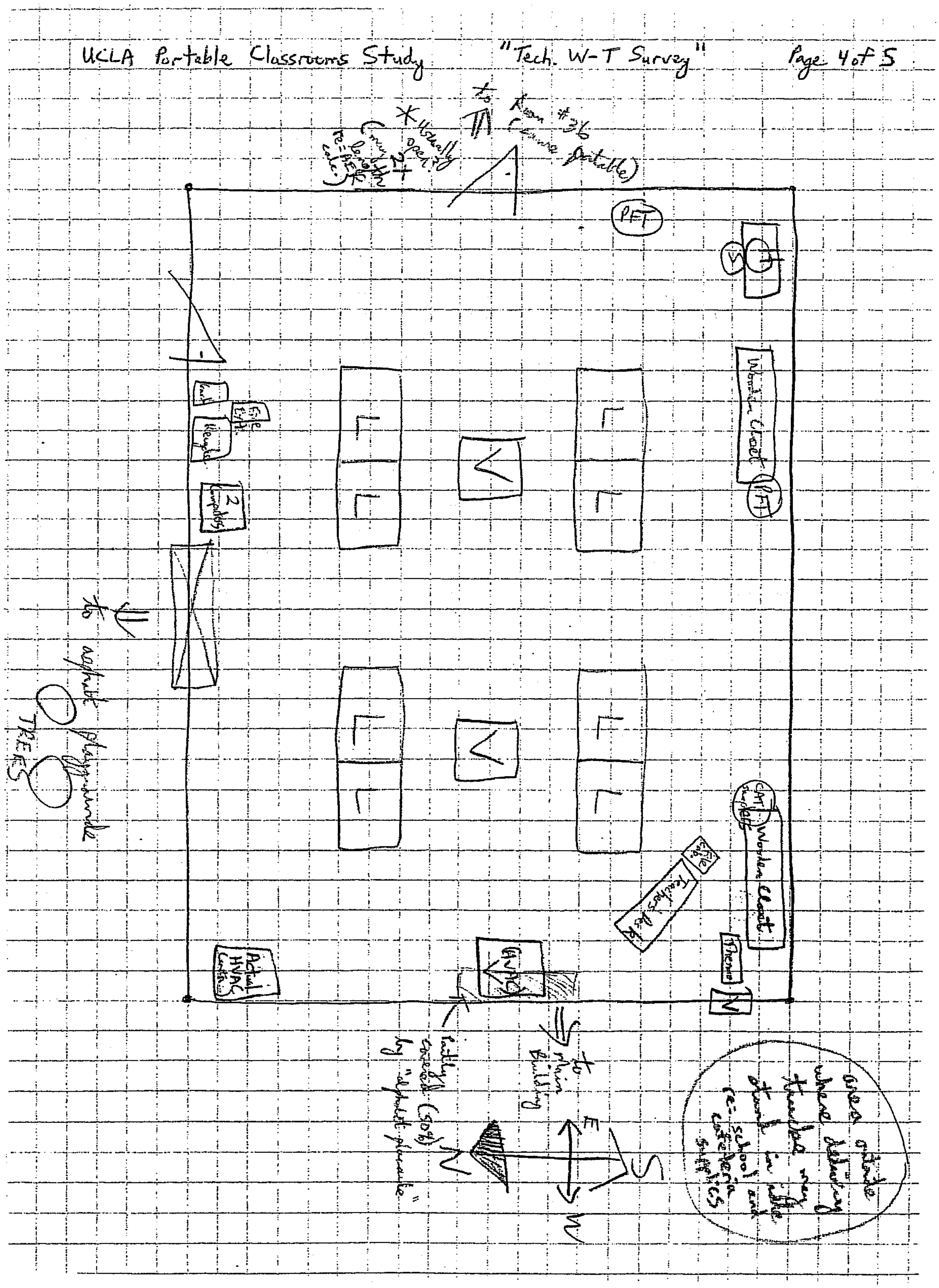


Table 2.2.3.2: Summary of the contents of the "Operations and Maintenance" questionnaire, by category and parameters assessed.

Category	Parameter
Identifying information	Name and title of interviewer and interviewee Name of school, address and contact information
School maintenance staff	Name and title of supervisor Size of staff, full-time and part-time
Classrooms included in study	Room number; age of portable classrooms, main building Date of last major renovation
HVAC system	Age, i.e., time of installation Time of day HVAC system turned on and off (auto setting) Is the current filter the original? When was filter last changed? Frequency of changing filters, and by whom The average (outdoor) air intake rate
Thermal comfort, related to HVAC	Indoor temperature when heat is turned on, and turned off Month when school teachers begin using heat Month when school teachers stop using heat Indoor temperature when air conditioning is turned on, and turned off (if classroom has air conditioner) Month when school teachers begin using air conditioning Month when school teachers stop using air conditioning Location of temperature control unit for each classroom
Staff training regarding HVAC and cleaning portable classrooms	Occurrence, timing, and frequency of staff training Existence of standardized written protocol or manual for operation and maintenance of HVAC units for the portable classrooms, including the replacement of filters Existence of a maintenance log for each portable classroom and main building classroom

2.3 Methodology to Conduct Monitoring of Classrooms and School Environment

2.3.1 UCLA PCS

The sampling period for quantitative measurements during the first seasonal sampling periods was one school week, Monday morning through Friday afternoon. Only T and RH data were available for individual school day time periods, approximately 8:00 to 14:00, because analyses of the other samplers resulted in integrated pollutant concentration averages or air exchange rates over defined intervals. Factors which influenced study design and sampler selection included available resources; travel and schedule logistics; known attributes and capabilities of samplers based on occupational and community residential studies; and, a specific objective to create sampling methodologies which did not invade, intrude or disrupt school for students and teachers.

Three visits were required to carry out the monitoring protocol. The first visit, on a Thursday or Friday before the sampling, occurred after school. The following tasks were accomplished. A "Technician Walk-Through" survey assessed characteristics of the portable classroom and the surrounding environment, as well as basic activities of the teacher and students. A suitable location for siting the passive samplers was determined. Two PFTs were deployed, so the PMCH achieved equilibrium before the CAT was deployed on the second visit. The PFTs were attached with clear tape to shelves and other locations out of the reach of children and where teachers could not damage them. Meeting times with custodial staff for the questionnaire and entry into the classrooms were reconfirmed.

The second visit was on the Monday morning of the sampling week. Samplers and instruments (refer to Table 2.2.1.1.1) were set up together in a location on top of a shelf or cabinet, out of a child's reach and where teachers could not damage or cover them while organizing their materials and supplies. The "O&M" questionnaire was then conducted with the head custodian or plant manager.

The final visit was on Friday afternoon of the sampling week after school. Instruments were removed and passive samplers were capped; upon return to UCLA, samples were processed and field data were downloaded. If necessary, the "O&M" questionnaire was completed before leaving the participating school. The school principal was told his or her staff would receive a summary of the results, similar to the report provided to the SD.

In summary, the three visits occurred before or after the official school day, and monitoring was conducted without batteries or pump-operated equipment, to minimize disturbance of disturbing the learning process and/or authority of the teacher. Furthermore, teachers and students were unaware of the passive samplers, which safely remained out of sight and reach of the classroom inhabitants. Comparison of data from different seasons was designed to allow investigation of the potential influences of meteorology, activity patterns, and teacher use of the HVAC system on differences in measured AER and exposure in portables. A strength of the approach was it involved neither personal sampling with young children nor disruptions of students or teachers during the normal school day, yet assessed potential exposure given the majority of time was spent indoors in one classroom. Limitations of the protocol included no biological sampling and no particle concentration measurements. Particle measurements would have involved air pumps and samplers, which could be disruptive.

One purpose of the UCLA PCS first seasonal sampling was to learn which target compounds could be quantified above MDLs, and which compounds could not be detected, with the passive samplers exposed for an entire school week (SWIA), approximately 6200 minutes. The second seasonal sampling had an improved study design (see Appendix A.3.2.1). Samples were collected for different time periods during a typical five-day school week provide a measure of time resolution in concentration measurements versus the weeklong integrated samples (SWIA). The periods of interest were the school day for students and/or teachers, approximately eight hours, averaged over a school week (SDIA), and the unoccupied late afternoon and overnight periods when the HVAC system was likely not operated, approximately 16 hours, averaged over the week (OUPIA). Potential differences in measured concentrations due to changes in meteorology and thus cooling versus heating demand could be explored. K-3rd grade levels, i.e., participating elementary schools, due to class size reduction policies and a need to maximize limited financial resources, were focused upon.

School day average (SDA) "grab samples" were collected to explore differences between concentrations of target aldehydes on a Monday and a Wednesday and/or Friday due to a potential "weekend off-gassing build up" effect. Over the weekend, the HVAC systems were off and doors and windows closed and locked.

In LAUSD (SD 2 or B), only elementary schools were included in the second seasonal sampling in winter 2001. The portables and multipurpose rooms of the participating senior high school were used day and evening, five days a week, due to scholastic sports and activities as well as a night time adult education program.

In BPUSD (SD 1 or A), no winter sampling was conducted. Instead, there was a second late spring cooling season sampling in June 2001, again during the first week of the month. The sample size for main building control classrooms in this SD would have been small, precluding a statistical comparison with portables, if the data set was stratified by season. Data from SD A could not be used to understand the relationship between the integrated weekly sample (SWIA) and the school day integrated sample (SDIA) in SD B, due to differences in microclimates, topography, and local outdoor sources. Therefore, doubling the number of cooling season SWIA samples in SD A to ten observations for portables and six observations for main building control classrooms improved statistical analyses. Since climate conditions were similar, these data were used to interpolate late afternoon/overnight periods of neither occupancy nor HVAC system operation from integrated weekly averages of the entire data set. As a result, statistics and an improved understanding of concentrations during different time periods within a school week were possible.

The first visit of the second sampling design was similar to the first sampling design, except the "Technician Walk-Through" survey was not conducted. The same teacher and students occupied a classroom the entire school year. The second visit and third visit were also similar except for two aspects. The "O&M" questionnaire was not administered again. The assumption was the behaviors and practices of custodians and SD O&M staff did not change significantly during a school year. The main difference between the first sampling and the second sampling was the second visit methodology was repeated every day of the week, morning and afternoon, with a set of passive samplers uncapped and then capped again, respectively, yielding both the SWIA samples and, from the cap-uncap experiments, the SDIA samples.

To maintain provision for 10% duplicates and 10% field blanks as part of the quality assurance/quality control program for the laboratory analyses, one duplicate was obtained for each sample type in each SD each season (AER, VOCs, DNSH for aldehydes). In addition, one duplicate for SDA samples (DNSH PAKS for aldehydes only) each weekday conducted was collected. Based on the overall sample size, an additional 10%, or three samples, for each of AER, VOCs, and DNSH PAKS were made field blanks in each sampling season.

2.3.2 LBNL RCS

In each eight or sampling period during the fall 2001 cooling and winter 2002 heating seasons, respectively, the two installed HVAC systems—the conventional technology and the advanced IDEC technology— alternated being on or off every 1-2 weeks. Aldehyde samples were collected once each week, for an integrated concentration over school day hours, inside and outside the RCs. The sampling period was 7:50-15:00 at the northern Central Valley SD (MCS, SD 4), and 8:15-15:35 at the inland San Jose metropolitan area SD (CUSD, SD 3). The samplers were again out of reach and sight of children, and separated from and out of the way of a teacher's storage and organization. Outdoor samplers were protected from sun and rain by aluminum foil cones; the roof overhangs of the RCs provided some additional protection. Samplers were approximately seven feet above the floor and about 0.5 m away from any wall indoors (Figure 2.3.2.1), and about 0.5-0.75 m away from the back wall and 1.5 meters above the ground outdoors (Figure 2.3.2.2, Appendix A.2.9.2 a-b).

The sampling involved programming the system to go on and off automatically one designated day each week; lunch and/or outdoor recess periods of no classroom occupancy could not excluded. Timer programs were entered at the end of a sampling day for the following week and verified the morning of the next visit. Pump flow rate calibration, using a BIOS International Dry Cal DC Lite-1 flow meter with a low-flow cell, was performed within 30 minutes after the start and before the end of each sampling period; the average of ten flow readings, and measured T, were recorded.

DNPH cartridges were placed and retrieved outside school hours, before and after the students and/or teacher arrived. This protocol was non-intrusive and non-disruptive. These samples were transported to the field in individual sealed packages in a plastic bag in a cooler, and after sampling returned to LBNL in individual foil envelopes, sealed with tape, in a plastic bag in a cooler. New and finished samples until extraction and analysis were stored in boxes and aluminum cans containing activated carbon pellets, respectively, in a freezer.

Figure 2.3.2.1 LBNL indoor cabinet (Sierra Cabinets, CA) with sampling ports.

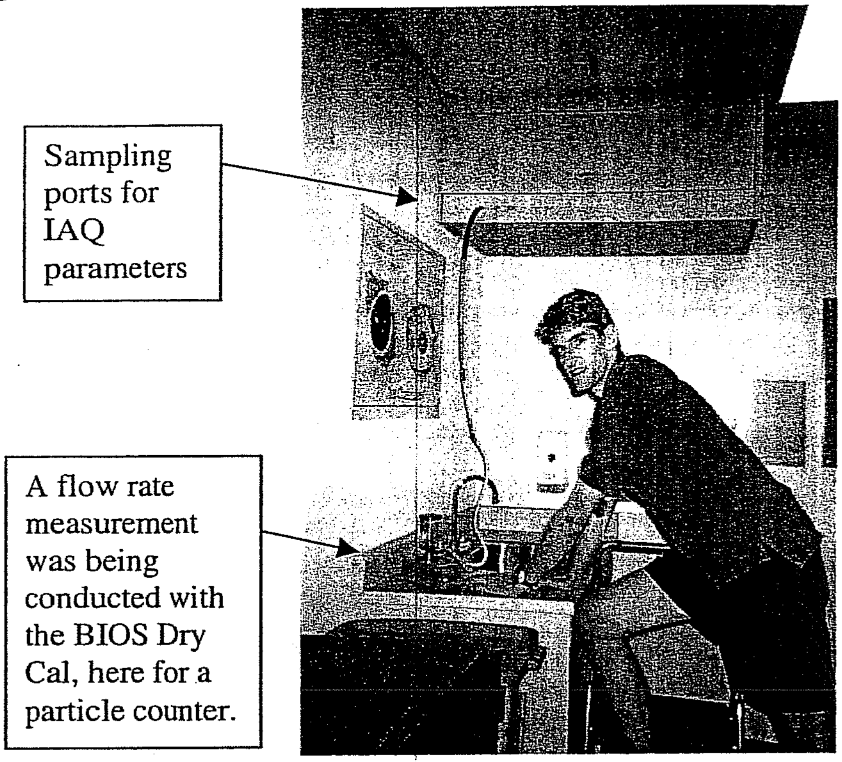
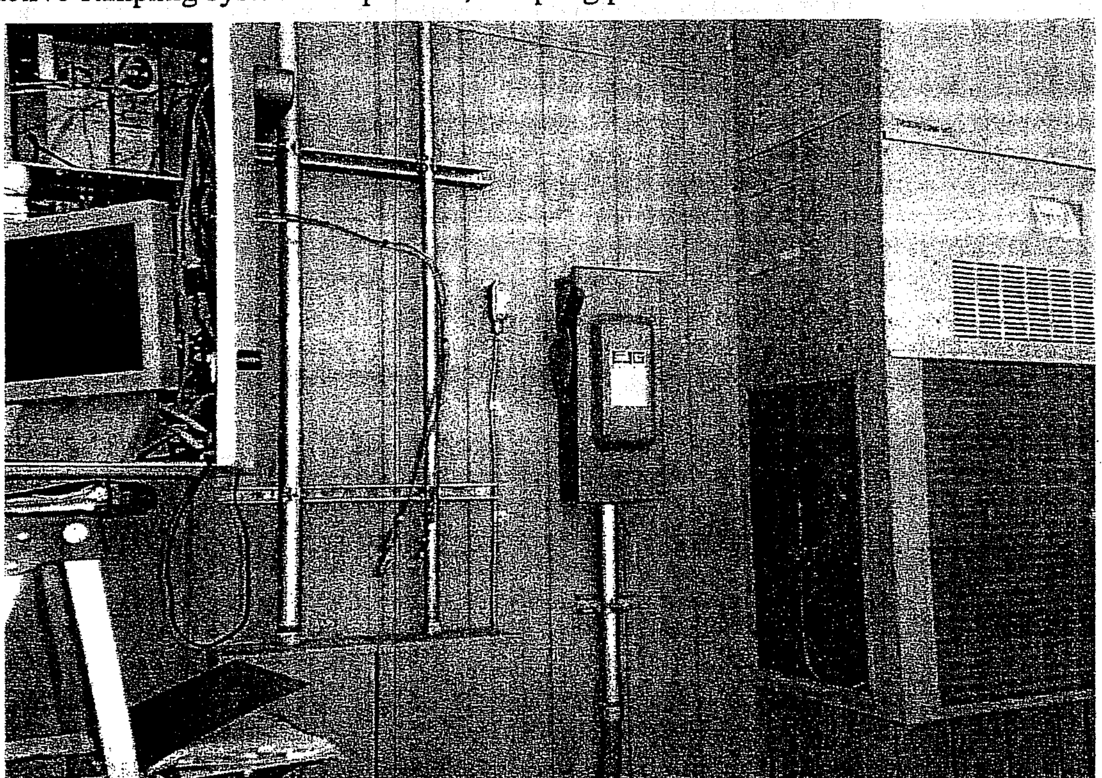


Figure 2.3.2.2 LBNL modified outdoor waterproof steel enclosures (Hoffman, Inc.) for active sampling system components; sampling ports out of the side.



2.4 Laboratory Chemical Analyses of Air Samples: Background, Precision, Accuracy, Sources of and Accounting for Error and Uncertainty

2.4.1 UCLA PCS

2.4.1.1 Overview, and Sample Handling, Storage, and Shipment

DNSH PAKS, VOC, and CAT samples were transported to and from the schools in cooler packs, and otherwise in a refrigerator at UCLA or in Berkeley or Walnut Creek, before and after use in the study until shipment for analysis. The CATs did not necessarily need to be kept cool, but this method maintained organization and separated the CATs from PFTs with multiple physical barriers beyond the required activated carbon paper. PFTs were transported in a plastic sealed bag with a piece of activated carbon paper; the bag was kept in the technician's tool kit.

Validated, precise, and sensitive chemical analyses were conducted by the same academic institutions UCLA collaborated with on another human exposure study. The three universities were the University of Texas-Houston School of Public Health for VOCs, EOHSI for aldehydes, and HSPH for AER. They were compensated for their services and reported back results within 2-4 months of receiving the samples.

Each site used Microsoft Excel for data management and calculations. For quality control and quality assurance, duplicate samples and field blank samples were collected and analyzed; 10% or more of the total UCLA PCS sample size was used for determining the number of replicate samples and the number of field blanks. Each collaborating laboratory used laboratory blanks and spiked samples.

2.4.1.2 VOCs

Previous studies by the University of Texas-Houston collaborators (Chung, C-W. et al, 1996a; Chung, C-W. et al, 1996b) provided detailed evaluation of the use of the 3M 3500 OVM samplers for community exposure assessment over short time periods and the accompanying analyses. In this study, samplers were shipped in cooler packs to Houston, then cans were opened and the badge dosimeters disassembled according to 3M instructions. The analysis process used was extraction followed by GC/MS, which was also implemented for samples from other exposure assessment studies (Morandi and Stock, 1998; Weisel et al, 1998; Chung et al, 1999a-b; Weisel et al, 2002). The single charcoal pad was extracted using high resolution gas chromatography grade acetone:carbon disulfide 2:1 solvent. Working standards were prepared from a 2000 μg/ml solution of the nineteen target compounds (Accustandard, Inc., New Haven, CT); one set of standards and two laboratory blanks were analyzed with each shipment of samples, duplicate samples, and field blanks. Method detection limits (MDLs) for target VOC compounds detected, and those not detected, in blank sample extracts were estimated as described by Chung et al (1999a-b).

VOCs data were returned as concentrations-- micrograms per cubic meter ($\mu g\ m^{-3}$) and in parts-per-billion (ppb) —with sample identification numbers and the method detection limits of the nineteen target compounds for each batch of samples analyzed.

The OVM extraction efficiency, specific to each target compound, was the fraction of mass of a given compound applied to an OVM, i.e, sampled or spiked with known quantity, which was then measured with solvent extraction (Chung et al., 1999b). The extraction protocol involved working analytic standards in the range of 0.1-10 $\mu g\ ml^{-1}$, an internal standard solution, and standard operating procedures (3M, 1991; 3M, 1993). Extraction coefficients, e.g., 100% extraction efficiency = 1.00, were calculated at laboratory room T from the slopes of linear regressions of the amount of mass extracted versus spiked mass loading. Method detection limits (MDLs) were calculated for each batch of samples analyzed using combined laboratory and field blanks. For example, in general, the MDL for toluene was high, approximately 10-11 $\mu g/m^3$, due to relatively high and variable background levels (Chung et al, 1996b).

There were no guidelines for acceptable accuracy of passive air samplers used in non-occupational environments; experimentally determined percent recoveries for individual target VOCs (100*(measured concentration/delivered concentration)) can be used to estimate negative or positive biases, i.e., underestimation or overestimation of true air concentrations, respectively. Table 2.4.1.2.1 lists mean percent recoveries determined in the dynamic environmental chamber evaluation studies of Chung et al (1999a-b) at delivered concentrations. The selected conditions of T and RH approximated values observed in the cooling and heating seasons in the UCLA PCS. The authors, who collaborated on this study, reported mean recovery rates could be used for estimating measurement biases when using 3M OVM 3500 or 3520 badges for indoor air monitoring of VOCs in community environments, e.g., homes, schools. Data reported back from University of Texas-Houston were corrected.

Table 2.4.1.2.1: Mean percent recovery rates (with 95% CI) of selected target compounds, determined empirically in lab environmental chamber at 10°C (50°F) or 25°C (77°F) and 50% RH, for use in estimating error in field concentration measurements with OVM 3500 badges (Chung, C-W et al, 1999a-b)

Environmental Condition (T, RH, concentration delivered to environmental chamber)	10°C (50°F), 50%, 10 μg/m^3	25°C (77°F), 50%, 10 μg/m^3	10°C (50°F), 50%, 20 μg/m^3	25°C (77°F), 50%, 20 μg/m^3
volatile organic compound				
benzene	95 (+/- 5)	62 (+/- 4)	96 (+/- 4)	92 (+/- 5)
1, 3-butadiene	74 (+/- 11)	67 (+/- 5)	93 (+/- 5)	61 (+/- 6)
carbon tetrachloride	92 (+/- 5)	62 (+/- 2)	90 (+/- 4)	90 (+/- 4)
chloroform	92 (+/- 6)	42 (+/- 2)	84 (+/- 3)	101 (+/- 5)
1, 4 (p)-dichlorobenzene	100 (+/- 7)	63 (+/- 3)	77 (+/- 7)	85 (+/- 4)
methylene chloride	80 (+/- 14)	79 (+/- 10)	98 (+/- 5)	112 (+/- 4)
styrene	69 (+/- 4)	47 (+/- 3)	83 (+/- 6)	56 (+/- 5)
tetrachloroethylene	94(+/- 4)	60 (+/- 2)	91 (+/- 4)	82 (+/- 4)
toluene	77 (+/- 13)	45 (+/- 9)	79 (+/- 3)	75 (+/- 4)

2.4.1.3 Aldehydes

DNSH PAKS were shipped from California to New Jersey in cooler packs. At the time of analysis, samples were removed from a refrigerator and allowed to equilibrate to room T. Cartridges were then eluted with a solvent, acetonitrile, and target compounds were identified and quantified using HPLC with fluorescence detection. This analysis provided lower detection limits than the ultraviolet (UV) detector associated with DNPH chemistry-based samplers (Zhang and Zhang, 2000). EOHSI researchers published the methodology (Zhang et al, 2000), including the diffusive sampling rate determination (7.5 cm^3 min^{-1}) and recovery tests in environmental chambers for eight aldehydes. There was also no effect of ozone up to 300 ppb, and derivatives were stable on the DNSH PAKS (Zhang and Zhang, 2000; Zhang et al, 2000).

Aldehyde data were returned as concentrations in $\mu g\ m^{-3}$ with sample identification numbers and the method detection limits, which for HCHO and CH_3CHO were 0.01 and 0.02, respectively, for sampling period times employed in this study.

Sample extracts, the carbonyl-DNSH derivatives dissolved in acetonitrile, were injected onto the column and analyzed by HPLC with fluorescence detection, with advantages as previously discussed. The HPLC column was a C_{18} reverse phase column (Nova-Pak C_{18} column, Waters Corporation, Milford, MA, 3.9 mm. X 150 mm.), operated at a flow rate of 1.0 ml min^{-1}. The fluorescence detector was set at an excitation wavelength of 240 nm, and an emission wavelength of 470 nm.

The calibration of the HPLC and method of analysis were comprehensive and clearly outlined step-by-step in the standard operating procedures (Zhang et al, 1999).

Calibration standards from low to high-expected concentrations were loaded and injected. Injections were repeated for each standard until consecutive responses agreed within 5% before each set of samples was analyzed. The procedure served as the initial calibration of the HPLC. At the start of each day of use, the mid-level initial calibration standard was loaded and injected again; the response factor from this daily analysis had to agree within 10% of the response factor from the initial calibration or the entire initial calibration was repeated before sample analysis. During analysis of samples, if the sample response was below or above the lowest or highest prepared calibration standard, respectively, at least two additional standards bracketing the response of the sample, e.g., +/- 20%, were prepared. Analysis of a reagent blank, a sample extract from a fresh DNSH-coated LC-C_{18} cartridge, must have demonstrated no interference, i.e., contamination, from the analytic system, glassware, and reagents before analysis of a batch of samples. Acetonitrile blanks, located at the start of a batch of samples and after each 10^{th} sample, field blanks and duplicate samples, and spiked control samples numbering 5% of the overall sample size were analyzed with a batch of samples. Spiked sample recoveries of 80% +/- 10% were expected. Actual retention times of the target compounds were quantified using the standards with each batch of samples. Approximate retention times for HCHO and CH_3CHO were 11 and 12 minutes, respectively.

Multiple steps ensured the highest possible accuracy and precision of both the analysis and concentration calculations (Zhang et al, 1999). A response factor was calculated for each target compound. To calculate the concentration of the target compound in the sample, the percent relative standard deviation of the mean response factor of replicate injections was confirmed to be less than 10%; corrective actions were taken and analyses repeated to achieve the criteria. Calibration curves constructed for each target compound produced the concentration of the target compound in the sample extract, C_{ex}, in $\mu g\ ml^{-1}$. C_{ex} entered an equation to calculate the concentration of the target compound in the air sampled, C_{air}:

$$C_{air} = ((C_{ex})*(\text{extraction volume, ml})*(1x10^{6}\ ml\ m^{-3})) / ((\text{sampling rate for target compound, ml min}^{-1})*(\text{exposure time, min}))$$

The DNSH PAKS sampling rates were empirically determined in controlled studies in dynamic environmental chambers (Zhang et al, 1999; Zhang et al, 2000) to be 7.21 ml min^{-1} for HCHO and 5.46 ml min^{-1} for CH_3CHO over ranges of T, RH, face velocity, exposure time, and aldehyde concentrations.

2.4.1.4 AER

PFTs, for calibration after 3-4 months of use, and batches of CAT samples, were mailed separately to HSPH, each with pieces of activated carbon paper in a plastic sealed bag inside a cardboard box. Data from the CAT and PFTs were sent as the amount of the tracer gas on the CAT in picoliters (pl) and the tracer gas emission or permeation rate in ng mL^{-1}, respectively. HSPH developed a draft protocol for calculating AER (Weker, 1999); UCLA provided comments and edits incorporated into the revised protocol. The formulas included these variables and the measured volume of the classroom, the experimentally determined CAT collection rate of 0.008308 L hr^{-1} per end of the tube opened, and the mean indoor air T during the sampling period. In the UCLA PCS, both ends of the CAT were opened.

There were two parts to the HSPH laboratory analysis (Weker, 1999). First, the PMCH was thermally desorbed in an inert nitrogen gas atmosphere. Second, identification and quantification of the tracer gas were completed using gas chromatography with electron capture detector. AER was inversely proportional to the pL of PMCH on the CAT. The ability to detect PFTs was demonstrated to range six order of magnitude from 0.01 pL to 10,000 pL (Dietz and Cote, 1982). These data provided support to the monitoring design of the UCLA PCS, which included CAT samples for time periods ranging from multiple school days to an entire school week. AER was quantifiable over the range 0.9 pL, the limit of detection (LOD) defined as three times the standard deviation of the smallest standard, to 200 pL of PMCH. This corresponded to 0.10 hr^{-1} to about 3.0 hr^{-1}, though the increased source strength used in the UCLA PCS should allow valid detection of higher AER, e.g., 5.0-6.0 hr^{-1}.

In both well-defined environmental chamber (Leaderer et al, 1985) and laboratory and/or home infiltration studies (Dietz and Cote, 1982; Wilson et al, 1986, 1996), CATs displayed predictable performance, precision, and accurately sampled concentrations as low as 1 pl L^{-1}. Leaderer et al (1985) calculated an empirical relative standard deviation for multiple paired CATs, i.e., sample and duplicate, of +/-1.9 +/-1.0%, which indicated sufficient precision in the manufacture, handling, and analysis of CATs. They also found sampler orientation had no significant effect on sampling rate for air velocities, away from forced air vents, less than 0.2 m s^{-1}; positive bias was less than 2-3%. The complete method, with the less precise plug type diffusion sources instead of the permeation type sources now used, showed identical results within experimental precision of about +/-

15% when compared to the SF_6 tracer decay approach (Dietz and Cote, 1982). More relevant to this study, with permeation type sources based on liquid PMCH, Wilson et al (1986, 1996) showed analytic precision for calculated AER in studies of Los Angeles area homes conducted eight years apart but compared over similar T ranges, even though the first study involved seven-day averages in three seasons but only wintertime two-day averages in the second study.

2.4.2 LBNL RCS: Laboratory Chemical Analyses for Aldehydes

Boxes of 20 DNPH cartridges per lot were stored in a refrigerator at LBNL, each in individual sealed packages, then in a cooler during transport to and from the field, and then in a refrigerator until extraction and analysis. Cartridges were allowed to come to room T over approximately 30 minutes. Cartridges were eluted with a solvent, acetonitrile, and extracts containing reaction derivatives representative of HCHO and CH_3CHO were identified and quantified with HPLC following the USEPA TO-11 method of analysis (Winberry et al, 1990; SKC Inc., 1996). This method combined HPLC with a UV detector for identification and quantification of target compounds. Multi-point, internal standard calibrations were prepared using pure target compounds (Hodgson et al, 2000). Field blanks, numbering 10% of the overall sample size each season, were handled in the exact same manner as samples except no air was actively drawn through them; passive sampling, of at most seconds in duration, was negligible. The flow rate of the pump, potentially affected by T, should not change by more than 5-10% over the sampling period (SKC Inc., 1996); the previously described BIOS calibration system used in this study had an accuracy of +/- 1% (SKC Inc., 2001). The relative precision of this sampling and analytic method conducted by LBNL scientists, as measured by a coefficient of variation, was determined to be about +/- 10% (Hodgson 1999; Hodgson et al, 2000).

Quality control and quality assurance included field data sheets, sample identification labels, data management files in Microsoft Excel, and the collection and analysis of replicate samples, blank samples, and spiked internal standard samples. Exact numbers, similar to the UCLA PCS, were established. They were 10% field blanks, 10% duplicate samples, one analytic duplicate and one internal standard (10 μl injection from a 1/40 dilution, 25 μl in 1 ml acetonitrile, about 9.6 ng HCHO and 9.9 ng CH_3CHO) per batch of prepared samples. Pump performance, analytic precision, and overall precision with field duplicates will be discussed in the results section.

2.5 Data Management and Analyses

For data management and statistical analyses, the Microsoft Office Professional 97 software package and SAS (Cary, NC) statistical software, versions 6.12 and 8, for Windows 98 were used.

Several statistical analyses and relative comparisons were conducted. Descriptive statistics for the concentrations of measured compounds and AER were calculated, including mean; median; standard deviation; maximum; minimum. Seasonal variation was assessed for measured variables. The relationship of the calculated AER with the ASHRAE standard 62 (1999) for the amount of outdoor fresh air intake per person, equal to or greater than 15 ft^3 min^{-1}, was evaluated for both main building and portable classrooms. Correlation coefficients between AER, T and RH and pollutant concentrations were computed, including stratification by room type to compare portables to main building classrooms. Multiple linear regression models were constructed for relevant primary hypotheses and secondary analyses previously described and then assessed and summarized. T-tests of means were computed for LBNL RCS data, with stratification by SD, season, and RC, i.e., standard RC construction practice versus inclusion of some alternative, advanced interior finish materials. Aldehyde data were compared and contrasted by region of California, by type of HVAC system, and/or by interior finish materials. Among portables, the age, i.e., the year constructed and initially sited on the school campus, may also be evaluated across sites.

Results were compared with the state indoor air quality guideline developed for HCHO (CARB, 1991), acute and chronic non-cancer reference exposure levels (RELs) developed by CalEPA/OEHHA (2000, 2001a), and human odor thresholds (Devos et al, 1990).

Descriptive statistics were prepared for results of the three qualitative field data instruments: "Classroom Checklist;" "Technician Walk-through Survey;" and, the "O&M" questionnaire conducted by interview with the head custodian or plant manager. A comparison of mean school-day morning and afternoon T data with "O&M" questionnaire responses and "Classroom Checklist" technician observations was conducted. A qualitative evaluation of potential biological exposures in the classrooms studied, based on technician observations recorded on the "Classroom Checklist," may be included.

Due to the relatively small sample sizes of the pilot studies comprising this dissertation, a function of the limited resources available and the sensitivity of the topics across stakeholders, use of the data for extrapolation to larger populations, i.e., Los Angeles County or the State of California, will not occur. Also, data may not be allowed for use as inputs into models for related purposes. These are convenience samples; recruitment of SD administrators and school principals for these projects was time consuming, difficult, and frustrating. Nevertheless, SD 2 was the largest school district in the state and second largest in the country. Few data on the environment inside portables or schools in general existed. Therefore, the results of this dissertation had potential value to researchers, educators, school district administrators, manufacturers of classrooms, and government agencies. The University of Southern California also needed significant effort and persistence to recruit SD and enough schools for several thousand children in 12 communities for their large prospective study of children's respiratory health and ambient criteria pollutants and aerosols (Avol, 2000). The CalEPA/OEHHA Air Toxicology and Epidemiology Branch consulted UCLA on recruitment and liability issues for their study of children's respiratory health and traffic density and emissions (Kim, 2000; Lipsett, 2000). They struggled continuously with SD until late October 2000; difficulties recruiting schools persisted through the end of 2000. The study was realized spring 2001 through spring 2002.

2.6 Formulated Method to Report a Results Summary to Participant Schools

In a federal report on a long-term coordinated strategy to measure human exposure to toxic chemicals in the environment (USGAO, 2000), the importance of health officials and scientists understanding and communicating risks to concerned citizens given limited information for comparisons and interpretation of measured exposures was emphasized.

Participant schools in the UCLA PCS received one results summary at the end of the project. The communication instrument developed was a single table accompanied by a cover letter. Scientific language, including names of chemicals, not familiar to the general public was limited. To facilitate communication, results were not reported as numerical concentrations. Instead, efforts focused on ease of comprehension by study participants. In addition, a general conclusion and recommendation were provided.

Occupational standards for indoor working environments developed by the United States Occupational Safety and Health Administration and/or the National Institute of Occupational Safety and Health were determined to be not relevant to this dissertation. Airborne pollutant concentrations encountered in occupational environments would, in general, far exceed the highest expected residential and school classroom measurements. Federal regulations and state guidelines for selected outdoor and indoor air contaminants were appropriate and available, including the CARB guideline for indoor HCHO (CARB, 1991), acute and chronic non-cancer RELs (OEHHA, 2000, 2001a), and odor thresholds for human olfactory detection and possible nuisance (Devos et al, 1990). Table 2.6.3.1 presents a summary of this available information. Each target compound's chemical formula and molecular weight were included to provide readers with information required for rapid conversion of presented values to ppb using the formula, $\mu g\ m^{-3}$ = (ppb)*(0.0405)*(molecular weight).

A qualitative classification scheme—low, medium, and high—to report quantitative indoor air concentration results was developed. Schools, if interested, could request further detailed explanations and implications of the results for their classrooms. The plan was if a classroom measured "high" for any compound, then more detailed information and guidance could be provided to the principals, teachers, and school staff upon request.

The variety of indoor sources and lack of outdoor monitoring in the UCLA PCS limited generalization to the entire school, implications of which will be described in chapter three, section five. The interpretation of the reporting classifications was unique for each group of pollutant compounds since regulations, guidelines, and odor thresholds, if they existed, varied.

2.6.1 Reporting Formaldehyde (HCHO) and Acetaldehyde (CH_3CHO) concentrations

The proposed protocol and classifications for reporting HCHO concentrations ($\mu g\ m^3$ unless specified) were based on the CARB indoor air guidelines (1991): "action level" of 0.10 ppm, or 122.8, and a "target level" of 0.05 ppm, or 61.4. The focus was on the "target level" after discussions with CARB staff (Jenkins, 2000), since a new proposed guideline may be more stringent. The proposed classifications were: low, less than 20; medium, between 20 and 60; and high, greater than 60. CalEPA/OEHHA established a chronic non-cancer REL of 2 ppb, or 3 $\mu g\ m^{-3}$, for respiratory system and eye effects though it was based on ambient air concentrations (OEHHA, 2001a). The established acute REL for eye irritation was 94 $\mu g\ m^{-3}$ over one hour and 33 $\mu g\ m^{-3}$ over eight hours (OEHHA, 2000), and thus higher than expected or observed for most UCLA PCS samples.

The proposed protocol and classifications for reporting CH_3CHO concentrations ($\mu g\ m^{-3}$) were based on the CalEPA/OEHHA (2001a) non-cancer chronic REL of 9 $\mu g\ m^{-3}$. The proposed classifications were: low, less than 4; medium, between 4 and 9; and high, above 9.

2.6.2 Reporting air exchange rates (AER)

An interpretation of the measured AER in terms of the ASHRAE 62 (1999) standard was reported. This was done by a conversion of units and comparison to the standard, at least 15 $ft^3\ min^{-1}$ per person, adult teacher or child. For class size reduction requirements, approximately 315 $ft^3\ min^{-1}$ outdoor air for 20 students and one teacher must be brought into the room. The method for making the comparison was demonstrated by the quantitative relationships below.

The class size reduction policy's ratio provided a conservative estimate for the number of room occupants, i.e., determined the maximum quantity of fresh outside air to be supplied by mechanical means to the classroom on average. By chance alone, one or more students may be absent for a day or portion of school hours; the portable may even be used by a smaller or larger class on occasion. An assumption was the HVAC system operated throughout the school day, approximately 7.5 hours long including time the teacher worked alone. Though fresh outdoor air represented only about 25-30% of the total air delivered to the interior by the design of the standard portable classroom HVAC system (Tiernan, 2000; Geary Pacific/Bard, internet, 2001), the mechanical intake of outside air drove the ventilation rate and mixing and exhausted an equivalent amount of room air (Apte, 2000). Portables were single room, self-contained environments, which could be divided into two teaching areas. The remaining 70-75% of air delivered by volume was recycled, filtered room air.

AER = X = # changes, hr^{-1}, for a classroom of volume V, in ft^3
NOTE: used calculated AER from SDIA CAT samples
(X) (V) / hr ≅ ((15 ft^3) / min-person)*(21 persons)
(X) (V) / hr ≅ ((315 ft^3) / min)*(60 minutes / one hr)
Then, (X) (V) / hr ≅ (18900 ft^3 / hr)?

X was calculated from the formula (Weker, 1999):
X = (2, # of PFTs emitting tracer gas PMCH)
*(0.008308, CAT collection rate, in L hr^{-1}, per end open)
*(2, # of ends opened in UCLA PCS)
*(Average permeation rate of PFTs used, in ng min^{-1})
*(CAT sample time, in min)
*(1 ft^3 / 28.3 L)
(1000 pl/1 nl)(24.45 nl / nmole, molecular volume)*(1 nmole / 350 ng)
*(1 / (volume of PMCH on CAT, in pl))
*(1 / (technician measured volume of classroom, in ft^3))

Classroom volume was calculated from the width, length and wall height measurements of the classroom interior, in inches, conducted by the field technician. Accuracy and precision of the measurements (e.g., 90 inches = 8.5 feet) resulted in calculations of classroom volume and AER to one decimal place.

2.6.3 Reporting Concentrations of Selected VOCs

There were no specific regulations or guidelines on concentrations of these toxic air contaminants under the Title 3 of the Federal Clean Air Act Amendments or California AB1807 at the time of this study. Results for benzene, 1,3-butadiene, and

MTBE, however, could be reported to participants because these carcinogenic and/or toxic chemicals were frequently cited in recent reports on air and drinking water quality (e.g., SCAQMD, 2000). VOCs related to common classroom cleaning compounds, pinenes and d-limonene, were also included. VOCs not detected in individual classrooms above MDLs were not reported.

This dissertation considered new guidelines and regulations federal and state agencies developed. Furthermore, published human odor thresholds of target compounds were considered (Devos et al, 1990), since odors could be nuisances and were qualitatively assessed and recorded on the UCLA PCS "Classroom Checklist" each visit to the study classrooms. An odor threshold, or nasal pungency, represented the air concentration at which humans can detect the odor of an organic compound with the trigeminal nerve in nasal passages (Weschler, 2002). Table 2.6.3.1 presents a summary of available information regarding odor thresholds and exposures for target VOCs. Overall, measured VOC concentrations were below these guidelines and thresholds.

2.6.4 Additional information reported

Figure 2.6.4.1 was the final version of the "Summary of Results" reporting form. This one page form, accompanied by a letter (see Appendix A.1.5.5), covered aforementioned information and included both a general conclusion and a recommendation, which were applicable to classrooms across schools and SD.

Table 2.6.3.1: California ambient and indoor air quality guidelines, reference exposure levels, and human odor thresholds (Devos et. al, 1990) of target VOCs including aldehydes, UCLA PCS.

Compound	Chemical Formula	Molecular Weight	*CalEPA/OEHHA* non-cancer chronic REL[1] **ug m^{-3}**	Key Criteria Used as Basis	*CalEPA/OEHHA* acute REL[2] **ug m^{-3}**	assumed averging time of exposure **hr**	Key Criteria Used as Basis	*(Devos et. al, 1990)* standardized human olfactory threshold, where limit value of zero = odorless **ug m-3**
* formaldehyde	$HCHO$	30	3	human data	33, 94	8, 1	human data	1.1×10^3
acetaldehyde	CH_3CHO	44	9	animal data	n/a	n/a	n/a	338.8
benzene	C_6H_6	78	60	human data	1300	6	rat data	1.2×10^4
1,3-butadiene	C_4H_6	54	20	animal data	n/a	n/a	n/a	n/a
toluene	C_7H_8	92	300	animal data	37000	1	human data	5.9×10^3
xylenes (m-, o-, p-)	C_8H_{10}	106	700	human data	22000	1	human data	n/a
ethyl benzene	C_8H_{10}	106	2000	animal data	n/a	n/a	n/a	12.9
styrene	C_8H_8	104	900	human data	21000	1	human data	n/a
methyl *tert*-butyl ether, MTBE	C_5H12O	88	8000	animal data	n/a	n/a	n/a	n/a, but small amount in water creates distinct taste and odor
d-limonene	$C_{10}H_{16}$	136.2	n/a	n/a	n/a	n/a	n/a	2.4×10^3
a-pinene	$C_{10}H_{16}$	136.2	n/a	n/a	n/a	n/a	n/a	3.9×10^3
b-pinene	$C_{10}H_{16}$	136.2	n/a	n/a	n/a	n/a	n/a	n/a
** carbon tetrachloride	CCl_4	153.8	40	animal data	1900	7	rat data	n/a
** trichloromethane (chloroform)	$CHCl_3$	119.4	300	animal data	150	7	rat data	5.9×10^4
** dichloromethane (methylene chloride)	CH_2Cl_2	84.9	400	human data	14000	1	human data	1.0×10^5
** (per-) tetrachloroethylene	C_2Cl_4	165.8	35	human data	20000	1	human data	4.3×10^4
** (p-) 1,4-dichlorobenzene	$C_6H_4Cl_2$	146.9	800	animal data	n/a	n/a	n/a	295.1
** trichloroethylene	C_2Cl_3H	131.35	600	human data	n/a	n/a	n/a	n/a
chloroprene			n/a	n/a	n/a	n/a	n/a	n/a
naphthalene	$C_{10}H_8$	128	9	animal data	n/a	n/a	n/a	79.4

n/a = not available

1 = chronic reference exposure level; ambient air basis (http://www.oehha.org/air/chronic_rels/AllChrels.html)

2 = acute reference exposure level; ambient air basis (http://www.oehha.org/air/acute_rels/allAcRELs.html)

* CARB Indoor Air Guideline No. 1 (1991)-- target level 0.1 ppm or ~120 ug m^{-3}; action level, with CDHS, 0.05 ppm or ~60 ug m^{-3}.

** in CARB Indoor Air Guideline No. 3 (2001), but no quantitative values presented except concentrations observed in CA homes

Office of the Principal
_______________________ School
Address
City State Zip

SUMMARY OF RESULTS FOR PARTICIPATING PUBLIC SCHOOLS
UCLA Public School Portable Classrooms Study

Dates of School Visits and Sampling Events: __/__/____ , __/__-__/__/____ (FIRST)
__/__/____ , __/__-__/__/____ (SECOND)

Classroom #___ Classroom # ___ Classroom #___

Pollutant Category

	Low	Med	High	Low	Med	High	Low	Med	High
air exchange, or ventilation, **rate** (compared to ASHRAE guideline of 15 cubic feet per minute per person)		(complied with guideline)	(higher usually not a problem)		(complied with guideline)	(higher usually not a problem)		(complied with guideline)	(higher usually not a problem)
formaldehyde									
acetaldehyde									
volatile organic compounds, e.g.:									
benzene									
toluene									
MTBE									
d-limonene									
alpha-pinene and or beta-pinene									

The volatile organic compounds below analytic detection limits, i.e., **concentrations measured zero for both sampling events,** were: 1, 3-butadiene, chloroprene, naphthalene, trichloroethylene, and styrene.

General conclusion: These results suggest interior finish materials like carpets and furniture made of particleboard, cleaning compounds, and classroom construction supplies were likely indoor sources of measured compounds. Overall, however, measured concentrations were low.

Recommendation: These results indicate classrooms, in general, were characterized by low ventilation rates. Incoming outdoor air, especially when filtered by a mechanical HVAC system, can reduce measured pollutant concentrations including particle levels. Please encourage teachers and staff to use windows, doors, fans, and HVAC systems as possible.

CHAPTER 3.—RESULTS AND DISCUSSION

3.1 UCLA PCS

Table 3.1.1 references for the coding used to maintain confidentiality in tables and appendices reporting measured T and RH, and selected variables in other tables and appendices describing assessed IEQ parameters, for the UCLA PCS.

Table 3.1.1: Coding used to maintain confidentiality in tables reporting measured T and RH inside portable classrooms and main building control classrooms, UCLA PCS participants, June 2000-June 2001.

ACTUAL SD AND SCHOOL NAMES; NOTE: unless specified, school was K-6 elementary	ACTUAL ROOM No.	SD Code (A or B, 1 or 2)	School # (n= 1-7)	Main Building (M.B.) or Portable (P) Classroom	Classroom Code
Baldwin Park Unified SD (BPUSD), Sierra Vista Jr. H.S.	8	A or 1	1	M.B.	0
BPUSD, Sierra Vista Jr. H.S.	22	A or 1	1	P	1
BPUSD, Foster	11	A or 1	2	M.B.	0
BPUSD, Foster	30	A or 1	2	P	1
BPUSD, Pleasant View	24	A or 1	3	M.B.	0
BPUSD, Pleasant View	19	A or 1	3	P	1
BPUSD, Pleasant View	26	A or 1	3	P	2
BPUSD, Pleasant View	Library	A or 1	3	P	3/Library
Los Angeles Unified SD (LAUSD), Region C, Mar Vista	7	B or 2	1	M.B.	0
LAUSD, Region C, Mar Vista	27	B or 2	1	P	1
LAUSD, Region C, Mar Vista	35	B or 2	1	P	2
LAUSD, Region C, Richland	14	B or 2	2	M.B.	0
LAUSD, Region C, Richland	23	B or 2	2	P	1
LAUSD, Region C, Richland	26	B or 2	2	P	2
LAUSD, Region C, Walgrove	8	B or 2	3	M.B.	0
LAUSD, Region C, Walgrove	29	B or 2	3	P	1
LAUSD, Region C, Walgrove	38	B or 2	3	P	2
LAUSD, Region C, Venice Sr. H.S.	234	B or 2	4	M.B.	0
LAUSD, Region C, Venice Sr. H.S.	11	B or 2	4	P	1
LAUSD, Region C, Venice Sr. H.S.	18	B or 2	4	P	2

3.1.1 HCHO and CH_3CHO Concentrations

3.1.1.1 Field Blanks

Concentrations reported were corrected for the mean concentrations measured on laboratory and field blanks. For the first cooling season sampling in SD 1, the mean blank concentrations for HCHO and CH_3CHO were 1.44 $\mu g\ m^{-3}$ and 0.18 $\mu g\ m^{-3}$, respectively; for the second cooling season sampling, the values were 0.76 $\mu g\ m^{-3}$ and 0.63 $\mu g\ m^{-3}$, respectively. For the cooling season sampling in SD 2, the mean blank concentrations for HCHO and CH_3CHO were 0.02 $\mu g\ m^{-3}$ and 0.02 $\mu g\ m^{-3}$, respectively; for the heating season sampling, the values were 0.09 $\mu g\ m^{-3}$ and 0.04 $\mu g\ m^{-3}$, respectively. The reason for higher blank levels during the first cooling season measurement in SD 1 was the PAKS samplers had not gone through the additional purification of DNSH reagent typical for samplers subsequently used.

3.1.1.2 First and Second Samplings, Cooling and Heating Seasons, HCHO

Table 3.1.1.2.1 presents a summary of measured HCHO concentrations in $\mu g\ m^{-3}$ for SD 1 and 2 across seasons, sampling events, room types and sample types for schools participating in the UCLA PCS. Among SD 1 main building classrooms in the cooling season, SWIA concentrations were slightly higher than SDIA concentrations. Among SD 1 portables in the cooling season, mean and median SWIA and SDIA values were the same, but the range of measured SDIA values was wider due to likely differences in ventilation and sources. In SD 2 across room types, SWIA concentrations were higher in the cooling season than in the heating season, and the range of values was narrower in the heating season. In SD 2 in the heating season across room types, SDIA concentrations exceeded SWIA concentrations and had a slightly narrower distribution.

Appendix A.4.3 presents estimated overnight, unoccupied period integrated averages (OUPIA) calculated from SWIA and SDIA measurements by classroom. These interpolated OUPIA values, in general, reflected the assumed lower AER during overnight periods due to closed doors and windows and no operation of HVAC systems, which may have allowed the buildup of pollutant concentrations. This may be one explanation if mean and median SWIA values exceeded SDIA values, but when mean and median SDIA values were identical to or exceeded SWIA values those occupants may have introduced or used otherwise concealed sources of HCHO during school hours. Indoor T and RH were also potential factors. These statements would also be relevant for the discussions of measured CH_3CHO and target VOC concentrations to be presented in subsequent sections.

Across SD and seasons, SDA values were higher than SWIA and SDIA values. In SD 1, Wednesday SDA concentrations were higher than Monday and Friday values, which were similar, and in SD 2, Friday values were higher than Monday values though the ranges of concentrations were similar. These data suggested no build-up of pollutants over unoccupied weekends affected measured concentrations. Further explanations would include uncertainties related to the presence of and age or frequency, duration and amount of use of sources in these classrooms as well as to the passive sampling method employed. Potential HCHO sources included construction and interior finish materials and furnishings like hardwood plywood, adhesives, carpets, vinyl and fabric covered tackable wall panels, fiberglass and mineral fiber ceiling tiles, and exposed, i.e., not laminated, particleboard surfaces and edges (CARB, 1991; CPSC, 1997; Hodgson et al, 2001; USEPA, 2002).

Overall, across room types, SD, seasons and sample types, none of the measured HCHO concentrations in the UCLA PCS exceeded the CARB indoor air guideline of ~60 $\mu g\ m^{-3}$. Four portable classroom SWIA samples and only about 25% of portable classroom SDA samples, four in the cooling season and five in the heating season, exhibited measured concentrations above the eight-hour CalEPA/OEHHA acute non-cancer REL of 33 $\mu g\ m^{-3}$; no SDIA samples were above this value. Across sample types, SD, and seasons, concentrations in portables appeared to be higher than in main building control classrooms, which suggested the greater prevalence of, or newer, sources. For example, the maximum SWIA value in the UCLA PCS was in SD 1, school 1, portable 1 in the first cooling season sampling, 55.2 $\mu g\ m^{-3}$. The SWIA sample from the second cooling season sampling in this same classroom declined to 19.6 $\mu g\ m^{-3}$. This comparison of data from a single new portable suggested a reduction in emissions of HCHO and other VOCs over time; ventilation can enhance this effect. Statistical tests to confirm significant differences by season and room type and to explore correlation between measured HCHO concentrations, T, RH and AER will be discussed in a separate section to follow.

Table 3.1.1.2.1: Summary of measured HCHO concentrations (in ug m^{-3}), sampling events June 2000-June 2001 and SD 1 and 2 included, UCLA PCS. The limit of quantitation with the HPLC with fluorescence detection analysis method was 0.01 ug m^{-3}. Each batch of samples each season was corrected for the mean of the corresponding field blanks.

SD	room type	sample type	season	mean	median	std. dev.	min.	max.
1	M.B.	SWIA[1]	cooling, 6/00	16.6	16.7	3.5	13.0	19.8
		SWIA	cooling, 6/01	15.8	15.4	1.5	14.6	17.4
		SDIA[2]	cooling	14.9	15.8	2.6	12.0	17.0
	portable	SWIA	cooling, 6/00	28.8	23.1	15.1	19.0	55.2
		SWIA	cooling, 6/01	17.8	17.7	1.5	15.7	19.6
		SDIA	cooling	17.7	17.7	2.0	14.9	21.1
		SDA[3]-Mon.	cooling	29.0	28.3	3.0	26.4	34.5
		SDA-Wed.	cooling	34.1	33.5	5.3	29.2	39.7
		SDA-Fri.	cooling	28.6	28.0	2.8	26.0	33.3
2	M.B..	SWIA	cooling	21.5	22.2	5.0	14.7	26.8
		SWIA	heating	18.9	19.5	1.7	16.5	20.3
		SDIA	heating	22.2	22.5	1.6	20.5	23.7
	portable	SWIA	cooling	28.5	29.6	6.1	16.5	35.0
		SWIA	heating	20.7	21.0	1.9	18.1	23.1
		SDIA	heating	23.2	22.9	1.3	21.2	24.9
		SDA-Mon.	heating	31.2	29.6	3.2	28.6	35.6
		SDA-Fri.	heating	33.0	33.0	1.8	30.1	35.1
Overall	M.B. and portables	SWIA	cooling and heating	22.1	19.6	7.9	13.0	55.2
Study	M.B. and portables	SDIA	cooling and heating	19.8	21.1	3.7	12.0	24.8
	portables	SDA	cooling and heating	31.1	30.0	3.5	26.0	39.7

[1] SWIA, school week integrated average, Monday AM to Friday PM and overnights

[2] SDIA, school day integrated average, Monday AM to Friday PM, no overnights

[3] SDA, school hours average, about 7-8 hours, on Monday, Wednesday, or Friday

3.1.1.3 First and Second Samplings, Cooling and Heating Seasons, CH_3CHO

Table 3.1.1.3.1 provides a summary of measured CH_3CHO concentrations in $\mu g\ m^{-3}$ for SD 1 and 2 across seasons, sampling events, room types and sample types for schools participating in the UCLA PCS. In SD 1 main building classrooms in the cooling season, SWIA concentrations were higher in the second sampling event than in the first sampling event, but the opposite was observed in portables. In SD 2 portables, SWIA concentrations were higher in the cooling season than in the heating season, though values in main building classrooms were similar. Since only SWIA samples were employed in the first sampling, these data suggested decreased emissions from permanent material sources in portables over time; SWIA concentrations in three SD 1 portables, for example, dropped ~40-50% between sampling events. In SD 1 in the cooling season and SD 2 in the heating season, across room types, SDIA values were greater than SWIA values, which suggested the importance of school day activities as sources. Nevertheless, when considering data from both SD across seasons and sample types, mean and median concentrations were below the CalEPA/OEHHA non-cancer chronic REL of 9 $\mu g\ m^{-3}$.

The maximum measured concentrations during the UCLA PCS were in three portables-- school 2 portable 1 and school 3 portable 1 of SD 1, and school 1 portable 1 of SD 2. These values may be partially explained by the influence of sources not usually considered indoors. Nearby freeway emissions in SD 1 or idling vehicles, particularly delivery trucks, near the mechanical HVAC system air intake of this SD 2 portable could have increased the formation of CH_3CHO outdoors; AER would affect the impact indoors. Occupant perspiration (Conkle et al, 1975), due to indoor T and RH and/or after entering the classroom following recess or physical education, can produce CH_3CHO. Statistical tests to confirm significant differences by season and room type and to explore correlation between measured CH_3CHO concentrations, T, RH and AER will be discussed in a separate section to follow.

Across SD and seasons, Monday SDA concentrations were slightly higher than Wednesday and Friday values, which were similar, and the range of measured SDA concentrations was wider as a given week progressed. These data, like those for HCHO, suggested no build-up of pollutants over unoccupied weekends. Further explanations would include uncertainties related to the presence of and age or frequency, duration and amount of use of sources in these classrooms as well as to the passive sampling method employed. Potential CH_3CHO sources included interior finish materials such as sheet vinyl flooring near front doors and sink areas, carpets, and vinyl and fabric covered wall panels (Hodgson et al, 2001). In addition, teachers could have used consumer products such as adhesives, inks, and nail polish removers which emitted CH_3CHO (CARB, 1993).

Across SD, SWIA concentrations were higher in portables than in main building classrooms, while SDIA concentrations were similar. Overall, these data suggested the main sources of CH_3CHO in UCLA PCS classrooms were interior finish materials, though other non-material sources likely influenced high values in specific portables.

Table 3.1.1.3.1: Summary of measured CH_3CHO concentrations (in ug m^{-3}), sampling events June 2000-June 2001 and SD 1 and 2 included, UCLA PCS. The limit of quantitation with the HPLC with fluorescence detection analysis method was 0.02 ug m^{-3}. Each batch of samples each season was corrected for the mean of the corresponding field blanks.

SD	room type	sample type	season	mean	median	std. dev.	min.	max.
1	M.B.	SWIA[1]	cooling, 6/00	0.9	0.8	0.8	0.1	1.7
		SWIA	cooling, 6/01	6.8	6.1	1.5	5.9	8.5
		SDIA	cooling	10.1	8.6	3.0	8.1	13.5
	portable	SWIA	cooling, 6/00	12.2	11.6	10.5	0.8	25.3
		SWIA	cooling, 6/01	8.7	8.9	3.3	5.2	11.7
		SDIA[2]	cooling	9.9	8.5	3.1	6.9	14.6
		SDA[3]-Mon.	cooling	10.5	10.3	1.5	8.8	12.8
		SDA-Wed.	cooling	9.1	9.3	1.9	7.1	10.9
		SDA-Fri.	cooling	9.2	8.0	2.8	6.5	12.8
2	M.B..	SWIA	cooling	4.8	4.8	2.1	2.8	7.0
		SWIA	heating	4.5	4.5	0.1	4.4	4.6
		SDIA	heating	7.6	7.8	0.5	7.1	8.0
	portable	SWIA	cooling	7.5	7.8	2.1	3.4	11.9
		SWIA	heating	5.6	5.1	1.9	3.9	9.4
		SDIA	heating	7.8	8.0	0.7	6.7	8.6
		SDA-Mon.	heating	10.2	10.3	0.3	9.9	10.5
		SDA-Fri.	heating	9.1	9.7	1.7	5.7	10.1
Overall	M.B. and portables	SWIA	cooling and heating	6.8	6.0	4.9	0.1	25.3
Study	M.B. and portables	SDIA	cooling and heating	8.8	8.1	2.4	6.7	14.6
	portables	SDA	cooling and heating	9.8	10.0	1.8	5.7	12.8

[1] SWIA, school week integrated average, Monday AM to Friday PM and overnights

[2] SDIA, school day integrated average, Monday AM to Friday PM, no overnights

[3] SDA, school hours average, about 7-8 hours, on Monday, Wednesday, or Friday

3.1.1.4 Field Duplicates for Overall Precision

Precision, the ability to replicate results within known uncertainties at the same time and identical location, is an important attribute of good field investigations, especially when employing a relatively new sampler. Data to reduce uncertainty and help ensure appropriate regulation of chemicals to protect children's health would include data from the development and improvement of methods for monitoring children's exposures, i.e., measurements of concentrations of environmental contaminants of concern where children spend time (Cohen Hubal et al, 2000).

Table 3.1.1.4.1 describes the assessment of field duplicates for overall precision of the aldehyde sampling method across sampling events, seasons, and participating SD for the UCLA PCS. The absolute differences for pairs of SWIA and SDIA samples documented good overall precision, as values were usually within 1-6% of each other; one sample of the first pair for CH_3CHO was near the detection limit, which resulted in a relatively large absolute difference, but these measured concentrations were low. The absolute differences for the two pairs of SDA samples were higher, as values were within 9-11% and 10 or 20% of each other for HCHO and CH_3CHO, respectively. The SDA sample was an integrated 7-8 hour measurement, and thus outside the time period formally validated for eight carbonyls in dynamic environmental chamber studies (Zhang et al, 2000). Therefore, this overall precision analysis, and field data presented and discussed in previous sections for measured SDA concentrations in portables on multiple weekdays, provided support for future development of this passive sampling method. Modifications to the DNSH PAKS as well as further laboratory and field validation assessments would benefit personal and microenvironment exposure assessment in educational and occupational settings for HCHO, CH_3CHO, and other carbonyls of concern. For example, acrolein was recently named one of the top five toxic air contaminants of concern to children's environmental health in California (OEHHA, 2001b); HCHO and benzene were priority candidates for the list.

Analytic duplicates for analytic method precision were conducted routinely by EOHSI, however none of the UCLA PCS samples were randomly selected for such duplicate HPLC injections given the relatively small sample size each season in comparison with those of other concurrent studies in which EOHSI participated. Appendix 2.6.1 provided details of the DNSH PAKS standard operating procedures, including extraction and analyses.

Table 3.1.1.4.1: Field duplicates for overall precision, aldehyde samples, SD 1 and 2 (A and B), UCLA PCS.

NOTE: No reported analytical duplicates for analytical method precision (extraction, HPLC with fluorescence detection) because samples were analyzed together with larger field and lab studies with greater resources which conducted such confirmatory work (see Zhang et. al, 2000 and text).

Season, date1 *School District* *School, type, #* *Type of duplicate*	Cooling, 6/1100 BPUSD 3, M.B., 1 Field, SWIA		Cooling, 9/1100 LAUSD 3, P, 2 Field, SWIA		Cooling, 9/1100 LAUSD 1, P, 2 Field, SDIA		Heating, 2/1101 LAUSD 1, P, 1 Field, SDIA		Heating, 2/1101 LAUSD 1, M.B., 1 Field, SWIA		Cooling, 6/1101 BPUSD 1, P, 1 Field, SDIA		Cooling, 6/1101 BPUSD 2, P, 1 Field, SWIA		Cooling, 6/1101 BPUSD 3, P, 1 Field, SDA M		Cooling, 6/1101 BPUSD 3, P, 2 Field, SDA F	
Compound	Pair of Values 3, ug m-3	Abs Diff, ug m-3	Pair of Values, ug m-3	Abs Diff, ug m-3	Pair of Values, ug m-3	Abs Diff, ug m-3	Pair of Values, ug m-3	Abs Diff, ug m-3	Pair of Values, ug m-3	Abs Diff, ug m-3	Pair of Values, ug m-3	Abs Diff, ug m-3	Pair of Values, ug m-3	Abs Diff, ug m-3	Pair of Values, ug m-3	Abs Diff, ug m-3	Pair of Values, ug m-3	Abs Diff, ug m-3
HCHO	19.41	0.37	27.53	0.07	24.87	0.17	22.93	0.02	19.97	0.29	18.37	0.33	17.23	1.00	28.99	1.29	26.35	2.77
	19.78		27.60		24.70		22.95		20.26		18.04		18.23		27.70		29.12	
average 2	*19.60*		*27.57*		*24.79*		*22.94*		*20.12*		*18.21*		*17.73*		*28.35*		*27.74*	
CH3CHO	0.14	1.27	8.16	0.26	8.25	0.21	8.61	0.22	4.57	0.11	8.21	0.04	11.71	0.08	9.66	0.83	7.79	1.30
	1.41		7.90		8.46		8.39		4.46		8.17		11.63		8.83		6.49	
average	*0.78*		*8.03*		*8.36*		*8.50*		*4.52*		*8.19*		*11.67*		*9.25*		*7.14*	

1 = chemical analyses completed within a month of receiving sample, then raw data QAQC was completed on entire batch of samples with UCLA
2 = arithmetic mean of the pair of values was used for final measured indoor concentrations
3 = values, as with final measured indoor concentrations, were corrected for the arithmetic mean concentration of the compound detected on field blanks

FOR SWIA AND SDIA SAMPLES 4

Compound	Sum of (Abs Diff)^2	Variance as (std dev)^2	Std Dev (as square root of variance)
HCHO	1.36	0.10	0.31
units	ug m-3	ug m-3	ug m-3
CH3CHO	1.79	0.13	0.36
units	ug m-3	ug m-3	ug m-3

4 = These sample types were for DNSH-PAKS exposure durations within the time period validated by EOHSI in environmental chamber studies and in the RIOPA study.

FOR SDA M AND SDA F SAMPLES 5

Compound	Sum of (Abs Diff)^2	Variance as (std dev)^2	Std Dev (as square root of variance)
HCHO	9.34	2.33	1.53
units	ug m-3	ug m-3	ug m-3
CH3CHO	2.38	0.59	0.77
units	ug m-3	ug m-3	ug m-3

5 = These sample types were for an DNSH-PAKS exposure duration below, i.e., outside, the time period formally validated by EOHSI in environmental chamber studies and in the RIOPA study.
These results, and the field data, suggest future modifications and formal validation studies in environmental chambers and at schools and/or occupational settings to improve the passive DNSH-PAKS sampler for 7-8 hr personal and indoor exposure would be of value.

3.1.1.5 Summary of Statistical Analyses

Tables 3.1.1.5.1 and 3.1.1.5.2 summarize t-tests of means and Pearson correlation coefficient R analyses using the HCHO and CH_3CHO data, and other IEQ measures like T and RH, from both the cooling and heating seasons of the UCLA PCS. Based on the small sample sizes created after grouping data by SD, season, room type and/or sample type, and generally similar means and medians, normal distributions were assumed.

In general, t-test results were confirmed by the Pearson correlation coefficients with respect to significance. T-tests results indicated there were no significant differences in mean concentrations between seasons, and SD, for SDA samples for both compounds in portables except Friday SDA HCHO concentrations where values in the heating season were higher. Similarly, across sample types, mean concentrations of CH_3CHO were higher across room types and SD in the cooling season, and across room types and seasons in SD 1. In addition, mean concentrations of HCHO across seasons, sample types and room types were higher in SD 2. Most important, across seasons, SD, and sample types, mean concentrations of HCHO and CH_3CHO were higher in portables; R-values between HCHO, and CH_3CHO, and room type were highest among those with significance. Explanations to consider include differences in the characteristics of the portables such as type and age of interior finish materials; HVAC system operating practices driving ventilation and measured AER; cleaning compounds and practices; prevalence and proximity of outdoor sources, e.g., traffic, in consideration of seasonal meteorology since these compounds were both primary and secondary pollutants; and, some combination of factors.

Based on non-significant t-tests of means, and low and non-significant R values, UCLA PCS data indicated inadequate ventilation was a problem for participant schools and influenced measured concentrations of HCHO and CH_3CHO across room types, SD, and seasons. Results on Table 3.1.1.5.2 for measured indoor air T and RH added support to this assertion. Expected relationships between T and RH and for each variable with season or time of day were confirmed significant with high R-values, whereas R-values between HCHO, and CH_3CHO, and measured indoor air T and RH were insignificant. Measured AER, as the quantitative indicator of ventilation in the UCLA PCS, will be presented and discussed in another section of this dissertation.

Table 3.1.1.5.1: Summary of t-tests of means, UCLA PCS, cooling season (spring 2000 and 2001) and heating season (winter 2001), school districts (SD) 1 and 2.

compound or parameter	class variable	variable stratified by	no. of obs.	mean	std. dev.	Prob > absT
HCHO, SDA[1]	SD 1/ season-C	n/a	13	30.2	4.0	0.167
	SD 2/ season-H		12	32.1	2.6	
CH3CHO, SDA	SD 1/ season-C	n/a	13	9.9	2.2	0.699
	SD 2/ season-H		12	9.6	1.3	
HCHO, SDA	SD 1/ season-C	SDA-Monday only	5	29.2	3.3	0.321
	SD 2/ season-H		6	31.2	3.2	
	SD 1/ season-C	SDA-Friday only	5	28.8	2.9	0.022
	SD 2/ season-H		6	33.0	1.7	
CH3CHO, SDA	SD 1/ season-C	SDA-Monday only	5	10.7	1.5	0.458
	SD 2/ season-H		6	10.2	0.2	
	SD 1/ season-C	SDA-Friday only	5	9.6	2.9	0.713
	SD 2/ season-H		6	9.1	1.7	

[1]SDA = school day average; collected in portables Monday, Friday (and Wed., SD 1); [2]C= cooling, H=heating

	SWIA, SDIA and OUPIA sample types included					
HCHO	season-C	n/a	44	20.6	7.7	0.829
	season-H		27	20.4	2.8	
CH3CHO	season-C	n/a	44	7.6	4.8	0.031
	season-H		27	5.5	2.4	
AER	season-C	n/a	41	0.7	1.0	0.352
	season-H		26	0.5	0.6	
HCHO	SD 1	n/a	32	18.7	7.3	0.032
	SD 2		39	22.0	5.0	
CH3CHO	SD 1	n/a	32	8.0	5.4	0.040
	SD 2		39	5.8	2.5	
AER	SD 1	n/a	29	0.5	0.4	0.282
	SD 2		38	0.7	1.1	
HCHO	M.B.	n/a	25	17.8	3.8	0.004
	portable		46	22.0	6.9	
CH3CHO	M.B.	n/a	25	5.2	3.0	0.014
	portable		46	7.7	4.5	
AER	M.B.	n/a	24	0.7	0.8	0.414
	portable		43	0.5	0.9	

Table 3.1.1.5.2: Summary of Pearson correlation coefficient R analyses, UCLA PCS, cooling season (spring 2000 and 2001) and heating season (winter 2001), school districts (SD) 1 and 2.

	statistically significant R (alpha=0.05)				*not significant, but of interest*			
compound or parameter	parameter	no. of obs.	R value	Prob > absR	parameter	no. of obs.	R value	Prob > absR
HCHO	SD code	71	0.260	0.0287	season (C-to-H)	71	-0.024	0.8443
	room type	71	0.322	0.0061	AER	67	-0.107	0.3889
					T_AM	71	0.092	0.4453
					T_PM	71	0.050	0.6811
					T_overnight	71	0.072	0.5483
					RH_AM	71	0.196	0.1016
					RH_PM	71	0.147	0.2208
					RH_overnight	71	-0.036	0.7688
CH3CHO	SD code	71	-0.254	0.0326	AER	67	-0.136	0.2731
	room type	71	0.278	0.0188	T_AM	71	0.025	0.8378
	season (C-to-H)	71	-0.242	0.0421	T_PM	71	-0.022	0.8550
	RH_overnight	71	-0.255	0.0318	T_overnight	71	0.095	0.4304
					RH_AM	71	-0.105	0.3855
					RH_PM	71	-0.048	0.6908
AER					SD code	67	0.127	0.3053
					room type	67	-0.099	0.4252
					season (C-to-H)	67	-0.109	0.3790
T_AM	season (C-to-H)	71	-0.809	0.0001	RH_AM	71	-0.006	0.9577
	T_PM	71	0.880	0.0001				
	T_overnight	71	0.904	0.0001				
	RH_PM	71	-0.310	0.0086				
	RH_overnight	71	-0.492	0.0001				
T_PM	season (C-to-H)	71	-0.694	0.0001	RH_AM	71	-0.004	0.9756
	T_overnight	71	0.839	0.0001				
	RH_PM	71	-0.458	0.0001				
	RH_overnight	71	-0.491	0.0001				
T_overnight	season (C-to-H)	71	-0.912	0.0001				
	RH_overnight	71	-0.602	0.0001				
RH_AM	RH_PM	71	0.685	0.0001	season (C-to-H)	71	-0.174	0.1458
	RH_overnight	71	0.561	0.0001				
RH_PM	RH_overnight	71	0.649	0.0001	season (C-to-H)	71	0.157	0.1918
RH_overnight	season (C-to-H)	71	0.513	0.0001				
T_AM SDA (M, W, F)	season (C-to-H)	25	-0.581	0.0023				
	T_PM SDA	25	0.793	0.0001				
	RH_AM SDA	25	-0.561	0.0035				
	RH_PM SDA	25	-0.762	0.0001				
T_PM SDA (M, W, F)	season (C-to-H)	25	-0.666	0.0003	RH_AM SDA	25	-0.352	0.0843**
	RH_PM SDA	25	-0.844	0.0001				
RH_AM SDA (M, W, F)	RH_PM SDA	25	0.542	0.0052	season (C-to-H)	25	-0.089	0.6718
RH_PM SDA (M, W, F)	season (C-to-H)	25	0.621	0.0009				

** = significant if alpha level of 0.10

3.1.2 VOCs Concentrations

Appendix A.4.1 references coding used to identify target VOCs discussed in data tables in this dissertation. Table 3.1.2.1 summarizes measured concentrations in $\mu g\ m^{-3}$ of target VOCs with respect to the empirically determined MDLs before correction by the mean of the field blanks for each sample type of specific duration of exposure across sampling events by SD, classroom type, and season. Across room types, similar numbers of target compounds were detected in both classroom types in both SD, though 3-4 more compounds were detected in portables during the cooling season in each SD. Those compounds were constituents of chemical cleaning solvents possibly used in greater quantities than in main building hallways and bathrooms. Five compounds were consistently below their MDL: 1, 3-butadiene, chloroprene, trichloroethylene, naphthalene, and styrene. The most likely reason these volatile, reactive compounds were not detected was the lack of indoor sources such as cigarette smoking, combustion of fossil fuels, mothballs, photocopiers, and printers.

3.1.2.1 Field Blanks

Concentrations reported were corrected for the mean concentrations measured on laboratory and field blanks. UT-Houston used one or two laboratory blanks for each shipment of samples (Stock, 2001a-c). In general, each of the target compounds was measured on the blanks as non-detectable or below reported MDLs. UT-Houston reported, however, low-level MTBE contamination of the extraction solvent (Stock, 2001a-c), though the MDL was validated due to good precision of the blanks (Stock, 2001b). Furthermore, for the batches of samples from the cooling and heating seasons in

SD 2, some d-limonene was measured on field and laboratory blanks except laboratory blanks used with heating season samples (Stock, 2001a and c). As reported before (Chung et al, 1999a-b), the highest and most variable background contaminant of the OVMs was toluene, which resulted in the relatively high MDLs shown in Tables 3.1.2.2.1-3.1.2.2.2 and Tables 3.1.2.3.1-3.1.2.3.2. In addition, there were analytic problems with naphthalene, which invalidated the data though this was of no significance given most values were below the MDL (Stock, 2001a). These QAQC findings were utilized to determine the MDLs and to report valid final concentrations.

Table 3.1.2.1: Summary of measured concentrations ($\mu g\ m^{-3}$) of target VOCs with respect to analytic method detection limits (MDL) for each sample type of specific duration of exposure, SD 1 and 2, UCLA PCS.

SD	sample type	room type	season	no. compounds of 19 > MDL in 67-75% of samples
1	SWIA	M.B.	cooling, 6/00	11
		portable		15
	SWIA	M.B	cooling, 6/01	13
		portable		14
	SDIA	M.B.	cooling, 6/01	10
		portable		11
2	SWIA	M.B.	cooling	11
		portable		14
	SWIA	M.B.	heating	14
		portable		14
	SDIA	M.B.	heating	12
		portable		12

3.1.2.2 First and Second Samplings, Cooling Season, SD 1

Table 3.1.2.2.1 summarizes measured indoor air VOC concentrations, in $\mu g\ m^{-3}$, in portables for the first (early summer 2000) and second (early summer 2001) sampling events at participating schools in SD 1. Table 3.1.2.2.2 provides the data in a similar manner for main building control classrooms. Overall, measured concentrations were below previously presented human odor thresholds and chronic and/or acute non-cancer RELs. Across room types and sample types, most of the compounds assessed were found to have low and narrowly distributed measured concentrations, likely because indoor and/or outdoor sources were not present in school classrooms in the UCLA PCS; specialized vocational shops and elementary school art and science rooms were not included. These compounds were 1,3-butadiene, benzene, ethylbenzene, styrene, o-xylene, naphthalene, p-dichlorobenzene, methylene chloride, chloroform, carbon tetrachloride, tetrachloroethylene, and trichloroethylene. Their sources not present included tobacco smoking and other combustion; copy machines and printers; solvents and detergents; drinking water disinfection byproducts and other contaminants which may off-gas from water if hot or boiled; toilet deodorizers; dry cleaning; moth repellent; and, paints and glues not water-based. The four most prevalent compounds, toluene, m-/p-xylene, a-pinene, and d-limonene, had higher measured SDIA concentrations than SWIA concentrations, and the minimum and maximum values covered a relatively wide range. Likely indoor sources in the school classroom environment for these compounds were commercially available personal, teaching, and cleaning products including hair sprays, perfume, nail color and remover, deodorants, lemon and pine-scented cleaners, air

Table 3.1.2.2.1: Summary of results of measured VOC concentrations (in ug m^{-3}) in portables, first (early summer 2000) and second sampling events (early su 2001), SD 1, UCLA PCS. MDL = method detection limit for given sampling duration. Five compounds-- 1, 3-butadiene, chloroprene, trichloroethylene, naphthalene, and styrene-- with data excluded were consistently below MDL or value was zero.

	first sampling, first week June 2000 (n=5)						*second sampling, first week June 2001* (n=5 per sample type)									
VOCs	MDL, SWIA[1]	Mean	Median	Std. Dev.	Min.	Max.	MDL, SWIA	MDL, SDIA[2]	Mean, SWIA	Mean, SDIA	Median, SWIA	Median, SDIA	Std. Dev., SWIA	Std. Dev., SDIA	Min.-Max., SWIA	Min.-Max., SDIA
1,3-butadiene	0.90				ND[3]	ND	0.88	2.28							ND, ND	ND, ND
methylene chloride	0.23	0.9	0.8	0.1	0.8	1.1	0.04	0.11	0.6	1.1	0.6	1.0	0.1	0.4	0.3, 0.7	0.8, 1.9
MTBE	1.01	5.1	5.0	0.3	4.7	5.7	0.20	0.52	4.2	5.9	4.5	4.7	1.3	2.7	1.7, 5.7	4.4, 11.4
chloroprene	0.16				ND	ND	0.16	0.41							ND, ND	ND, ND
chloroform	0.11	0.1	0.2	0.1	ND	0.3	0.10	0.27	0.1	0.1	0.1	ND	0.1	0.1	ND, 0.2	ND, 0.3
carbon tetrachloride	0.13	0.4	0.4	ND	0.4	0.5	0.17	0.44	0.4	0.6	0.4	0.6	0.1	0.2	0.2, 0.5	0.5, 1.1
benzene	0.36	1.4	1.5	0.2	1.2	1.6	0.46	1.19	1.3	1.8	1.4	1.4	0.3	1.3	0.7, 1.6	1.1, 4.4
trichloroethylene	0.12				ND	0.1	0.17	0.44							0.1, 0.2	0.1, 0.3
toluene	3.78	7.2	7.6	2.4	4.2	10.0	1.41	3.67	5.8	8.7	5.9	6.1	1.3	6.3	3.4, 7.3	5.1, 21.4
tetrachloroethylene	0.21	1.5	0.8	1.9	0.5	5.5	0.12	0.32	0.7	1.3	0.8	1.2	0.3	0.4	0.4, 1.1	0.8, 2.0
ethylbenzene	0.23	1.2	1.2	0.2	1.0	1.5	0.18	0.47	1.0	1.3	1.0	1.1	0.4	0.6	0.4, 1.4	0.8, 2.5
m-/p-xylene	0.77	4.1	4.0	0.4	3.7	4.6	0.31	0.79	2.7	3.9	3.0	3.0	0.8	1.9	1.2, 3.2	2.8, 7.8
naphthalene	1.43				ND	ND	0.36	0.93							ND, ND	ND, ND
o-xylene	0.36	1.5	1.5	0.2	1.4	2.0	0.13	0.33	0.9	1.3	1.0	1.1	0.3	0.7	0.4, 1.2	1.0, 2.8
styrene	0.10				0.5	0.7	0.18	0.47							ND, 0.2	ND, 0.5
a-pinene	0.13	12.3	12.1	11.5	0.8	31.0	0.12	0.32	2.6	6.9	2.8	1.0	1.6	13.6	0.8, 4.9	0.7, 34.6
b-pinene	0.15	2.2	1.6	3.1	ND	8.3	0.14	0.37	0.4	1.3	0.4	ND	0.3	3.0	ND, 0.9	ND, 7.4
d-limonene	2.33	8.7	8.3	4.6	1.8	14.4	0.55	1.44	2.2	4.6	2.3	2.1	0.5	6.6	1.5, 2.8	1.1, 17.9
p-dichlorobenzene	0.48	1.2	1.3	0.4	0.6	1.8	0.29	0.74	0.4	0.9	0.4	0.4	0.1	1.2	0.3, 0.5	0.2, 3.3

[1] SWIA, school week integrated average, Monday AM to Friday PM and overnights

[2] SDIA, school day integrated average, Monday AM to Friday PM, no overnights

[3] ND = not detectable; to calculate mean, ND = 0.0

Table 3.1.2.2.2: Summary of results of measured VOC concentrations (in ug m^{-3}) in main building control classrooms, first (early summer 2000) and second sampling events (early summer 2001), SD 1, UCLA PCS. MDL = method detection limit for given sampling duration. Five compounds-- 1, 3-butadiene, chloro trichloroethylene, naphthalene, and styrene-- with data excluded were consistently below MDL or value was zero.

	first sampling, first week June 2000 (n=3)						*second sampling, first week June 2001* (n=3 per sample type)									
VOCs	MDL, SWIA[1]	Mean	Median	Std. Dev.	Min.	Max.	MDL, SWIA	MDL, SDIA[2]	Mean, SWIA	Mean, SDIA	Median, SWIA	Median, SDIA	Std. Dev., SWIA	Std. Dev., SDIA	Min.-Max., SWIA	Min.-Max., SDIA
1,3-butadiene	0.90				ND[3]	ND	0.88	2.28							ND, ND	ND, ND
methylene chloride	0.23	0.5	0.7	0.4	0.1	0.7	0.04	0.11	0.5	1.0	0.5	1.1	ND	0.2	0.5, 0.6	0.8, 1.1
MTBE	1.01	3.3	4.4	2.6	0.3	5.2	0.20	0.52	4.6	5.1	4.7	5.3	0.1	0.3	4.4, 4.7	4.7, 5.3
chloroprene	0.16				ND	ND	0.16	0.41							ND, ND	ND, ND
chloroform	0.11	ND	ND	ND	ND	ND	0.10	0.27	0.1	ND	0.2	ND	0.1	ND	ND, 0.2	ND, ND
carbon tetrachloride	0.13	0.3	0.4	0.2	ND	0.4	0.17	0.44	0.4	0.5	0.4	0.5	ND	ND	0.4, 0.5	0.5, 0.6
benzene	0.36	1.2	1.4	1.1	ND	2.2	0.46	1.19	1.7	1.7	1.5	1.5	0.5	0.4	1.4, 2.4	1.3, 2.2
trichloroethylene	0.12				ND	ND	0.17	0.44							0.1, 0.2	0.1, 0.2
toluene	3.78	2.8	3.6	3.1	ND	5.4	1.41	3.67	9.5	6.8	5.0	5.5	8.0	2.4	4.8, 18.	5.4, 9.6
tetrachloroethylene	0.21	0.5	0.6	0.4	ND	0.9	0.12	0.32	0.9	1.1	0.8	1.1	0.2	0.2	0.8, 1.1	0.9, 1.2
ethylbenzene	0.23	0.6	0.7	0.5	0.1	1.1	0.18	0.47	0.9	1.0	0.9	1.1	0.1	0.1	0.9, 1.0	1.0, 1.1
m-/p-xylene	0.77	2.1	2.5	1.7	0.3	3.6	0.31	0.79	2.7	3.0	2.7	3.0	0.2	0.2	2.5, 3.0	2.9, 3.2
naphthalene	1.43				ND	ND	0.36	0.93							ND, ND	ND, ND
o-xylene	0.36	0.9	1.2	0.7	0.1	1.4	0.13	0.33	1.0	1.1	1.0	1.1	0.1	0.1	0.9, 1.1	1.0, 1.2
styrene	0.10				ND	0.5	0.18	0.47							ND, ND	ND, ND
a-pinene	0.13	0.4	0.5	0.3	ND	0.6	0.12	0.32	0.5	0.5	0.5	0.4	0.1	0.2	0.3, 0.6	0.4, 0.7
b-pinene	0.15	ND	ND	ND	ND	ND	0.14	0.37	0.1	ND	ND	ND	0.1	ND	ND, 0.2	ND, ND
d-limonene	2.33	1.7	1.8	0.9	0.8	2.5	0.55	1.44	1.4	1.3	1.5	1.1	0.4	0.6	1.0, 1.8	0.8, 1.9
p-dichlorobenzene	0.48	0.7	0.8	0.5	0.1	1.2	0.29	0.74	1.0	1.4	0.4	0.7	1.1	1.6	0.3, 2.2	0.3, 3.2

[1] SWIA, school week integrated average, Monday AM to Friday PM and overnights

[2] SDIA, school day integrated average, Monday AM to Friday PM, no overnights

[3] ND = not detectable; to calculate mean, ND = ND

fresheners, and soaps (Wallace et al, 1991). Since concentrations of these compounds were relatively lower in main building classrooms than in portables, there was uncertainty regarding frequency, duration and amounts used or the presence of other sources; ventilation was another factor. A laboratory study of interior finish materials for typical California portables suggested toluene, whose mean and median concentrations across sampling events and room types were the highest measured in SD 1, was emitted from resilient floor tiles as well as vinyl and fabric covered tackable wall panels (Hodgson et al, 2001).

3.1.2.3 First and Second Samplings, Cooling and Heating Seasons, SD 2

Table 3.1.2.3.1 summarizes measured indoor air VOC concentrations, in $\mu g\ m^{-3}$, in portables for the first (late summer-early fall 2000) and second (winter 2001) sampling events at participating schools in SD 2. Table 3.1.2.3.2 provides the data in a similar manner for main building control classrooms. The secondary school included in the first sampling was excluded from the winter sampling due to available resources, logistics, and the focus on elementary school demand for portables due to class size reduction initiatives. The same group of compounds with low measured concentrations (<1 to 3 $\mu g\ m^{-3}$) across room types and sample types in SD 1 were also found to have similarly low measured concentrations in SD 2 across room types, sample types, and seasons. For the four most prevalent compounds measured in SD 1 and again in SD 2, measured concentrations were relatively higher in the heating season than in the cooling season and the SDIA values were similar to or higher than the SWIA values. For d-limonene, high concentrations were measured in 1-2 rooms. For p-dichlorobenzene in the cooling season, only one measured SWIA concentration among main building classrooms was above the MDL. This sample was from a secondary school science classroom adjacent to a hallway on the second floor with other classrooms and bathrooms. Besides mothballs, some bathroom deodorizers and air fresheners contained p-dichlorobenzene (CARB, 2001). In the heating season, relatively high maximum SDIA values for compounds whose means and medians were consistently low, e.g., benzene, were found in one elementary school main building classroom (school two). We speculate a custodial cleaning solvent may have been used in an early afternoon in the room or on the adjacent hallway floor in a larger quantity during the study week.

Table 3.1.2.3.1: Summary of results of measured VOC concentrations (in ug m^{-3}) in portables, first (late summer-early fall 2000) and second sampling events (winte 2001), SD 2, UCLA PCS. MDL = method detection limit for given sampling duration. Five compounds-- 1, 3-butadiene, chloroprene, trichloroethylene, naphthalene, and styrene-- with data excluded were consistently below MDL or value was zero.

	first sampling, Sept.-early Oct. 2000 (n=8)						*second sampling, late Feb.-early March 2001* (n=6 per sample type)									
VOCs	MDL, SWIA[1]	Mean	Median	Std. Dev.	Min.	Max.	MDL, SWIA	MDL, SDIA[2]	Mean, SWIA	Mean, SDIA	Median, SWIA	Median, SDIA	Std. Dev., SWIA	Std. Dev., SDIA	Min.-Max., SWIA	Min.-Max., SDIA
1,3-butadiene	0.89				ND[3]	ND	0.89	2.31							ND, ND	ND, ND
methylene chloride	0.24	0.4	0.2	0.4	0.1	1.3	0.12	0.32	0.8	1.0	0.7	1.0	0.2	0.2	0.6, 1.1	0.8, 1.3
MTBE	0.94	3.7	2.0	2.4	1.6	7.0	0.18	0.46	3.2	4.2	3.7	4.6	1.3	0.6	1.3, 4.3	3.0, 4.8
chloroprene	0.16				ND	ND	0.16	0.42							ND, ND	ND, ND
chloroform	0.11	0.2	0.2	0.1	ND	0.3	0.05	0.13	0.2	0.2	0.2	0.2	ND	0.1	0.1, 0.2	ND, 0.2
carbon tetrachloride	0.17	0.4	0.4	ND	0.3	0.5	0.19	0.49	0.4	0.5	0.4	0.5	ND	ND	0.4, 0.5	0.4, 0.5
benzene	0.27	1.6	1.4	0.9	0.4	2.7	0.25	0.64	2.6	2.3	2.3	2.3	0.6	0.4	2.0, 3.4	1.7, 3.0
trichloroethylene	0.03				ND	0.2	0.12	0.32							ND, 0.2	ND, 0.1
toluene	1.07	3.7	4.0	1.3	1.7	5.7	0.27	0.70	8.0	7.6	8.1	7.0	1.4	1.8	6.3, 10.4	4.7, 10.1
tetrachloroethylene	0.16	0.7	0.8	0.2	0.3	0.9	0.02	0.04	1.4	1.6	1.4	1.6	0.3	0.2	1.2, 1.9	1.2, 1.9
ethylbenzene	0.18	0.7	0.6	0.4	0.3	1.4	0.04	0.09	1.5	1.5	1.4	1.3	0.4	0.5	1.1, 2.4	1.1, 2.6
m-/p-xylene	0.46	2.5	2.1	1.5	1.0	5.5	0.09	0.23	5.0	5.3	5.0	4.8	1.0	1.6	3.9, 7.0	3.8, 8.5
naphthalene	1.42				ND	ND	1.42	3.69							ND, ND	ND, 0.2
o-xylene	0.27	0.9	0.8	0.5	0.3	1.8	0.06	0.15	1.7	1.8	1.6	1.7	0.4	0.5	1.3, 2.4	1.3, 2.7
styrene	0.17				ND	0.6	0.72	1.88							0.3, 0.6	0.1, 0.4
a-pinene	0.09	1.4	1.3	0.9	0.3	3.2	0.12	0.32	1.8	1.5	1.8	1.6	1.1	0.9	0.6, 3.7	0.4, 3.1
b-pinene	0.15	0.5	0.6	0.4	ND	1.1	0.15	0.38	0.5	0.3	0.3	ND	0.7	0.7	ND, 2.0	ND, 1.9
d-limonene	0.87	2.5	1.6	3.6	0.5	11.8	0.34	0.88	29.0	28.2	14.0	17.0	45.1	41.5	2.5, 128.7	2.2, 121.0
p-dichlorobenzene	0.95	0.1	0.1	0.2	ND	0.5	0.10	0.27	0.5	0.8	0.4	0.7	0.3	0.4	0.3, 1.2	0.3, 1.5

[1] SWIA, school week integrated average, Monday AM to Friday PM and overnights

[2] SDIA, school day integrated average, Monday AM to Friday PM, no overnights

[3] ND = not detectable; to calculate mean, ND = ND

Table 3.1.2.3.2: Summary of results of measured VOC concentrations (in ug m^{-3}) in main building control classrooms, first (late summer-early fall 2000) and seco sampling events (winter 2001), SD 2, UCLA PCS. MDL = method detection limit for given sampling duration. Five compounds-- 1, 3-butadiene, chloroprene, trichloroethylene, naphthalene, and styrene-- with data excluded were consistently below MDL or value was zero.

	first sampling, Sept.-early Oct. 2000 (n=4)						*second sampling, late Feb.-early March 2001* (n=3 per sample type)										
VOCs	MDL, SWIA[1]	Mean	Median	Std. Dev.	Min.	Max.	MDL, SWIA	MDL, SDIA[2]	Mean, SWIA	Mean, SDIA	Median, SWIA	Median, SDIA	Std. Dev., SWIA	Std. Dev., SDIA	Min.-Max., SWIA	Min.-Max., SDIA
1,3-butadiene	0.89				ND[3]	ND	0.89	2.31							ND, ND	ND, ND
methylene chloride	0.24	0.3	0.2	0.2	0.2	0.7	0.12	0.32	0.7	1.5	0.7	1.0	0.2	1.1	0.5, 0.9	0.8, 2.8
MTBE	0.94	3.8	3.2	2.3	1.7	6.8	0.18	0.46	3.5	5.8	4.3	4.3	1.5	3.3	1.8, 4.5	3.5, 9.6
chloroprene	0.16				ND	ND	0.16	0.42							ND, ND	ND, ND
chloroform	0.11	0.2	0.2	ND	0.2	0.2	0.05	0.13	0.1	0.2	0.1	0.2	0.1	0.2	0.1, 0.2	ND, 0.4
carbon tetrachloride	0.17	0.4	0.4	ND	0.4	0.4	0.19	0.49	0.3	0.6	0.4	0.5	0.1	0.3	0.2, 0.4	0.4, 1.0
benzene	0.27	0.9	0.8	0.5	0.5	1.6	0.25	0.64	1.6	2.7	1.9	2.0	0.7	1.6	0.9, 2.1	1.6, 4.6
trichloroethylene	0.03				ND	0.1	0.12	0.32							ND, 0.1	ND, 0.2
toluene	1.07	3.3	3.0	0.9	2.6	4.6	0.27	0.70	5.4	8.8	5.2	8.5	2.3	5.3	3.3, 7.9	3.6, 14.2
tetrachloroethylene	0.16	0.5	0.6	0.2	0.2	0.7	0.02	0.04	0.9	2.0	1.0	1.4	0.3	1.4	0.6, 1.1	1.1, 3.6
ethylbenzene	0.18	0.6	0.5	0.3	0.4	1.0	0.04	0.09	0.9	1.5	0.9	1.2	0.3	0.9	0.5, 1.2	0.8, 2.5
m-/p-xylene	0.46	2.1	1.7	1.1	1.2	3.6	0.09	0.23	3.2	5.6	3.6	4.5	1.3	3.3	1.8, 4.3	3.1, 9.3
naphthalene	1.42				ND	ND	1.42	3.69							ND, ND	ND, ND
o-xylene	0.27	0.7	0.6	0.4	0.4	1.2	0.06	0.15	1.1	1.9	1.2	1.5	0.4	1.0	0.6, 1.4	1.1, 3.0
styrene	0.17				0.1	0.2	0.72	1.88							0.1, 0.3	ND, 0.8
a-pinene	0.09	0.3	0.3	0.1	0.2	0.5	0.12	0.32	0.5	0.8	0.6	0.6	0.2	0.4	0.3, 0.6	0.5, 1.3
b-pinene	0.15	0.3	0.2	0.4	ND	0.8	0.15	0.38	0.2	0.3	0.2	ND	0.1	0.5	0.2, 0.3	ND, 0.8
d-limonene	0.87	3.5	2.8	3.8	0.4	8.1	0.34	0.88	3.8	11.3	3.5	8.4	2.6	11.8	1.3, 6.5	1.3, 24.3
p-dichlorobenzene	0.95	2.6	ND	5.3	ND	10.6	0.10	0.27	0.3	0.4	0.3	0.4	0.1	0.2	0.2, 0.4	0.2, 0.5

[1] SWIA, school week integrated average, Monday AM to Friday PM and overnights

[2] SDIA, school day integrated average, Monday AM to Friday PM, no overnights

[3] ND = not detectable; to calculate mean, ND = ND

3.1.2.4 Field Duplicates for Overall Precision

Although the passive sampler employed in the UCLA PCS field studies has been proven in previous occupational and residential studies, the use in school environments is relatively new. Given the expected low concentrations of many of the target compounds, and the lack of data from previous studies, the ability to replicate results, given known uncertainties, at the same time and identical location was important for validation of these field methods to inform future school studies. For example, quantitatively, measured VOC concentrations in the Texas School Indoor Air Study (TESIAS; Torres et al, 2002; Corsi, 2002) may not be valid due to concerns about storage conditions and time of storage before extraction and analysis; individual samples may have underestimated true measured concentrations.

Table 3.1.2.4.1 presents the field duplicate data for the assessment of overall method precision across sampling events, seasons, and participating SD for the UCLA PCS. Overall, these results supported a conclusion of good overall precision for the methodology employed including shipments, storage when new and after use, handling, field deployment, extraction and analyses. Standard deviations based on the absolute differences between duplicate pairs of values were negligible or less than 0.3 μg m^{-3} for 17 of 19 compounds. The standard deviation was 0.56 μg m^{-3} for d-limonene, but the absolute differences between duplicate pairs of values were within 1-10% of the relatively high measured concentrations. The absolute difference between each duplicate pair of values for toluene (VOC 9) ranged 7-25% of the measured concentrations; the standard deviation was 0.75 μg m^{-3}. Given the relatively high and variable background contamination previously noted, the overall precision for toluene was acceptable.

3.1.2.5 Analytic Duplicate to Confirm Analytic Method Precision

Duplicates for analytic method precision were conducted routinely by UT-Houston, and target compound recoveries were well understood and documented (see Table 2.4.1.2.1). Nevertheless, UCLA PCS samples usually were not systematically selected (one per 20 samples) given the relatively small sample sizes compared to those of other concurrent studies UT-Houston participated in. During analyses of samples taken in the first sampling in the cooling season in SD 2 and the second cooling season sampling in SD 1, however, 1-2 samples were selected for a second GC/MS injection. UT-Houston reported the results of two analytic duplicates run with the SD 2 cooling season samples, sent in two batches, indicated excellent analytic precision (Stock, 2001a). Table 3.1.2.5.1 presents data for the sample from a portable in SD 1 and its duplicate injection. The calculated absolute difference for each pair of values was negligible or about 3-9% of the measured concentrations for 17 of 19 compounds. For two compounds, the calculated absolute difference was about 10% or 20% of the measured concentrations, but these were below 1.0 μg m^{-3}. Overall, results confirmed good analytic precision.

Table 3.1.2.4.1: Field duplicates for overall precision, VOC samples, SD 1 and 2 (A and B), UCLA PCS.

Season, date[1]	Cooling, 6/00		Cooling, 9/00		Heating, 2/01		Heating, 2/01		Cooling, 6/01		Cooling, 6/01				
School District	1		2		2		2		1		1				
School, type, #	2, P, 1		2, P, 1		2, P, 1		2, P, 2		2, P, 1		1, P, 1				
Type of duplicate	Field, SWIA		Field, SWIA		Field, SWIA		Field, SDIA		Field, SWIA		Field, SDIA		VALUES IN ug m^{-3}		
Compound	Pair of Values, ug m^{-3}	Abs Diff, ug m^{-3}	Pair of Values, ug m^{-3}	Abs Diff, ug m^{-3}	Pair of Values, ug m^{-3}	Abs Diff, ug m^{-3}	Pair of Values, ug m^{-3}	Abs Diff, ug m^{-3}	Pair of Values, ug m^{-3}	Abs Diff, ug m^{-3}	Pair of Values, ug m^{-3}	Abs Diff, ug m^{-3}	Sum of (Abs Diff)^2	Variance as (std dev)^2	Std Dev (as square root of variance)
VOC 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00		0.00		0.00		0.00		0.00		0.00				
average	*0.00*		*0.00*		*0.00*		*0.00*		*0.00*		*0.00*				
VOC 2	1.05	0.03	0.24	0.04	0.71	0.00	1.13	0.22	0.60	0.04	0.97	0.02	0.05	0.00	0.06
	1.08		0.28		0.71		1.34		0.64		0.99				
average	*1.07*		*0.26*		*0.71*		*1.23*		*0.62*		*0.98*				
VOC 3	4.99	0.25	1.89	0.11	3.55	0.17	4.23	0.58	4.59	0.13	4.71	0.30	0.55	0.04	0.20
	5.24		2.00		3.72		4.82		4.72		4.41				
average	*5.12*		*1.95*		*3.63*		*4.53*		*4.66*		*4.56*				
VOC 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00		0.00		0.00		0.00		0.00		0.00				
average	*0.00*		*0.00*		*0.00*		*0.00*		*0.00*		*0.00*				
VOC 5	0.20	0.20	0.15	0.02	0.20	0.01	0.19	0.04	0.20	0.01	0.00	0.00	0.04	0.00	0.05
	0.00		0.17		0.20		0.23		0.21		0.00				
average	*0.10*		*0.16*		*0.20*		*0.21*		*0.21*		*0.00*				
VOC 6	0.44	0.05	0.38	0.01	0.41	0.03	0.50	0.02	0.42	0.05	0.56	0.02	0.01	0.00	0.02
	0.49		0.39		0.45		0.52		0.47		0.54				
average	*0.47*		*0.39*		*0.43*		*0.51*		*0.45*		*0.55*				
VOC 7	1.47	0.13	2.72	0.00	3.28	0.13	2.27	0.27	1.33	0.10	1.30	0.11	0.13	0.01	0.09
	1.60		2.72		3.41		2.54		1.43		1.41				
average	*1.54*		*2.72*		*3.34*		*2.41*		*1.38*		*1.36*				
VOC 8	0.03	0.05	0.01	0.02	0.07	0.00	0.02	0.03	0.10	0.02	0.21	0.06	0.01	0.00	0.02
	0.08		0.03		0.08		0.05		0.12		0.27				
average	*0.06*		*0.02*		*0.07*		*0.04*		*0.11*		*0.24*				
VOC 9	7.91	1.29	2.02	0.81	8.11	0.63	7.02	1.41	5.95	1.31	5.07	1.25	7.96	0.57	0.75
	9.20		2.83		8.74		8.43		7.26		6.32				
average	*8.55*		*2.42*		*8.42*		*7.72*		*6.61*		*5.70*				
VOC 10	0.92	0.04	0.68	0.18	1.88	0.02	1.54	0.12	0.74	0.05	1.22	0.14	0.07	0.01	0.07
	0.96		0.86		1.86		1.65		0.79		1.36				
average	*0.94*		*0.77*		*1.87*		*1.59*		*0.77*		*1.29*				
VOC 11	1.31	0.14	0.52	0.10	1.41	0.10	1.12	0.23	0.90	0.07	1.02	0.11	0.11	0.01	0.09
	1.45		0.61		1.50		1.35		0.97		1.13				
average	*1.38*		*0.57*		*1.46*		*1.23*		*0.94*		*1.08*				
VOC 12	4.25	0.40	1.86	0.24	4.97	0.34	4.22	0.76	2.99	0.17	3.00	0.46	1.15	0.08	0.29
	4.65		2.11		5.31		4.98		3.16		3.46				
average	*4.45*		*1.98*		*5.14*		*4.60*		*3.08*		*3.23*				
VOC 13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00		0.00		0.00		0.00		0.00		0.00				
average	*0.00*		*0.00*		*0.00*		*0.00*		*0.00*		*0.00*				
VOC 14	1.43	0.05	0.69	0.10	1.57	0.15	1.39	0.34	0.98	0.07	1.03	0.09	0.17	0.01	0.11
	1.49		0.79		1.72		1.73		1.05		1.12				
average	*1.46*		*0.74*		*1.65*		*1.56*		*1.02*		*1.08*				
VOC 15	0.63	0.02	0.10	0.01	0.35	0.02	0.15	0.13	0.00	0.00	0.00	0.00	0.02	0.00	0.04
	0.64		0.10		0.33		0.29		0.00		0.00				
average	*0.64*		*0.10*		*0.34*		*0.22*		*0.00*		*0.00*				
VOC 16	15.83	1.08	2.02	0.20	1.83	0.04	1.66	0.33	3.39	0.04	0.89	0.17	1.35	0.10	0.31
	16.91		2.22		1.87		2.00		3.43		1.06				
average	*16.37*		*2.12*		*1.85*		*1.83*		*3.41*		*0.98*				
VOC 17	1.82	0.04	0.56	0.10	0.38	0.38	0.00	0.00	0.48	0.05	0.00	0.00	0.15	0.01	0.11
	1.87		0.66		0.00		0.00		0.43		0.00				
average	*1.84*		*0.61*		*0.19*		*0.00*		*0.46*		*0.00*				
VOC 18	8.00	0.59	1.63	0.07	14.01	0.15	17.79	2.00	2.23	0.04	1.10	0.07	4.38	0.31	0.56
	8.59		1.69		14.16		19.79		2.27		1.17				
average	*2.80*		*0.90*		*2.19*		*2.28*		*1.43*		*1.23*				
VOC 19	1.42	0.07	0.10	0.08	0.33	0.10	0.48	0.41	0.40	0.01	0.44	0.01	0.19	0.01	0.12
	1.49		0.18		0.43		0.90		0.39		0.43				
average	*1.46*		*0.14*		*0.38*		*0.69*		*0.40*		*0.44*				

1 = chemical analyses completed within a month of receiving sample, then raw data QAQC was completed on entire batch of samples with UCLA

NOTE: arithmetic mean of the pair of values was used for final measured indoor concentrations; values, as with final measured indoor concentrations, were corrected for the arithmetic mean concentration of the compound detected on field blanks

Table 3.1.2.5.1: Analytical duplicate, analytical method precision (extraction with CS_2 followed by GC/MS), VOC samples, SD 1 (A), UCLA PCS. Refer also to text and Table 2.4.1.2.1 (from Chung C-W et. al, 1999).

Season, date[1]	Cooling, 6/01	
School District	BPUSD	
School, type, #	3, P, 1	
Type of duplicate	Analytical, reported	
Compound	Pair of Values, ug m^{-3}	Abs Diff, ug m^{-3}
VOC 1	0.00	0.00
	0.00	
average	*0.00*	
VOC 2	1.81	0.16
	1.97	
average	*1.89*	
VOC 3	11.23	0.42
	11.65	
average	*11.44*	
VOC 4	0.00	0.00
	0.00	
average	*0.00*	
VOC 5	0.00	0.63
	0.63	
average	*0.32*	
VOC 6	1.08	0.05
	1.13	
average	*1.11*	
VOC 7	4.29	0.17
	4.46	
average	*4.38*	
VOC 8	0.31	0.03
	0.34	
average	*0.33*	
VOC 9	20.09	2.55
	22.64	
average	*21.37*	
VOC 10	1.97	0.17
	2.14	
average	*2.06*	

Season, date[1]	Cooling, 6/01	
School District	BPUSD	
School, type, #	3, P, 1	
Type of duplicate	Analytical, reported	
Compound	Pair of Values, ug m^{-3}	Abs Diff, ug m^{-3}
VOC 11	2.46	0.16
	2.62	
average	*2.54*	
VOC 12	7.74	0.01
	7.75	
average	*7.75*	
VOC 13	0.00	0.00
	0.00	
average	*0.00*	
VOC 14	2.11	0.83
	2.94	
average	*2.53*	
VOC 15	0.43	0.09
	0.52	
average	*0.48*	
VOC 16	34.13	1.01
	35.14	
average	*34.64*	
VOC 17	7.08	0.55
	7.63	
average	*7.36*	
VOC 18	17.99	0.13
	17.86	
average	*4.29*	
VOC 19	3.17	0.23
	3.40	
average	*3.29*	

1 = chemical analyses completed within a month of receiving sample, then raw data QAQC was completed on entire batch of samples with UCLA

NOTE: arithmetic mean of the pair of values was used for final measured indoor concentrations.

NOTE: values, as with final measured indoor concentrations, were corrected for the arithmetic mean concentration of the compound detected on field blanks

3.1.2.6 Summary of Statistical Analyses and Results in Portables

Table 3.1.2.6.1 summarizes correlation analyses with VOC data and other IEQ measures for the UCLA PCS. There were no significant R values by room type or by measured AER except for MTBE, whose concentrations were suspect, and for p-dichlorobenzene, whose measured concentrations were suspect and low. Indeed, for p-dichlorobenzene, one high SWIA value in the main building classroom of SD 2, school 4 in the cooling season, previously discussed, may have driven this result. Nine of 14 compounds had measured concentrations significantly correlated to season, and thus possibly also to SD, but R-values were only between 0.25 and 0.50. Nine of 14 compounds had significant negative R-values with indoor air T averages during morning, afternoon, and/or overnight time periods. Thus, measured concentrations of these compounds were predicted to be lower as average T increased, against what would be expected from physicochemical properties determining volatility. These results, however, may be artifacts given the low concentrations measured. In general, measured average indoor RH during morning, afternoon, and overnight time periods were not significantly correlated with measured VOC concentrations. However, VOCs with the relatively higher measured concentrations—toluene, m-/p-xylene, and d-limonene—had significant R-values with RH in specific time periods, which may have suggested when teachers and custodians used sources. Sources were less likely used in the mornings, characterized by higher RH and also lower T not favoring volatility. In the afternoon and overnight periods, if RH increased d-limonene concentrations increased; d-limonene was common in lemon-scented air fresheners, disinfectant sprays, and cleaning compounds ' likely used by teachers and custodians after school (Wallace et al, 1991; Wainman et al, 2000).

Table 3.1.2.6.2 summarizes results from multiple linear regression models through forward selection and backward elimination procedures with VOC data and other IEQ measures. Results for 10 of 14 compounds agreed with correlation analyses. The final model R^2 values ($p < 0.05$ unless noted) ranged from 0-0.36; much of the variance was left unexplained. Given the most important variables were usually related to overnight periods or AER, these regression models further supported the ideas of inadequate ventilation as a problem for schools, and the impact of specific indoor sources used by teachers and custodians on measured indoor air VOC concentrations.

Overall, results suggested indoor VOC sources previously described contributed most to measured indoor air VOC concentrations in the UCLA PCS.

Table 3.1.2.6.1: Summary of correlation analyses, VOCs, UCLA PCS, Spring 2000-Spring 2001.

correlation coefficient, R	R value	p-value	R value	p-value	R value	p-value	R values (p-values)	
VOCs	*(MB, portable)*		(cooling, heating)				*(A=AM, P=PM, O=unocc. overnight)*	
compound	room type		season		AER, hr^{-1}		T, deg F	RH, %
methylene chloride	-0.116	0.3369	0.292	0.0133*	-0.159	0.1999	A* (-0.246), P* (-0.254), O* (-0.277)	A*(-0.354), P (-0.113), O (-0.097)
chloroform	-0.062	0.6180	0.297	0.0140*	-0.069	0.5836	A* (-0.261), P (-0.198), O* (-0.308)	A (0.066), P (0.196), O (0.151)
carbon tetrachloride	0.116	0.3361	-0.060	0.6199	0.002	0.9843	A (0.045), P (0.063), O (0.070)	A (-0.037), P (-0.040), O (-0.077)
perchloroethylene	-0.143	0.2353	0.300	0.0111*	-0.052	0.6737	A* (-0.222), P* (-0.270), O* (-0.240)	A (-0.149), P (-0.033), O (0.108)
benzene	0.126	0.2969	0.476	0.0001*	-0.093	0.4529	A* (-0.442), P* (-0.404), O* (-0.459)	A (-0.060), P (0.144), O* (0.274)
toluene	0.033	0.7888	0.255	0.0358*	-0.133	0.2895	A* (-0.240), P* (-0.255), O* (-0.249)	A* (-0.271), P (-0.088), O (-0.070)
ethylbenzene	-0.027	0.8237	0.383	0.0010*	-0.061	0.6264	A* (-0.279), P* (-0.265), O* (-0.362)	A* (-0.240), P (-0.077), O (0.066)
m-/p- xylene	-0.029	0.8092	0.502	0.0001*	-0.044	0.7216	A* (-0.416), P* (-0.357), O *(-0.488)	A* (-0.207), P (-0.004), O (0.164)
o-xylene	0.004	0.9735	0.446	0.0001*	-0.065	0.6031	A* (-0.371), P* (-0.310), O* (-0.427)	A* (-0.216), P (-0.031), O (0.120)
alpha-pinene	0.124	0.3033	-0.154	0.2006	-0.178	0.1501	A (0.028), P (-0.008), O (0.051)	A (-0.114), P (-0.064), O** (-0.215)
beta-pinene	0.200	0.1292	-0.098	0.4599	-0.171	0.2041	A (0.012), P (-0.007), O (0.017)	A (-0.062), P (-0.007), O (-0.153)
d-limonene	0.156	0.2052	0.361	0.0025*	-0.152	0.2271	A* (-0.292), P (-0.192), O* (-0.306)	A (0.024), P* (0.250), O* (0.339)
p-dichlorobenzene	0.342	0.0052*	-0.139	0.2694	0.451	0.0002*	A (0.110), P (0.055), O (0.141)	A (0.176), P* (0.312), O (0.184)
methyl tert-butyl ether (MTBE)	0.036	0.0022*	-0.176	0.1408	0.235	0.0560**	A (0.151), P** (0.202), O (0.164)	A (0.038), P (-0.095), O (-0.035)

* = significant, alpha level of 0.05
** = significant, alpha level of 0.10

Table 3.1.2.6.2: Summary of multiple linear regression models through forward selection and backward elimination procedures, VOCs, UCLA PCS, Spring 2000-Spring 2001.

VOCs

compound	final model R^2 value ($p<0.05$ unless noted)	most important predictor variable in model
methylene chloride	0.20	morning RH
chloroform	0.08	overnight T
carbon tetrachloride	0	none
perchloroethylene	0.07	afternoon T
benzene	0.23	overnight T
toluene	0.15	not clear, B and F disagreed
ethylbenzene	0.20	overnight T
m-/p- xylene	0.24	overnight T
o-xylene	0.24	overnight T, morning RH
alpha-pinene	0.05 (p = 0.0621)	overnight RH
beta-pinene	0	none
d-limonene	0.16 (backward), 0.31 (forward)	overnight RH
p-dichlorobenzene	0.26 (backward), 0.36 (forward)	afternoon RH, AER
methyl tert-butyl ether (MTBE)	0.06 (p = 0.0560)	AER

Previous sections presented and discussed data from the UCLA PCS, which suggested concentrations of target toxic and odorous VOC were, in general, low. There were, however, relatively high concentrations of individual compounds across the classrooms or in a specific classroom during one sampling event. Each chemical in a child's environment need not be identified and exposure quantified to achieve real risk reduction in the near term (Wargo and Wargo, 2002). An alternative goal could be identifying primary sources, such as consumer products and cleaning agents, of measured exposures to the most hazardous and/or prevalent chemicals in specific microenvironments and media special to children, and then avoiding or mitigating them with new constituents or alternative products (Armstrong et al, 2000). As previously discussed, the presence and magnitude of measured concentrations of the four most prevalent compounds in the UCLA PCS across SD, seasons, sample types and rooms types-- toluene, m-/p-xylene, a-pinene, and d-limonene-- were likely due to cleaning products as well as interior finish and teaching materials. Indeed, the European Union authorized task force on IEQ in European schools cited the presence of multiple VOC sources such as paints, cleaners, interior finish materials and furnishings (Carrer et al, 2002).

Addressing these VOC sources would be important for other reasons. Recent studies have indicated d-limonene and other VOCs in heterogeneous reactions on indoor surfaces, especially in the presence of ozone entering from the outdoors, may produce concentrations of other pollutants of health concern, including fine and ultrafine particles and oxidation products (Wainman et al, 2000). Health effects assessed included sensory and eye irritation of male mice and human subjects to concentrations of d-limonene, alpha- and beta-pinene, and/or ozone and heterogeneous reaction products in environmental chambers under controlled conditions of T, RH, and reaction time (Wolkoff et al, 2000; Fielder et al, 2002; Klenø and Wolkoff, 2002; Rohr et al, 2002; Wilkins et al, 2002). The interest in such health effects research has increased due to the prevalence of those terpenes in cleaning and household consumer products.

Cavallo et al (1993) investigated IAQ in main building classrooms and special purpose rooms in ten K-12 schools in Milan, Italy characterized by natural ventilation in the winter season. Four of the schools were pre K- K and six of the schools served 1st-12th grades; four indoor samples and one outdoor sample were taken at each school. The observed total VOC concentrations were high, and indoor/outdoor ratios were large, but the technician walk-through inspections determined no important permanent sources of VOCs identified from chromatographic profiles, e.g., d-limonene. The authors determined cleaning and detergent products were the likely sources of the compounds and the measured indoor VOC contamination, particularly in the pre K-K rooms.

In the pilot study of the French Permanent Survey on IAQ (Kirchner et al, 2002a), passive measurements of integrated indoor concentrations of each target VOC, which included alpha- and beta-pinene and 1,2,4-trimethylbenzene, were < 10 $\mu g\ m^{-3}$ in the 18 classrooms except one compound in one classroom. These data agreed with the relatively low measured VOC concentrations found in the UCLA PCS.

Six target VOCs were measured above detection limits in 80% of the classrooms assessed with the full protocol (n=18) in TESIAS, including d-limonene and p-dichlorobenzene (Torres et al, 2002). These data also suggested the use of chemical cleaning compounds and air fresheners during occupied hours and/or during overnight custodial cleaning, when there was likely inadequate ventilation, drove measured concentrations.

Smedje and Norback (1999) discovered one-day measured microbial VOC concentrations, as the sum of eight target compounds, were consistently above MDLs in their 1993-95 investigation of 181 main building school classrooms in the county of Uppsala, Sweden. The walk-through surveys, however, recorded visible signs of building dampness or moisture damage in only 15% of classrooms; moisture and mold damage may be behind walls. As measured concentrations of most target VOC compounds in the UCLA PCS were also low, microbial VOCs should probably be target compounds in future school IEQ assessments along with those compounds associated with newer interior finish materials and cleaning compounds.

3.1.3 AER Measurements

Each input parameter for the determination of measured AER was verified, whether originating as part of the "technician walk-through" questionnaire, with the HSPH PFTs and CAT method, or calculated using these primary measures (see Appendix A.4.2.1 and A.4.2.2). As previously described, two main building SWIA samples from the first sampling event in the cooling season in SD 2 were excluded. Those classrooms had not only a door and/or windows opening to the outside, but also a door or doors opening into a central corridor. As a result, a second tracer gas and method would have been required to accurately distinguish relative contributions to classroom ventilation (Wallace, 2001).

Table 3.1.3.1 presents descriptive statistics for the measured AER in hr^{-1} by and across SD as well as by room type, sampling event and season in the UCLA PCS. Data from each batch of samples analyzed were corrected using the mean of the corresponding field blanks for the volume of PMCH on a CAT (see Appendix A.2.5). Only two of the six field blanks, however, had measured amounts of PMCH on the CAT (0.32 pL and 0.30 pL, respectively), measurable but less than the calculated LOD. These results strengthened the validity of the overall method, especially the handling, storage, transport and shipment of CATs, and thus the final data set.

Table 3.1.3.2 presents the field duplicates as the quantitative assessment for overall precision concerning the AER measurements. The results, whether viewed as pL of the tracer gas on the CAT sample or as the measured AER, showed excellent agreement between paired values overall and by season as they were within 0-9% of each other. One pair of values differed by 20%, but the measured AER were low and within 0.1 hr^{-1}.

Table 3.1.3.1: Summary of measured air exchange rates (in hr $^{-1}$), sampling events June 2000-June 2001 and SD 1 and 2 included, UCLA PCS. The limit of quantitation with the sampling and analysis methods described in the text was 0.1 hr^{-1}. The maximum valid AER measurement was believed to be 3.0 hr^{-1}. Each batch of samples each season was corrected for the mean of the corresponding field blanks.

SD	room type	sample type	season	mean	median	std. dev.	min.	max.
1	M.B.	SWIA	cooling, 6/00	0.7	0.5	0.5	0.4	1.3
		SWIA	cooling, 6/01	0.5	0.4	0.1	0.3	0.6
		SDIA	cooling	1.1	0.9	0.6	0.6	1.8
	portable	SWIA	cooling, 6/00	0.2	0.2	0.2	0.1	0.4
		SWIA	cooling, 6/01	0.3	0.2	0.2	0.1	0.6
		SDIA	cooling	0.5	0.4	0.5	0.1	1.3
2	M.B..	SWIA*	cooling	0.4	0.4	0.2	0.3	0.6
		SWIA	heating	0.5	0.5	0.2	0.4	0.6
		SDIA	heating	0.9	0.9	0.4	0.6	1.2
	portable	SWIA	cooling	1.1	0.3	1.8	0.2	5.4
		SWIA	heating	0.4	0.2	0.5	0.1	1.4
		SDIA	heating	0.7	0.3	1.1	0.2	2.9
Overall	M.B. and portables	SWIA	cooling and heating	0.6	0.3	0.9	0.1	5.4
Study	M.B. and portables	SDIA	cooling and heating	0.8	0.6	0.7	0.1	2.9

* only two SWIA samples determined valid from this batch

Table 3.1.3.2: Field duplicates for overall precision, AER measurements, SD 1 and 2 (A and B), UCLA PCS.

NOTE: No reported analytical duplicates for analytic method precision, though HSPH analyzed most samples twice as part of standard operating procedures quality control quality assurance (refer to A.2.5)

Season, date [1] *School District* *School, type, #* *Type of duplicate*	Cooling, 6/2000 BPUSD 3, P, 3 Field		Cooling, 9/2000 LAUSD 2, P, 2 Field, SWIA		Heating, 2/2001 LAUSD 2, P, 1 Field, SDIA		Heating, 2/2001 LAUSD 2, P, 2 Field, SWIA		Cooling, 6/2001 BPUSD 1, P, 1 Field, SDIA		Cooling, 6/2001 BPUSD 1, M.B., 1 Field, SWIA	
Parameter	Pair of Values [3]	Abs Diff	Pair of Values	Abs Diff	Pair of Values	Abs Diff	Pair of Values	Abs Diff	Pair of Values	Abs Diff	Pair of Values	Abs Diff
AER-- tracer gas on CAT sample, both ends open; values in pL	36.50 36.40	0.10	45.97 50.16	4.19	19.00 15.00	4.00	63.00 60.00	3.00	15.20 15.80	0.60	38.50 38.80	0.30
average [2]	*36.45*		*48.07*		*17.00*		*61.50*		*15.50*		*38.65*	
AER, measured; values in hr^{-1}	0.4 0.4	0.0	0.3 0.3	0.0	0.3 0.4	0.1	0.2 0.2	0.0	0.8 0.7	0.1	0.6 0.6	0.0
average	*0.4*		*0.3*		*0.4*		*0.2*		*0.8*		*0.6*	

1 = chemical analyses completed within a month of receiving sample, then raw data QAQC was completed on entire batch of samples with UCLA
2 = arithmetic mean of the pair of values was used for final measured indoor concentrations
3 = values, as with final measured indoor concentrations, were corrected for the arithmetic mean concentration of the compound detected on field blanks

STUDY

Parameter	Sum of (Abs Diff)^2	Variance, as (std dev)^2	Std Dev (as square root of variance)
AER-- tracer gas on CAT sample, both ends open	43.02	3.58	1.89
units	pL	pL	pL
AER, measured	0.02	0.00	0.04
units	hr^{-1}	hr^{-1}	hr^{-1}

FOR COOLING SEASON ONLY

Parameter	Sum of (Abs Diff)^2	Variance, as (std dev)^2	Std Dev (as square root of variance)
AER-- tracer gas on CAT sample, both ends open	18.02	2.25	1.50
units	pL	pL	pL
AER, measured	0.01	0.00	0.04
units	hr^{-1}	hr^{-1}	hr^{-1}

FOR HEATING SEASON ONLY

Parameter	Sum of (Abs Diff)^2	Variance, as (std dev)^2	Std Dev (as square root of variance)
AER-- tracer gas on CAT sample, both ends open	25.00	6.25	2.50
units	pL	pL	pL
AER, measured	0.01	0.00	0.05
units	hr^{-1}	hr^{-1}	hr^{-1}

Overall, across SD, room types, and sample types, measured AER were low, with minimum values of 0.1 hr^{-1} and a range of mean values of 0.2-1.1 hr^{-1}. Across SD and room types, the means were 0.6 hr^{-1} for SWIA AER and 0.8 hr^{-1} for SDIA AER, and median SDIA values were higher than SWIA values. These relative comparisons by sample type demonstrated likely influences of occupant behaviors with respect to the use of doors, windows and/or HVAC systems during school hours. Night custodians were expected to have short-term, limited influences on measured AER. The mean measured AER were higher in main building control classrooms than in portables, except during the cooling season in SD 2. In SD 2, measured SWIA AER were nearly the same in main building control classrooms across seasons, though in portables mean SWIA values were higher in the cooling season. For portables, the mean SWIA AER in the cooling season was higher in SD 2 than in SD 1.

Given the median and minimum measured AER in SD 2 portables were similar across seasons and sample types, the differences in the means and the standard deviations were likely due to one portable, school three portable one, in which measurements represented the maximum validated AER for the UCLA PCS. In the cooling season, observations and teacher anecdotes about occupant discomfort of the stuffy, warm air suggested the two doors to the outdoors were frequently opened and two large portable fans, one on each side of the room, were operated. In the heating season, fans were likely used when it rained or, if there was no rain, doors were opened and fans were off. This portable, known as a "bungalow," had no wall or roof-mount HVAC system, was constructed of thick concrete blocks, and was 40-45 years old so infiltration through cracks was likely. Furthermore, operable windows on one wall were seldom recorded on the "classroom checklist" as used. Indeed, the teacher usually had the blinds down and drawn and/or artwork on some of them.

Table 3.1.3.3 and 3.1.3.4 compared final measured AER from the UCLA PCS with the existing ASHRAE 62 (1999) ventilation standard of 15 $ft^3\ min^{-1}\ person^{-1}$ in SD 1 and SD 2, respectively. For the purposes of these analyses, the assumption was 20 students and one teacher occupied the classroom, given class size reduction initiatives for grades K-3. Actual expected classroom occupation levels covered a range of values, with actual daily attendance likely to vary over a school year. These data suggested how the standard was not met for any of the classrooms except one, the previously described older portable in SD 2, as indicated by the low measured AER in both seasons. A CEC investigation (1995) of California schools and other non-residential buildings found measured AER in about 33% of classrooms tested were < 50% of the level required by state codes and ASHRAE for ventilation. Reasons for the generally observed low AER, and supported by the comparison, were likely limited or no use of operable windows and/or the mechanical HVAC system during school hours. Doors were likely closed for security reasons or to minimize the impact of ambient noise. In the UCLA PCS, SDIA samples from two classrooms in SD 1 in the second sampling event in the cooling season, a portable housing a library and a main building classroom, were within 10-20% of the standard. Of the windows in these two rooms, only a few small ones well out-of-reach of the teachers were operable, but each room did have two doors to the outside usually observed and recorded on the "classroom checklist" as kept open by those teachers.

Table 3.1.3.3: Comparison of final measured AER with existing ventilation standard, assuming 20 students and one teacher occupy the classroom given class size reduction initiatives for grades K-3, SD 1 (A), UCLA PCS.

<- NUMERATOR DENOMINATOR ->

School	Room #	Room type	Visit#	FINAL, T corrected in ng./min. Rperm	ID# of CAT used	2, two ends open in L/hr. collection rate, Rcat	in min. exposure time, Tcat	(classroom) volume, ft.3	volume, L	Volume PMCH on CAT, ng (from pL)	AER, 1/hr	AER in equivalent ft3/hour (ASHRAE, for 20 students & 1 teacher, 315 ft3/min = 18900 ft3/hr)	AER in equivalent ft3/min (ASHRAE, for 20 students & 1 teacher, 315 ft3/min)	Yes or No or Yes, exceeds Comply with ASHRAE 62-1999 (62-1989)?	Technician field notes, from data sheets or classroom diagram
1	1	P	1	741	13623	0.016616	6267	7554.4	213789.5	2.21	0.2	1232	21	NO	
1	0	M.B.	1	736	15180	0.016616	6269	8231.8	232959.9	0.25	1.3	10767	179	NO	
2	1	P	1	733	12729	0.016616	6188	11805.4	334092.8	2.55	0.1	1181	20	NO	
2	0	M.B.	1	698	336	0.016616	6193	9695.8	274391.1	0.55	0.5	4596	77	NO	
3	1	P	1	723	10074	0.016616	6130	7826.8	221498.4	2.89	0.1	900	15	NO	
3	2	P	1	821	16752	0.016616	6135	11067.0	313196.1	0.66	0.4	4427	74	NO	
3	3/Lib.	P	1	754	3736	0.016616	6226	13650.3	386303.5	0.52	0.4	5277	88	NO	
3	0	M.B.	1	799	347	0.016616	6123	8224.2	232744.9	0.92	0.4	3107	52	NO	
field blank	1	Put in P.22	1	741	15354	0.016616	0	7554.4	213789.5	0.00	0.0	N/A	N/A		
field dupl.	3/Lib.	P	1	747	10109	0.016616	6226	13650.3	386303.5	0.52	0.4	5239	87	NO	
1	1	P	b2	855	3018	0.016616	2505	7554.4	213789.5	0.22	0.8	5778	96	NO	
1	0	M.B.	b2	751	10276	0.016616	2551	8231.8	232959.9	0.15	0.9	7415	124	NO	
1-- blank	1	Put in P.22	2	855	772	0.016616	0	7554.4	213789.5	0.00	0.0	N/A	N/A		
1	1	P	b2	855	7061	0.016616	2506	7554.4	213789.5	0.23	0.7	5561	93	NO	
1	1	P	a2	855	18266	0.016616	6262	7554.4	213789.5	1.72	0.2	1824	30	NO	
1	0	M.B.	a2	751	551	0.016616	6285	8231.8	232959.9	0.55	0.6	5030	84	NO	
1-- dupl.	0	M.B.	a2	751	296	0.016616	6285	8231.8	232959.9	0.56	0.6	4991	83	NO	
2	1	P	b2	733	10295	0.016616	2215	11805.4	334092.8	0.54	0.2	1771	30	NO	
2	0	M.B.	b2	733	7954	0.016616	2240	9695.8	274391.1	0.16	0.6	5853	98	NO	
2-- blank	1	Put in P.30	2	733	6150	0.016616	0	11805.4	334092.8	0.00	0.0	N/A	N/A		
2	1	P	a2	733	6179	0.016616	6180	11805.4	334092.8	1.38	0.2	1889	31	NO	
2	0	M.B.	a2	733	9826	0.016616	6210	9695.8	274391.1	0.65	0.4	4128	69	NO	
3	1	P	a2	772	17687	0.016616	6218	7826.8	221498.4	4.04	0.1	697	12	NO	
3	1	P	b2	772	15085	0.016616	2361	7826.8	221498.4	1.45	0.1	739	12	NO	
3	2	P	a2	804	8074	0.016616	6240	11067.0	313196.1	0.82	0.3	3541	59	NO	
3	2	P	b2	804	18164	0.016616	2372	11067.0	313196.1	0.23	0.4	4869	81	NO	
3	3/Lib.	P	a2	828	8198	0.016616	6227	13650.3	386303.5	0.38	0.6	7976	133	NO	
3	3/Lib.	P	b2	828	16853	0.016616	2350	13650.3	386303.5	0.06	1.3	17726	295	NO (within 10%)	due to two open doors? no windows
3	0	M.B.	a2	773	7865	0.016616	6228	8224.2	232744.9	0.99	0.3	2862	48	NO	
3	0	M.B.	b2	773	10472	0.016616	2393	8224.2	232744.9	0.07	1.8	15178	253	NO (within 20%)	due to open door? no windows used

Table 3.1.3.4: Comparison of final measured AER with existing ventilation standard, assuming 20 students and one teacher occupy the classroom given class size reduction initiatives for grades K-3, SD 2 (B), UCLA PCS.

			<- NUMERATOR			DENOMINATOR ->								
			FINAL, i.e., T corrected in ng./min.		0.008308*2, two ends open in L/hr.	in minutes (of classroom)					(L3*I3)	(L3*I3)/60	Yes or No or Yes, exceeds	
School	Room type, No.	Visit#	Rperm	ID# of CAT used	Rcat	exposure time, Tcat	volume, ft.3	volume, L	Volume PMCH on CAT, ng (from pL)	AER 1/hr	AER in equivalent ft3/hour (ASHRAE, for 20 students & 1 teacher, 315 ft3/min = 18900 ft3/hr)	AER in equivalent ft3/min (ASHRAE, for 20 students & 1 teacher, 315 ft3/min)	Comply with ASHRAE 62?	Technician field notes, from data sheets or classroom diagram
3	M.B.	1	910.6	7276	0.016616	6229	9245.8	261656.1	1.13	0.3	2959	49	NO	
3	P2	1	772	8888	0.016616	6226	12042.2	340794.3	1.1	0.2	2529	42	NO	
3	P1	1	840.5	16295	0.016616	6226	6958.3	196919.9	0.08	5.4	37436	624	YES, exceeds	2 doors open, 2 fans on
4	P2	1	870.7	9149	0.016616	6253	9160.2	259233.7	0.39	0.9	8244	137	NO	older--cracks in bldg envelope?
4	P1	1	818.7	7200	0.016616	6261	8834.4	250013.5	0.25	1.4	11926	199	NO	
4	M.B.	1	818.6	9180	0.016616	6252	12559	355419.7	0.06	3.8	47724	795	YES, exceeds	doors to hallway not outside
2	P2	1	756.6	9160	0.016616	6257	12707.6	359625	0.66	0.3	4194	70	NO	
2	P1	1	782.8	11078	0.016616	6257	11339	320893.8	1.09	0.2	2721	45	NO	
2	M.B.	1	839.1	9230	0.016616	6261	9614.8	272098.8	1.05	0.3	2981	50	NO	door to hallway and to outside
2-- field duplicate	P2	1	816.7	11017	0.016616	6257	12707.6	359625	0.72	0.3	4194	70	NO	
2--field blank	M.B.	1	839.1	15738	0.016616	0	9614.8	272098.8	0	0.0	N/A	N/A		
1	P1	1	812.4	18284	0.016616	6149	20860	590338	0.65	0.2	4589	76	NO	
1	P2	1	728.3	9212	0.016616	6169	13938.4	394456.8	1.04	0.2	2509	42	NO	
1	M.B.	1	791.5	18532	0.016616	6193	7273.8	205848.5	0.71	0.6	4073	68	NO	
3	M.B.	a2	695.8	8975	0.016616	6213	9245.8	261656.1	0.74	0.4	3421	57	NO	
3	M.B.	b2	695.8	6387	0.016616	2349	9245.8	261656.1	0.19	0.6	5178	86	NO	
3	P2	a2	718.1	13378	0.016616	6218	12042.2	340794.3	1.52	0.1	1686	28	NO	
3	P2	b2	718.1	9245	0.016616	2389	12042.2	340794.3	0.5	0.2	2047	34	NO	
3	P1	a2	628.7	15743	0.016616	6210	6958.3	196919.9	0.24	1.4	9394	157	NO	
3	P1	b2	628.7	9020	0.016616	2345	6958.3	196919.9	0.04	2.9	20179	336	YES	lower than cooling season; 2 doors open but not 2 fans, plus cracks in bldg envelope?
2	P2	a2	720.9	15879	0.016616	6219	12707.6	359625	0.9	0.2	2923	49	NO	
2-- field duplicate	P2	a2	720.9	9273	0.016616	6219	12707.6	359625	0.86	0.2	3050	51	NO	
2	P2	b2	720.9	9211	0.016616	2380	12707.6	359625	0.23	0.3	4321	72	NO	
2	P1	a2	635.5	15948	0.016616	6225	11339	320893.8	1.19	0.2	1928	32	NO	
2	P1	b2	635.5	6678	0.016616	2381	11339	320893.8	0.27	0.3	3288	55	NO	
2-- field duplicate	P1	b2	635.5	19014	0.016616	2381	11339	320893.8	0.21	0.4	4082	68	NO	
2	M.B.	a2	702.2	7056	0.016616	6262	9614.8	272098.8	0.94	0.3	2692	45	NO	door to hallway and to outside
2	M.B.	b2	702.2	8461	0.016616	2434	9614.8	272098.8	0.2	0.5	5000	83	NO	door to hallway and to outside
2-- field blank	M.B.	2	702.2	15700	0.016616	0	9614.8	272098.8	0	0.0	N/A	N/A		
3	P1	a2	760.4	9081	0.016616	6225	20860	590338	0.64	0.2	4172	70	NO	
3	P1	b2	760.4	5283	0.016616	2364	20860	590338	0.2	0.3	5215	87	NO	
3--field blank	P1	2	760.4	7494	0.016616	0	20860	590338	0	0.0	N/A	N/A		
3	P2	a2	720.6	11035	0.016616	6212	13938.4	394456.8	0.84	0.2	3066	51	NO	
3	P2	b2	720.6	18669	0.016616	2356	13938.4	394456.8	0.14	0.5	6969	116	NO	
3	M.B.	a2	690.2	15956	0.016616	6228	7273.8	205848.5	0.54	0.6	4655	78	NO	
3	M.B.	b2	690.2	11045	0.016616	2421	7273.8	205848.5	0.11	1.2	8583	143	NO	

Shaughnessy et al (1997) reported on an intervention study concerning energy, ventilation and IAQ in two adjacent classrooms with inoperable windows and no outside air intakes in each of two, year-round elementary schools in Las Vegas, NV in the cooling season for two one-week periods. Classrooms at one school were in the wing of a main building, and at the other school were portables; the portables had wall-mount HVAC systems as well as manually operated auxiliary window air conditioning units. One classroom at each school was a control and the other received an energy recovery ventilator and had outdoor air supply vents and ducts opened. The baseline conditions measured included AER, based on tracer gas decay (SF_6, ASTM E741-93, B&K 1302 Multi-gas analyzer), of 0.2 hr^{-1} for both main building classrooms and 0.7^{-1} for both portables. The measured AER in portables were likely higher due to the combined use of the HVAC system and the window air conditioner, given the normal ambient conditions were T > 100 °F (38°C) and RH <20%. These low measured AER generally agreed with UCLA PCS cooling season results.

Turk et al (1997) conducted an intervention study in three 50-60 year old, single-story buildings at a Santa Fe, NM elementary school to assess the impact of mechanical ventilation on IEQ in rooms previously outfitted with only operable windows and a door leading to the outside. The parameters included AER, determined by measurements in two classrooms during occupancy for up to 3.5 morning hours on Wednesdays and Thursdays over five weeks using the same tracer gas technique as Shaughnessy et al (1997). The technique was comparable to the UCLA PCS but of shorter sampling duration. In one building, when windows and doors were closed and the mechanical

HVAC was on, or when windows and doors were open but only the HVAC system's heat recovery ventilator fan supplied air, the average AER was 2.1 hr^{-1}; the measured AER was 0.6 hr^{-1} before the intervention. In another building, when windows and doors were closed or open and the mechanical HVAC system was on, the mean measured AER was 3.0 hr^{-1}; before the intervention, regardless of window or door status, the mean measured AER was 1.2 hr^{-1}. The control building mean measured AER was 0.7 hr^{-1}. The pre-intervention and control building AER measurements generally agreed with mean measured AER in UCLA PCS main building classrooms, but were higher than some individual UCLA PCS samples.

Smedje and Norback (1999) investigated indoor exposures for one day in 181 main building school classrooms, 2-5 per school, in 57 different buildings at 39 of 40 randomly selected public elementary schools, and the nine secondary schools, in the county of Uppsala, Sweden in 1993-95. Quantitative measures were compared and regressed against technician walk-through and custodian interview survey collected data. The median (25^{th}-75^{th} interquartile range) measured AER were 2.6 h^{-1} (0.9-4.2 hr^{-1}), which suggested ventilation in these Swedish schools was better than in LA County schools included in the UCLA PCS. Furthermore, controlling for season, AER was the main classroom exposure factor predictor ($r = -0.558$, $p<0.001$).

Thorstensen et al (1990) conducted a study in greater Copenhagen, Denmark which combined trained expert judgement of IAQ, a student survey, a checklist including classroom and building characteristics, and selective quantitative short-term monitoring in one of 2-9 main building classrooms at each of ten schools over a five-day period in

March 1989, followed by ventilation rate measurements in May-June 1989. Eight of the ten schools had one of three mechanical HVAC system configurations also found in the U.S., of which 75% had exhaust and supply air and 25% circulated air. The measured mean (range) AER were 0.85 hr^{-1} (0-2.47 hr^{-1}). Compared to main building classrooms in the UCLA PCS, the range was wider and mean was higher. Given the shorter time period assessed, 10-120 minutes, differences may have been in part due to influences of time-activity patterns and occupant operation of the mechanical HVAC systems in response to different ambient conditions.

A pilot study of IAQ in a Parisian suburb including one elementary school (Riberon et al, 2002) assessed IAQ and the affect of occupant behavior and mechanical versus operable window-based natural ventilation. The measured AER, estimated from CO_2 concentration decays, were ~0.4 hr^{-1} in mechanically ventilated classrooms and 0.1-0.6 hr^{-1} in classrooms with only operable windows. These limited data agreed with the low mean values by sample type across seasons during the UCLA PCS, which included similar ventilation scenarios across classroom types.

In a study of 28 main building classrooms in 24 randomly selected schools in Warsaw, Poland (Sowa, 2002), estimated AER measurements from CO_2 decays using validated afternoon and overnight concentration data from 21 of 27 classrooms ranged 0.2-1.0 hr^{-1}. These classrooms, 16 in elementary schools, appeared to have little or no ventilation provided naturally through operable windows. Again, though methods differed, the measured AER were similar to the range of values reported by the UCLA PCS for main building classrooms across seasons and sample types.

The Norwegian project "Indoor Environment in Schools" (Myhrvold and Olsen, 1997) included 35 main building classrooms from eight schools; quantitative IEQ monitoring was conducted during the late winters of 1994-96. This study reported how regardless of interventions or the type of HVAC system and/or natural ventilation present, adherence with Norwegian and ASHRAE 62 (1999) guidelines for indoor CO_2 concentrations (< 1000 ppm) required an AER of 0.2 $person^{-1}$ hr^{-1} or an outdoor air ventilation rate of 9 L s^{-1} $person^{-1}$. This ventilation rate, determined with the field measures, was higher than the 7.5 L s^{-1} $person^{-1}$ specified in ASHRAE 62 (1999). The typical dimensions of the classrooms in this study (60 m^2 area, 2.7 m floor-to-ceiling), however, were larger than portables and main building classrooms assessed in this dissertation.

Kurnitski and Enberg (1997) also calculated ventilation rates per person in their study of IEQ in relation to ventilation system type in Finnish schools. 56 classrooms in ten schools were included in the more comprehensive first phase, and one classroom in each of ten schools in the second phase to collect integrated mass and continuous count data on particles over an entire school day versus just one 45 minute class. The average classroom dimensions were similar to those previously described in the study by Myhrvold and Olsen (1997). Across ventilation systems, the average of the mean measured ventilation rates, derived from exhaust flow measurements, was 3.5 L s^{-1} $person^{-1}$. For the natural ventilation system, the value was 1.6 L s^{-1} $person^{-1}$, and for the mechanical supply and exhaust system, similar to HVAC units typical of American portables, the value was 5.5 L s^{-1} $person^{-1}$. Finland's guideline value was 6 L s^{-1} $person^{-1}$.

Therefore, the Finnish, the Norwegian, and the ASHRAE 62 (1999) guidelines were not achieved. These data concurred with the interview and technician walk-through questionnaire results from 32 schools in phase three, which suggested the most common problem, besides signs of water damage, was the old-fashioned or missing ventilation systems.

Thorstensen et al (1990) reported a mean (range) ventilation rate of 5.5 L s^{-1} $person^{-1}$ (1.5-10.0 L s^{-1} $person^{-1}$) based on measurements conducted at six of eight schools with mechanical HVAC systems. The mean value was also below existing American and Northern European standards.

Measured CO_2 concentrations and questionnaire responses about classroom odors may be considered indicators of inadequate ventilation in indoor microenvironments. Thus, given the relative lack of information about school environments, such data may be compared with empirical AER from the UCLA PCS.

A European Union task force (EFA project) examined policies, preventive programs, and existing data from 73 journal papers or conference proceedings presented during 1990-2000 on IEQ in European schools (Carrer et al, 2002). Their main findings were inadequate ventilation indicated by elevated CO_2 concentrations and RH.

TESIAS (Corsi et al, 2002) found no statistically significant differences for mean school-day and peak CO_2 concentrations between portable and main building classrooms, or when data were separated by teacher responses to questions regarding classroom odors. Teachers from 30 randomly selected schools in two SD reported “sometimes” or “frequently” detecting metabolic-related odors, food odors, perfumes, and/or chemical cleaners and air fresheners. Given ~2/3 of the 115 classrooms assessed had school-day averaged CO_2 concentrations above the ASHRAE 62 (1999) guideline value of 1000 ppm, TESIAS data were similar to UCLA PCS data with respect to the prevalence of inadequate ventilation.

An IAQ study during occupied hours in four main building classrooms of a few K-12 schools was conducted in the city of La Coruña, Spain in winter 1996 to assess natural ventilation by manually-operated windows (Rodríguez et al, 1997). In the K-1st grade and 6th grade classrooms daily CO_2 concentration profiles suggested natural ventilation was inadequate relative to ASHRAE 62 (1999).

The UCLA PCS conducted measurements of AER integrated over different time periods due to the method employed, available resources, and practical limitations. AER, however, may vary, especially during the school day, due to HVAC system operation, use of doors and/or operable windows if present, and occupant time-activity patterns. Measurements of indoor air T and RH also exhibit diurnal variation, which will be discussed.

3.1.4 Indoor Air T and RH

Table 3.1.4.1 is a summary of descriptive statistics for 2000-01 cooling season indoor air T (°F) and RH (%) by SD from continuous measurements conducted during the UCLA PCS. Table 3.1.4.2 presents results in a similar manner for SD 2 from the winter 2001 heating season. Data points were logged as five-minute averages. For integrated averages, these data were stratified into two time periods separated by the lunch and recess break: AM, data point with 7:45-data point with 11:15; and, PM, data point with

11:15-data point with 14:45. These intervals included times teachers may have worked alone or in meetings. Integrated averages for periods matching the integrated air sample types, SWIA and SDIA, were also calculated. Data could be compared with ASHRAE Standard 55 (1992) acceptable comfort ranges for people in typical clothing during light, primarily sedentary activity in the cooling season-- 73-74°F (23°C) to 78-81°F (26-27°C), 30-60% RH-- and in the heating season-- 68-69°F (20°C) to 74-76°F (23-24°C), 30-60% RH-- even though the UCLA PCS did not include a rigorous thermal comfort assessment.

Table 3.1.4.1: Seasonal summary for cooling season sampling periods, 2000-01, indoor air temperature (degrees F) and relative humidity (RH, %), UCLA PCS

SD 1(A) and SD 2(B) portables
Temperature (degrees F)

		Weekday AM	Weekday PM	SWIA [1]	SDIA [2]
conventional HVAC weeks	mean	72.6	75.4	73.9	73.9
	median	72.8	75.2	73.8	74.1
	min	54.8	64.9		
	max	82.2	86.6		

SD 1(A) and SD 2(B) main building (MB) classrooms
Temperature (degrees F)

		Weekday AM	Weekday PM	SWIA	SDIA
conventional HVAC weeks	mean	73.4	74.9	74.5	74.1
	median	73.5	74.8	74.5	74.2
	min	67.0	54.1		
	max	82.2	86.6		

SD 1(A) and SD 2(B) portables
RH (%)

		Weekday AM	Weekday PM	SWIA	SDIA
conventional HVAC weeks	mean	57.9	52.4	53.5	54.9
	median	57.0	53.1	53.7	54.8
	min	36.6	26.8		
	max	82.1	80.3		

SD 1(A) and SD 2(B) MB classrooms
RH (%)

		Weekday AM	Weekday PM	SWIA	SDIA
conventional HVAC weeks	mean	55.1	55.5	54.2	54.9
	median	55.6	54.7	54.2	54.8
	min	34.1	29.0		
	max	74.1	78.0		

1 = SWIA, school week integrated average, Monday AM to Friday PM and overnights
2 = SDIA, school day integrated average, Monday AM to Friday PM, no overnights

Table 3.1.4.2: Seasonal summary for heating season, winter 2001, indoor air temperature (degrees F) and relative humidity (RH, %), UCLA PCS

SD 2(B) portables
Temperature (degrees F)

		Weekday AM	Weekday PM	SWIA [1]	SDIA [2]
conventional HVAC weeks	mean	67.2	69.7	66.9	68.4
	median	67.5	69.3	66.8	68.5
	min	29.0	33.6		
	max	81.5	82.2		

SD 2(B) main building (MB) classrooms
Temperature (degrees F)

		Weekday AM	Weekday PM	SWIA	SDIA
conventional HVAC weeks	mean	66.9	70.1	66.9	68.2
	median	67.4	69.4	66.9	68.4
	min	35.4	34.9		
	max	79.4	84.4		

SD 2(B) portables
RH (%)

		Weekday AM	Weekday PM	SWIA	SDIA
conventional HVAC weeks	mean	51.8	52.7	54.2	53.4
	median	53.6	53.2	54.4	53.5
	min	29.0	29.5		
	max	79.4	71.3		

SD 2(B) MB classrooms
RH (%)

		Weekday AM	Weekday PM	SWIA	SDIA
conventional HVAC weeks	mean	50.7	49.1	52.6	51.4
	median	51.0	50.0	52.8	51.5
	min	31.8	25.7		
	max	69.4	62.8		

1 = SWIA, school week integrated average, Monday AM to Friday PM and overnights
2 = SDIA, school day integrated average, Monday AM to Friday PM, no overnights

In the cooling season across SD, the mean and median T were similar across sample types and room types; measurements for the PM were slightly higher than for the AM. Overall, the data were narrowly distributed and the maximum five-minute average T in the AM and PM were the same. For each time period considered, the mean and median T were within the ASHRAE 55 (1992) acceptable comfort range for the cooling season, but minimum five-minute average T were below it and maximum values exceeded the upper bound. The mean and median SDIA RH were slightly higher than the corresponding SWIA values, likely due to the influence of occupants. In portables, mean and median RH values were higher in the AM than in the PM, likely related to the opposite trend observed for T; in main building classrooms, AM and PM averaged RH were similar. During school hours mean and median RH values were within the upper bound of the ASHRAE 55 (1992) acceptable comfort range for the cooling season. As with T, however, the minimum five-minute average RH values were below the range and the maximum values exceeded the upper bound.

In the heating season in SD 2, across time periods considered, mean and median T were nearly identical for main building and portable classrooms, but minimum five-minute average T were lower in portables. Maximum five-minute average T were likely driven by the use of the HVAC system or wall heater, if present, to meet heating demand in occupied classrooms; windows and doors were usually observed to be closed due to the cool, rainy weather during the UCLA PCS. As in the cooling season, minimum five-minute average T values were below, and maximum values exceeded the upper bound of the ASHRAE 55 (1992) acceptable comfort range. The mean and median AM T values were also below the range, but PM T values were just above the lower bound. In each time period considered, mean and median RH values were slightly higher in portables than in main building classrooms, and maximum five-minute average RH values in portables were ~10% RH greater than corresponding measures in main building classrooms. Across room types, AM and PM mean and median RH values were similar, but AM maximum five-minute RH values were higher than in the PM. This was likely because of the cool and rainy weather and the incoming occupants; heating by the HVAC system or wall heater, if operated, would not have had an immediate effect in drying out the indoor air. Except for the AM in main building classrooms, minimum five-minute average RH values were again below the ASHRAE 55 (1992) acceptable comfort range; as with T, maximum five-minute RH values exceeded the upper bound, especially in portables in the AM. Mean and median RH in the AM and PM, however, were within the range.

Table 3.1.4.3 compared the T recorded on the "classroom checklist" from the thermostat, typical classroom T set points reported by the head custodian during the "O&M" interview questionnaire, and the average measured AM and PM T. Data were stratified by SD, season, school, and room type and classroom number. The measured mean AM and PM indoor air T were within the range observed by the technician except for two classrooms where measured values were slightly higher; in two classrooms, no thermostat was present and in another it was broken. The reported typical HVAC thermostat T set points, if not "per teacher preference," were slightly lower than the

Table 3.1.4.3: Comparison of observed (on HVAC thermostat), head custodian reported, and average measured temperatures (T, in degrees F) in portable (P) and main building (MB) control classrooms, School Districts (SD) 1 and 2, UCLA PCS and SD 3 and 4, LBNL RCS.

		COOLING SEASON, early June or Sept				HEATING SEASON, late Feb-early Mar			
SD	School, Type, No.	Reported "standard" HVAC thermostat A/C settings, head custodian (O&M Qx)	Observed HVAC thermostat T range by field technician	Measured arithmetic mean AM indoor T	Measured arithmetic mean PM indoor T	Reported "standard" HVAC thermostat heat settings, head custodian (O&M Qx)	Observed HVAC thermostat T range by field technician	Measured arithmetic mean AM indoor T	Measured arithmetic mean PM indoor T
1	1, MB		68-73	70.8	71.3				
1	1, P	68-70	68-77	73.3	73.3	75-80			
1	2, MB		69-72	70.4	71.4				
1	2, P	65	64-72	68.8	71.4	65			
1	3, MB		72-83	71.9	73.2				
1	3, P, 1	64-65	65-75	71.7	73.3	72-75			
1	3, P, 2	64-65	68-74	75.2	78.9	72-75			
1	3, P, 3	64-65	71-84	74.3	77.2	72-75			
2	1, MB		55, broken?	74.8	76.5		55-56, broken?	66.8	68.9
2	1, P, 1	68	71-82	72.0	75.7	65	60-82	68.7	72.6
2	1, P, 2	68	76	72.8	73.1	65	57-76	68.4	70.9
2	2, MB		75-80	75.2	76.1		59-78	68.4	71.5
2	2, P, 1	per teacher preference	72-81	72.5	72.1	68	55-72	66.0	69.5
2	2, P, 2	per teacher preference	69-78	70.9	72.9	68	51-70	70.4	69.8
2	3, MB			76.9	80.6		57-69	65.4	69.9
2	3, P, 1	72	63-84	73.3	79.1	72	52-69	63.0	65.2
2	3, P, 2	72	68-78	71.4	75.0	72	57-75	66.4	70.4
2	4, MB		70	73.9	75.4				
2	4, P, 1	not known	75-81	73.0	80.6				
2	4, P, 2	not known		74.6	77.0				
3	8, P, A	per teacher preference	60-70 (C [1]), 63-74 (I [2])#	70.4 (C [1]), 69.4 (I [2])	73.4 (C), 70.6 (I)	68-72	45-69 (C), 64 72 (I)#	64.1 (C), 69.1 (I)	67.6 (C), 68.3 (I)
3	8, P, B	per teacher preference	60-70 (C), 60-70 (I)#	69.6 (C), 67.7 (I)	73.3 (C), 70.7 (I)	68-72	42-64 (C), 60 68 (I)#	64.3 (C), 66.5 (I)	67.3 (C), 66.7 (I)
4	7, P, A	75	65-74 (C), 60-75 (I)#	73.4 (C), 71.1 (I)	75.2 (C), 73.7 (I)	65-68	53-70 (C), 64 69 (I)	69.8(C), 70.5 (I)	71.1 (C), 70.4 (I)
4	7, P, B	75	64-76 (C), 60-74 (I)#	69.9 (C), 69.4 (I)	73.5 (C), 71.8 (I)	65-68	53-70 (C), 62 68 (I)#	66.1 (C), 68.3 (I)	67.6 (C), 69.4 (I)

NOTE: SD 1 cooling season was representative of two different sampling periods in the cooling season.

1 = C, conventional HVAC operated

2 = I, advanced HVAC (IDEC) operated

[shaded] data not available

= few observations < 60, I sometimes set back overnight to save energy but to minimum (50) was accident especially in cooling season

technician observed ranges. In most cases, technician observations were recorded before and after students were present in the classroom. After school, however, teachers were usually present. The wide range of observed T reflected changes in occupant preferences for operation of the HVAC system, wall heater and/or operable windows based on ambient conditions and activities; the teacher or the central office controlled the thermostat. As a result, there was variability in measured classroom thermal comfort parameters during a school day and over a week across seasons, SD, schools, and room types. Refer to Appendix A.4.5 about T data and Appendix A.4.6 about RH data.

Figures 3.1.4.1, 3.1.4.2, 3.1.4.3, and 3.1.4.4 were typical profiles of diurnal and weekly variation in T and RH measured during the UCLA PCS with the HOBO H8 Pro and BoxCar software. Figure 3.1.4.1 and Figure 3.1.4.2 were for a newer portable in SD 2 during the cooling season and heating season, respectively. Figure 3.1.4.3 and Figure 3.1.4.4 were for an older portable in SD 2 during the cooling season and heating season, respectively. The red and blue lines on the figures represented the aforementioned upper and lower bounds, respectively, of the season-specific ASHRAE 55 (1992) acceptable comfort ranges for T and RH. The variability of T and RH was driven by the influence of occupants, opening and closing of doors, and potential use of operable windows, HVAC systems, and/or wall heaters. Variability appeared more pronounced on weekdays than during weekends, especially for RH. Periods of time on weekdays when T and RH were relatively steady in the newer portable in both seasons and in the older portable in the heating season likely indicated use of the HVAC system and the wall heater, respectively. In contrast, during unoccupied periods, ambient conditions appeared to drive T and RH inside classrooms; T steadily declined and RH steadily increased in the heating season, while in the cooling season T increased in the late afternoon then decreased overnight and RH followed opposite trends. These observations would be relevant to a complete quantitative and subjective thermal comfort assessment following ASHRAE 55 (1992).

Figure 3.1.4.1: Typical profile of T and RH data with HOBO H8 Pro and BoxCar v.3.5/4.0 programs, newer portable, SD 2, cooling season, UCLA PCS

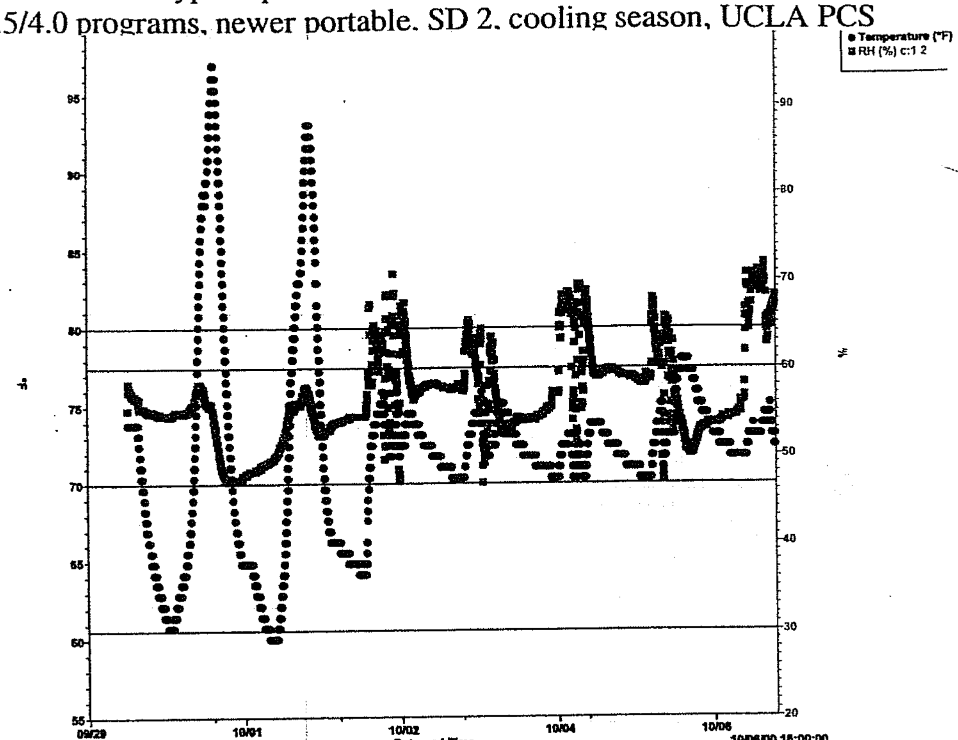


Figure 3.1.4.2: Typical profile of T and RH data with HOBO H8 Pro and BoxCar v.3.5/4.0 programs, newer portable, SD 2, heating season, UCLA PCS

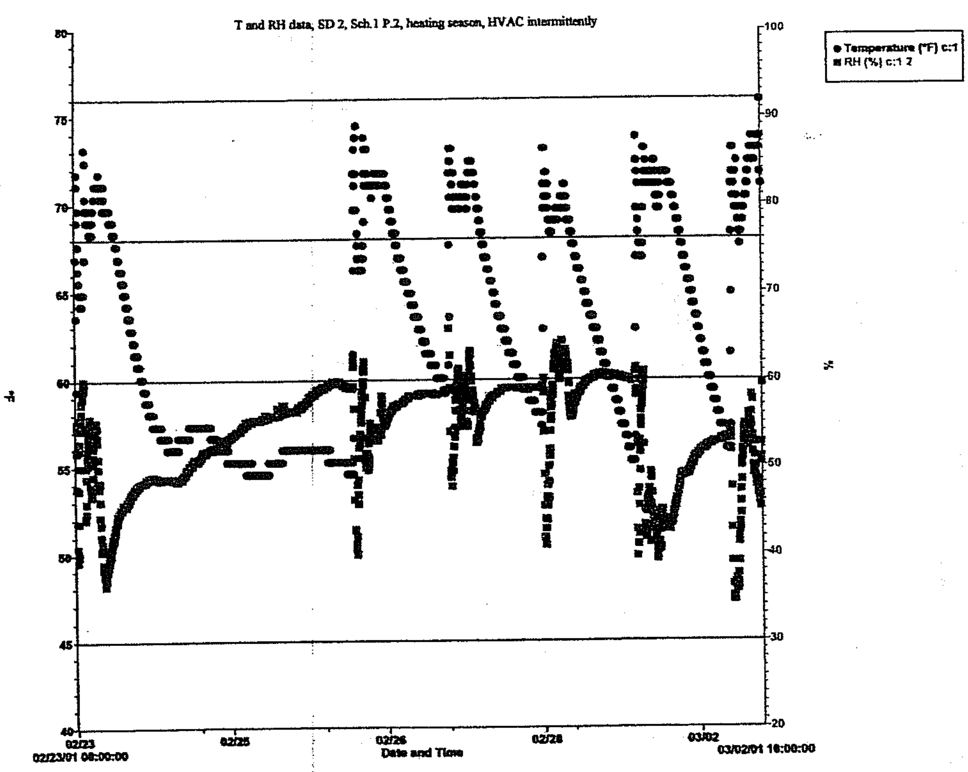


Figure 3.1.4.3: Typical profile of T and RH data with HOBO H8 Pro and BoxCar v.3.5/4.0 programs, older portable, SD 2, cooling season, UCLA PCS

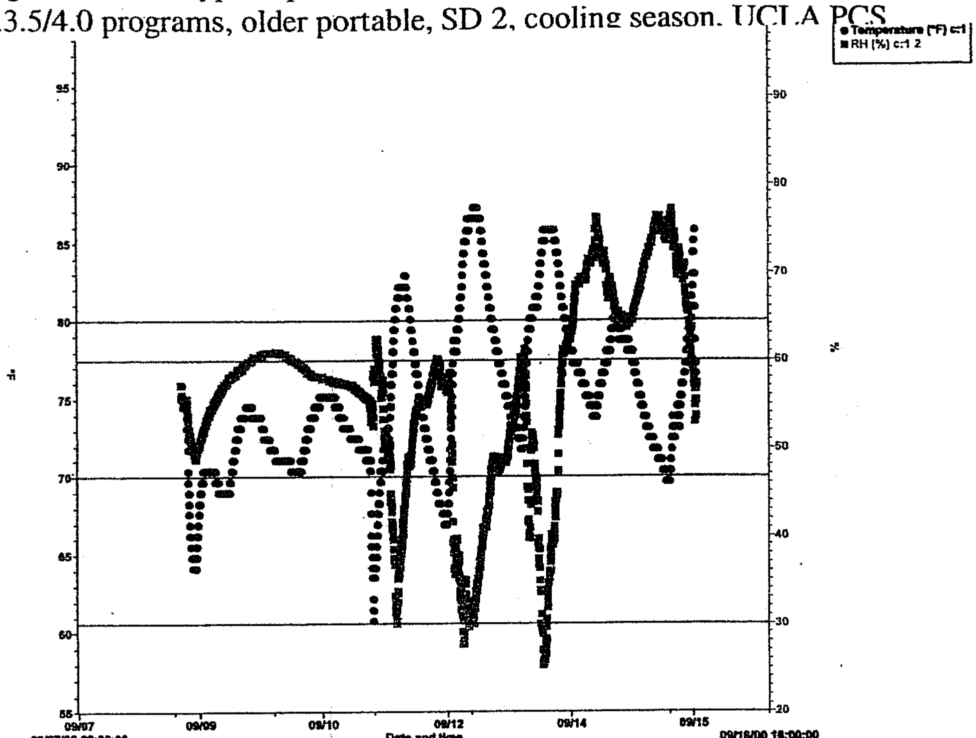
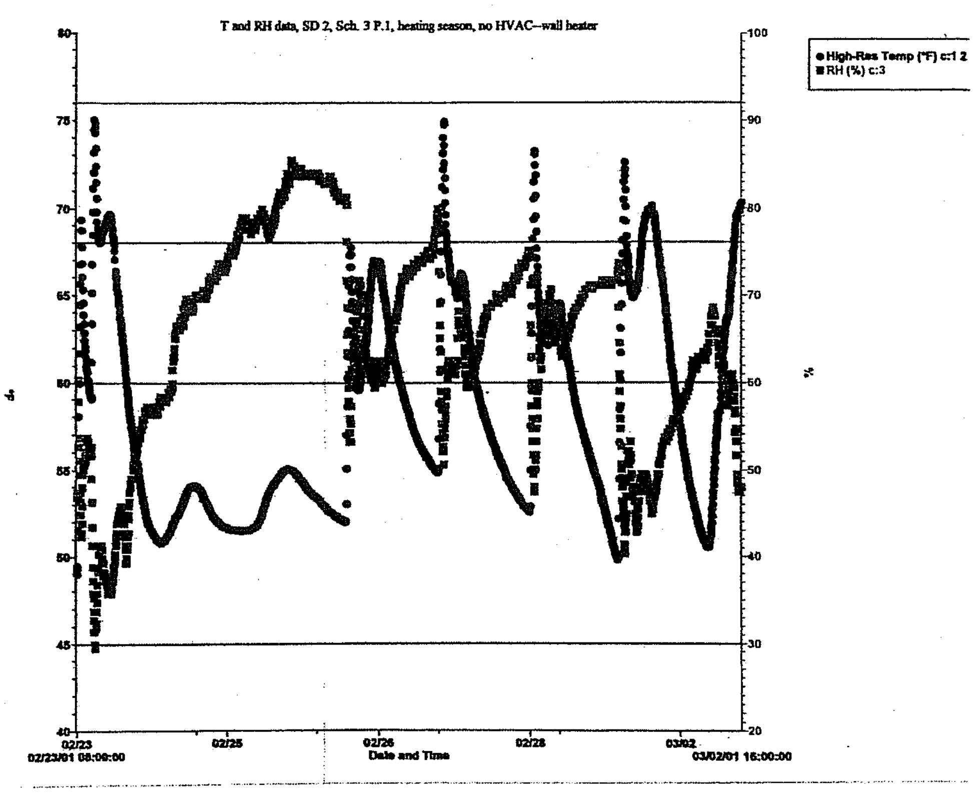


Figure 3.1.4.4: Typical profile of T and RH data with HOBO H8 Pro and BoxCar v.3.5/4.0 programs, older portable, SD 2, heating season, UCLA PCS



3.1.5 Carbon Monoxide (CO) Concentrations, Winter Heating Season, SD 2

Table 3.1.5.1 presents descriptive statistics for CO concentrations inside SD 2 portables, for measurement periods including two school days, during the heating season sampling period February-March 2001. The ranges of mean and median values, which were nearly identical for each classroom assessed, were 0-2 ppm. With the same AM and PM definitions used with the T and RH data, mean CO concentrations were consistently higher in the AM than in the PM, and usually higher than in the overnight period. Minimum values were zero and the maximum recorded five-minute averages ranged from 0.65 to 2.65 ppm. These data may be explained by the cool, rainy ambient conditions, a minimal impact by nearby outdoor sources, and the infrequent use of the electric heat pump HVAC systems in newer portables and of the wall heaters fueled by electricity and/or natural gas in older portables. In the UCLA PCS, measured CO concentrations during occupied and unoccupied hours were below the ASHRAE 62 (1999) guideline of 9.0 ppm over an eight-hour exposure period for indoor non-occupational microenvironments. The "1st Friday" maximum and relatively higher mean measured CO concentrations in school one portables may have been due to the use of an old, likely inefficient wall heating unit or the HVAC system intake which faced an area where delivery trucks could have remained in idle for a period of time, respectively.

Nikolic (2000) reported on a study of IAQ in two primary schools in Nis, Yugoslavia during 20 consecutive days in the winter, with "school 1" located in an industrial zone near a busy street and "school 2" situated away from major outdoor pollution sources and enclosed by vegetation. The mean ± SD (range) integrated daily indoor CO concentrations in $\mu g\ m^{-3}$ for "school 1" and "school 2," respectively, were 15.7 ± 9.3 (6-27.6) and 13.2 ± 7.6 (25-43). These concentrations were remarkably higher than those measured during the late winter in SD 2 in the Los Angeles County area, where there was rain and most likely higher ambient T as well as different classroom HVAC systems; Nikolic did not describe observed HVAC systems. Furthermore, as with HCHO, measured CO concentrations were relatively higher in "school 1" than in "school 2," likely due to relative proximity to primary and secondary sources.

Fontana et al (2000) reported on measurements conducted for three days during occupied hours in an USEPA school demonstration study on IAQ. Four indoor sites and one outdoor location per school at five public schools were selected; one school was in California in a mild, dry climate zone. Continuous CO measurements were conducted, with instrumentation similar in technology to the UCLA PCS including loggers which recorded data as five-minute averages. One minor difference was the sampling rate was one second, compared to ten seconds in the UCLA PCS. Measured indoor CO concentrations did not exceed the existing guidelines and/or were below the limit of quantification, 2.0 ppm. These data were similar to the low measured winter CO concentrations in UCLA PCS portables.

Table 3.1.5.1: Carbon monoxide (CO) concentrations inside portable classrooms during the heating season (February-March 2001), SD 2, UCLA PCS.

data presented in units of parts per million (ppm)

HIGH RESOLUTION CO[1]	School # (n= 1=3), Portable Classroom # (n=1-2)	1st Friday AM[2]	1st Friday PM[3]	Weekend Fri.PM to Mon.AM	Monday AM	Monday PM	Monday overnight	Tuesday AM	Tuesday PM	Tuesday overnight	Wednesday AM	Wednesday PM	Wednesday overnight	Thursday AM	Thursday PM	Thursday overnight	Friday AM	Friday PM	Friday late PM
Arithmetic Mean																			
	1, 1	1.99	0.28	0.80	0.65	0.25	0.63												
	1, 2	1.34	0.08	0.15	0.51	0.41	0.45												
	2, 1							1.45	0.40	0.23	0.61	0.67	0.47						
	2, 2							0.76	0.20	0.23	0.92	0.69	0.28						
	3, 1												1.14	0.77	0.03	1.05	1.85	0.28	0.00
	3, 2												0.38	0.44	0.19	0.21	1.14	0.91	0.07
Median																			
	1, 1	2.15	0.00	0.80	0.65	0.13	0.65												
	1, 2	1.35	0.00	0.10	0.50	0.40	0.45												
	2, 1							1.60	0.35	0.20	0.70	0.65	0.45						
	2, 2							0.75	0.15	0.25	1.00	0.75	0.30						
	3, 1												1.15	0.40	0.00	1.25	2.00	0.00	0.00
	3, 2												0.40	0.35	0.20	0.20	1.15	0.95	0.00
Maximum Conc.	ALL	2.65	1.20	1.20	1.45	0.65	1.15	2.05	0.85	0.65	1.10	1.00	1.75	1.90	0.30	2.20	2.05	1.25	0.70
Minimum Conc.	ALL	0.20	0.00	0.00	0.00	0.00	0.05	0.25	0.00	0.00	0.00	0.20	0.00	0.15	0.00	0.00	0.50	0.00	0.00

1 = "high resolution CO" measurements with the Langan T15 DataBear CO datalogging monitor were recorded with 0.05 ppm (50ppb) resolution
2 = Let AM = set up until 11:15 AM, about lunchtime
3 = Let PM = 11:15 AM until 3:00 PM, the end of the day for teachers and about 30-45 minutes after students left

3.1.6 Descriptive Results from the "Technician Walk-Through" survey

Table 3.1.6.1 summarizes field observations collected using the UCLA "Technician Walk-Through" survey for public schools. Classroom diagrams were separated and used in the field for recording measurements of dimensions and later for reference (refer to Appendix A.2.3.2). The left-hand column gives the topic or exact question used, and the right-hand column presents the sample sizes considered and observations recorded. The technician estimated distances. The number of student desks or chairs at tables ranged from 16-35 in the main building control classrooms and from 13-40 in the portables. Thus, the class size reduction initiatives appeared to be exceeded regularly or intermittently in these classrooms. During the 366-426 minute school day, if there was no rain or other inclement weather, students were outside the classroom for recess, lunch, physical education, a weekly short assembly, and/or periodic library or science classes approximately 40-135 minutes in SD 1 and 30-90 minutes in SD 2 per day. These data confirmed children spent the majority of the school day indoors, particularly in one classroom. There were no stationary sources of target pollutants in the immediate vicinity of the classrooms, though at one school in SD 2 the HVAC system outdoor air intake of one portable was adjacent to an area where delivery trucks sometimes remained idling. Portables in the UCLA PCS had carpeted floors. Most portables in the UCLA PCS were sited on asphalt. Of the 23% sited on soil, rocks and/or grass, however, if natural cross-ventilation and/or drainage underneath was poor, standing water may have collected in the subfloor crawl space in the winter heating season after rain and thus increased the risk of moisture damage and mold growth.

Table 3.1.6.1: Summary of results from field observations collected using the UCLA "Technician Walk-Through Survey" for public schools. Classroom diagrams have been separated (refer to Appendix A.2.3.2).

Study	**UCLA "Portable Classrooms Pilot Study"** SAMPLE SIZE, N, IN PARENTHESES
QUESTION	
No. of student desks/tables (as an indicator of maximum occupancy)	16-35 (n=7 main building (MB) classrooms) 13-40 (n=13, portables)
No. of hours in school day for students and teacher	6.1-7.1 hours (n=20)
Time in typical activities outside the classroom during the school day:	
Lunch	15-50 minutes, may include extra recess time (n=20)
Recess/physical education	15-40 minutes (n=20)
Other classes, e.g., library skills	10-30 minutes, for example library or science (n=20)
Special assemblies, infrequent	10-15 minutes weekly outside and/or 15-90 minutes on occasion in auditorium, gym, or multipurpose room (n=20)
Was portable raised above ground level?	92% yes (n=13), of which
Surfaces/foundations portables sited on	69% pavement/asphalt, 8% concrete slab, and 23% dirt/soil and pressure-treated wood
Interior floor covering	tiled floors with or without small area rugs (n=7, MB); carpet or carpet and resilient floor tiling (n=13, portables)
Stationary sources within 50 yards	none (n=20)
Stationary sources within 0.5 km	45% gas station, 20% industrial facility, cement factory and gas station 20%, restaurants and gas station 15% (n=20)
Estimated horizontal distance to nearest major primary surface street or freeway	0.1-2.0 miles (freeway), 0.1-0.33 miles (primary arterials) (n=20)
Estimated horizontal distance to school staff parking lot, and to parent/guardian/caregiver pick-up and drop-off area	50-275 feet (n=20), and 50-400 feet (n=20), respectively
Estimated horizontal distance to supply truck loading/unloading area, i.e., diesel-fueled vehicles may be in idle	40% none, 15% 100 yards, 45% 0.5-0.75 miles (n=20)
Estimated horizontal distance to school bus boarding area, i.e., diesel engine buses may be in idle	50-400 feet, and 20% were 0.2 miles from a bus depot (n=20)
Plants and/or flowers present inside the classroom?	85% no, 15% yes with potted plants, e.g., sunflowers (n=20)
Trees, plants and/or flowers present immediately outside classroom windows or doors?	40% no, 60% yes of which 84% trees large and/or small of multiple species, 8% trimmed bushes, 8% small garden (n=20)

NOTE: Six classrooms, I.e., two schools, approximately within one mile of Santa Monica Municipal Airport and flight paths overhead, though it is separated from school sites by hills.

3.2 LBNL RCS

3.2.1 HCHO and CH_3CHO Concentrations Inside Classrooms

3.2.1.1 Field Blanks and Limits of Quantification

Target aldehyde concentrations to be reported in the LBNL RCS data tables were corrected with the mean concentrations of the compounds on the field blanks during each season. There were two field blanks collected in each SD in each season. The mean ± SD of the amount of HCHO and CH_3CHO in nanograms (ng) on the field blanks for the cooling season were 18 ± 13 and 82 ± 46, respectively. The mean amount of HCHO on the field blanks for SD 3 and SD 4 from the heating season were 16.3 ng and 33.5 ng, respectively; the values for CH_3CHO were 21.5 ng and 39.3 ng, respectively. The limits of quantification for the analytic method employed in the LBNL RCS with respect to output from the HPLC computer program (Hewlett Packard ChemStation) were 30.0 ng for HCHO and 40.0 ng for CH_3CHO. For this data set, empirically determined limits of quantification for measured concentrations reported were 3.24 $\mu g\ m^{-3}$ for HCHO and 1.51 $\mu g\ m^{-3}$ for CH_3CHO.

3.2.1.2 Sampling Pumps Performance-Changes in Measured Flow

Appendix A.4.4.1 and A.4.4.2 present a summary of flow rate measurement data used to assess active sampling system pump performance in the cooling and heating seasons, respectively, of the LBNL RCS. The goal for ideal or good pump performance, was an observed change in flow rate from morning to afternoon of ±5%; the bounds of acceptable change in flow rate measurements were designated ±10% unless relatively high morning and/or afternoon measurements were characterized and believed. Overall, across seasons, pump performance did not invalidate any of the samples, including field duplicates. Measurements made in SD 4 on 9/14/01 were likely influenced by the use of different apparatuses for morning (bubble tube) and afternoon (BIOS DryCal) measurements. The relatively high morning flow rate recorded for the outdoor sampling pump in SD 4 on 10/25/01 was likely due to cold overnight T affecting initial operation, even after a twenty minute warm-up, or was a random occurrence. Winter 2002 pump performance data were superior to the fall 2001 cooling season; most of the flow rate changes were less than 5%, and for each sample was less than 10%.

3.2.1.3 Cooling and Heating Seasons, HCHO

Table 3.2.1.3.1 presents the summary of measured HCHO concentrations in $\mu g\ m^{-3}$ indoors and outdoors—by classroom, HVAC system in operation, and SD—for the fall 2001 cooling and winter 2002 heating seasons. Appendix A.4.4.3 and A.4.4.4 provide these measured concentrations also by week as indoor as well as indoor minus outdoor values for the cooling and heating seasons, respectively. Across SD, mean and maximum concentrations did not exceed the CARB (1991) indoor air guideline of~60 $\mu g\ m^{-3}$ for HCHO. The maximum measured concentrations in the cooling season in SD 3 during standard HVAC system operation weeks, and in SD 4 across HVAC systems, were near or exceeded the relevant eight-hour CalEPA/OEHHA acute non-cancer REL of 33 $\mu g\ m^{-3}$. In the heating season, only the maximum values in SD 4 RCs, which were during standard HVAC system operation weeks, exceeded the acute non-cancer REL. In SD 3, measured concentrations in the cooling season were higher in RC B than in RC A, but were slightly higher in RC A than in RC B during the heating season. In SD 4, across seasons, measured concentrations in RC A were higher than in RC B though in the heating season the mean was only slightly higher and the RC B median was greater than the RC A median. Concentrations across seasons, SD and RCs were higher during standard HVAC system operation weeks.

Heating season data not supporting a study hypothesis, which was alternative interior finish materials (RC A) should lead to lower measured indoor HCHO concentrations than standard materials (RC B), and where maximum concentrations exceeded the acute non-cancer REL, were likely due to two main factors. First, the actual operation time of the HVAC systems was frequently variable; continuous ventilation improved IEQ by diluting pollutant concentrations and hastening the new material off-gas process during aging. Second, sources appeared to have been introduced into the RCs after the school year had begun. In SD 4 RC A, small but numerous student dry-erase boards with exposed particleboard backing were discovered. In SD 3 RC A, student art projects completed at home and displayed in the RCs over the second month of the heating season appeared to be constructed of special art materials and adhesives.

Overall, across RCs, measured indoor and indoor minus outdoor HCHO concentrations were higher during standard HVAC system operation weeks, and values in SD 4 exceeded those in SD 3 in part due to higher outdoor background concentrations driven by upwind line sources, especially in the cooling season. Variation in HVAC system operation behaviors and introduced sources were also influences. In the cooling season, the ranges of measured values were similar for IDEC operation weeks, and maximum values during standard HVAC system operation weeks were the highest

Table 3.2.1.3.1: Summary of measured formaldehyde (HCHO) concentrations (ug m^{-3}) indoors and outdoors-- by classroom, HVAC system in operation, and SD-- for the fall 2001 cooling (September 5-October 25) and winter 2002 heating (January 8-March 7) seasons, SD 3 (CUSD) and 4 (MCS), LBNL RCS

			SD 3			Indoor Values			SD 4			Indoor Values		
Parameter	Season	Statistics	RC A (Rm 31)	RC B (Rm 30)	outdoor, at CUSD school	both RCs	during advanced (IDEC) HVAC operation	during conventional (Bard) HVAC operation	RC A (Rm 28)	RC B (Rm 29)	outdoor, at MCS school	both RCs	during advanced (IDEC) HVAC operation	during conventional (Bard) HVAC operation
indoor	cooling	mean	17.4	22.3	3.3	19.8	11.7	28.0	29.2	18.1	5.9	23.7	16.5	32.8
		stdev (SD)	10.4	9.5	0.7	9.9	6.6	4.0	10.3	9.1	1.4	11.0	6.2	8.7
		median	14.7	26.0	3.5	22.7	8.8	29.0	32.2	15.8	6.2	19.2	16.5	34.9
		min	7.0	7.6	2.4	7.0	7.0	20.2	14.2	7.3	3.9	7.3	7.3	15.0
		max	31.2	32.1	4.1	32.1	25.9	32.1	40.0	34.9	8.1	40.0	29.5	40.0
indoor	heating	mean	10.2	9.3	2.8	9.8	6.1	13.5	19.6	18.6	2.5	19.1	9.7	28.5
		SD	5.9	4.6	0.9	5.1	1.4	4.8	13.8	10.2	0.9	11.8	2.9	9.3
		median	8.3	7.2	2.8	7.7	6.0	13.5	13.2	15.4	2.6	14.3	9.8	29.8
		min	4.4	4.2	1.5	4.2	4.2	6.7	5.3	5.3	0.3	5.3	5.3	15.4
		max	22.1	16.2	4.5	22.1	8.3	22.1	45.2	34.3	3.8	45.2	13.2	45.2
indoor-outdoor	cooling	mean	14.1	19.0		16.6	8.6	24.5	23.3	12.2		17.8	10.7	26.9
		SD	10.2	9.5		9.9	6.9	4.0	9.8	8.9		10.7	5.5	8.6
		median	11.2	22.9		19.1	5.8	26.4	24.9	9.4		13.7	10.3	28.9
		min	3.6	4.2		3.6	3.6	16.5	10.3	3.4		3.4	3.4	9.7
		max	27.1	28.6		28.6	23.5	28.6	34.2	28.9		34.2	21.4	34.2
indoor-outdoor	heating	mean	7.5	6.6		7.0	3.4	10.7	17.2	16.2		16.7	7.6	25.9
		SD	5.4	4.3		4.8	1.1	4.1	13.3	9.6		9.9	1.9	8.8
		median	5.7	4.3		4.9	3.3	10.8	10.2	13.3		9.9	7.8	27.3
		min	2.3	2.1		2.1	2.1	4.4	5.0	5.0		5.0	5.0	13.3
		max	17.6	13.4		17.6	5.5	17.6	41.4	30.5		41.4	10.2	41.4

observed. T-tests and correlation coefficients may further clarify the role of HVAC systems, interior finish materials, SD, and seasons.

3.2.1.4 Cooling and Heating Seasons, CH_3CHO

Table 3.2.1.4.1 gives a summary of measured CH_3CHO concentrations in $\mu g\ m^{-3}$ indoors and outdoors—by classroom, HVAC system in operation, and SD—for the fall 2001 cooling and winter 2002 heating seasons. Appendix A.4.6.3 and A.4.6.4 provide these measured concentrations also by week as indoor as well as indoor minus outdoor values for the cooling and heating seasons respectively.

In SD 3 in the cooling season, measured concentrations in RC B were slightly higher than in RC A, though the ranges of values were similar. In the heating season, however, measured concentrations were similar in the two RCs, including minimum values, and the maximum value in RC A likely skewed the distribution to the right. Overall, measured concentrations were higher during standard HVAC system operation weeks. Maximum values in both RCs in the cooling season, and across seasons during standard HVAC system operation weeks, were at or exceeded the CalEPA/OEHHA non-cancer chronic REL of 9 $\mu g\ m^{-3}$.

In SD 4 in the cooling season, measured concentrations in RC A were higher than in RC B. Across RCs and HVAC systems, mean, median and maximum values exceeded the chronic non-cancer REL except for the median during IDEC operation weeks. In the cooling season, relatively high outdoor background concentrations likely influenced measured indoor concentrations; technician observations recorded during field visits suggested the RC A teacher used the HVAC systems more frequently, as the RC B teacher usually used doors and windows for natural ventilation only. In the heating season, as expected, measured concentrations in RC B were higher than in RC A. Across seasons, the maximum measured concentrations were higher, and ranges of observed values wider, during standard HVAC system operation weeks and in RC A; these maximum values exceeded the chronic non-cancer REL. After subtracting the outdoor concentrations from the indoor concentrations as a correction, maximum observed values across seasons, except during heating season weeks of IDEC operation, still exceeded the chronic non-cancer REL. Interior finish materials such as sheet vinyl flooring near front doors and sink areas, carpets, and vinyl and fabric covered wall panels, which were identified as sources of CH_3CHO (Hodgson et al, 2001), were new in the cooling season; emissions declined as materials aged, a process enhanced by ventilation.

In general, concentrations measured during standard HVAC system operation weeks were higher than in IDEC operation weeks, and were higher in SD 4 than in SD 3 partially due to the higher outdoor background concentrations. CH_3CHO can be a primary pollutant and a secondary pollutant of traffic emissions due to tropospheric photochemistry; on a regional scale, SD 4 was downwind of the San Francisco Bay area freeways, and of two north-south freeways through the Central Valley. Subtracting the outdoor concentrations from the indoor concentrations, however, made no difference except values were more similar across seasons during IDEC operation weeks. Thus, the LBNL RCS CH_3CHO data suggested ventilation, especially if continuous with 100% filtered outdoor air as provided by the IDEC, may be more important than source control indoors with alternative interior finish materials, cleaning and teaching products or the

Table 3.2.1.4.1: Summary of measured acetaldehyde (CH_3CHO) concentrations (ug m^{-3}) indoors and outdoors-- by classroom, HVAC system in operation, and SD-- for the fall 2001 cooling (September 5-October 25) and winter 2002 heating (January 8-March 7) seasons, SD 3 (CUSD) and 4 (MCS), LBNL RCS

			SD 3			Indoor Values			SD 4			Indoor Values		
Parameter	Season	Statistics	RC A (Rm 31)	RC B (Rm 30)	outdoor, at CUSD school	both RCs	during advanced (IDEC) HVAC operation	during conventional (Bard) HVAC operation	RC A (Rm 28)	RC B (Rm 29)	outdoor, at MCS school	both RCs	during advanced (IDEC) HVAC operation	during conventional (Bard) HVAC operation
indoor	cooling	mean	7.0	8.4	3.0	7.7	4.8	10.7	13.5	11.2	5.6	12.3	9.0	16.6
		stdev (SD)	3.7	3.7	1.9	3.6	2.2	1.9	5.8	4.8	2.0	5.3	4.4	2.2
		median	6.2	9.0	2.5	8.1	4.0	11.1	16.1	12.3	5.2	13.2	7.5	17.1
		min	2.8	2.6	0.5	2.6	2.6	7.2	4.4	3.8	3.0	3.8	3.8	13.9
		max	12.6	12.6	6.5	12.6	8.9	12.6	20.3	18.2	8.2	20.3	17.5	20.3
indoor	heating	mean	5.1	4.7	2.2	4.9	3.5	6.3	8.3	10.4	3.0	9.3	4.2	14.5
		SD	2.7	1.6	0.8	2.2	0.8	2.2	7.0	7.1	1.2	7.0	1.7	6.4
		median	4.1	4.5	2.1	4.4	3.5	6.0	5.5	7.3	3.3	6.8	4.4	12.7
		min	2.6	2.6	1.4	2.6	2.6	3.7	1.4	1.9	1.0	1.4	1.4	6.8
		max	10.9	7.6	3.7	10.9	4.7	10.9	24.0	22.7	4.9	24.0	6.7	24.0
indoor-outdoor	cooling	mean	4.0	5.4		4.7	2.2	7.2	7.9	5.6		6.8	3.2	11.4
		SD	3.2	3.5		3.3	2.6	1.7	4.9	4.8		4.9	3.0	1.8
		median	3.5	6.9		5.4	1.7	6.9	9.5	4.5		6.9	3.6	12.2
		min	0.3	0.1		0.1	0.1	4.7	0.7	-0.4		-0.4	-0.4	8.5
		max	9.7	8.6		9.7	8.4	9.7	13.0	13.2		13.2	9.3	13.2
indoor-outdoor	heating	mean	2.8	2.4		2.6	1.5	3.7	5.3	7.5		6.4	1.3	11.4
		SD	2.2	1.1		1.7	0.5	1.7	6.7	6.7		6.6	1.1	5.8
		median	2.0	2.2		2.1	1.3	3.5	2.1	5.9		4.4	1.4	9.3
		min	0.9	1.2		0.9	0.9	1.5	-0.3	0.9		-0.3	-0.3	5.4
		max	7.2	3.9		7.2	2.6	7.2	20.3	19.0		20.3	3.3	20.3

influence of local ambient sources. T-tests and correlation coefficients will be presented to further clarify the role of HVAC systems, interior finish materials, SD, and seasons with respect to measured CH_3CHO concentrations.

3.2.1.5 Field Duplicates for Overall Precision

Appendix 4.4.5 and 4.4.6 provide results of analyses of field duplicates for overall precision of the field, handling, storage and analytic methods in the cooling and heating seasons, respectively. Overall precision was judged by the coefficient of variation (COV). The goal for good overall precision was ±5%, and the bounds were designated as ±10% unless relatively high measurements were characterized and believed. In the cooling season, this analysis confirmed good overall precision for the LBNL RCS; the COV for HCHO was 2.7% and for CH_3CHO was 5.3%, which was slightly higher due to lower measured indoor concentrations. In the heating season, overall precision was acceptable for HCHO, after SD 3 week 1 was excluded, and for CH_3CHO; the COV values were 5.7% and 11.4%, respectively. In week one, the difference of about 25% between the HCHO samples could not be explained. There was no discernible computer program error in drawing the baseline for peak area integration during sample quantification. In addition, there were no problems recorded in the laboratory notebook about the sample or the injection mechanism. Although slightly exceeding the ±10% threshold, the heating season COV for CH_3CHO was not cause for concern given the low indoor and outdoor concentrations measured.

3.2.1.6 Analytic Duplicates for Analytic Method Precision

Appendix 4.4.7 and 4.4.8 give results of analyses of analytic duplicates for assessing the precision of extraction and analytic methods in the cooling and heating seasons, respectively. Precision was again judged by the COV. Good analytic precision was confirmed in the LBNL RCS for cooling season laboratory work. The COV for HCHO was 1.1%. For CH_3CHO, after excluding the first week's analytic duplicate, the COV was 4.1%; the COV for CH_3CHO was 10.5% with week one included. In week one, the difference of about 20% between the duplicate injections to the HPLC could not be explained. There was no discernible computer program error in drawing the baseline for peak area integration during sample quantification. In addition, there were no problems recorded in the laboratory notebook about the sample or the injection mechanism. Data confirmed good analytic precision for LBNL RCS heating season laboratory work as well. The COV for HCHO was 1.5%, similar to the value for the cooling season. The COV for CH_3CHO was 7.1%, again a higher value due to the low indoor and outdoor concentrations measured.

3.2.1.7 Summary of Statistical Analyses

Table 3.2.1.7.1 presents the results of t-tests of means for the LBNL RCS, for the fall 2001 cooling season and winter 2002 heating season, by compound, SD, RC, and HVAC system including means and standard deviations. Table 3.2.1.7.2 gives similar results for the entire study, with season another variable assessed. Whether by individual season or across seasons, there were significant differences in the means for outdoor HCHO and CH_3CHO by SD, and indoors except HCHO in the cooling season; SD 4 values exceeded those from SD 3. These differences were expected, given the SD were in different climate zones of Northern California, with different meteorology and outdoor sources. For example, SD 4 on a regional scale was located downwind of San Francisco Bay area freeways and two north-to-south freeways through the Central Valley. The target aldehydes in ambient air were primary pollutants and secondary pollutants due to photochemistry.

In the cooling season in SD 4, the mean concentration of HCHO in RC A was significantly higher than in RC B, opposite from expectations. This result supported the argument previously stated during discussion of the descriptive statistics, which was multiple, small sources were introduced to this RC after the beginning of the school year in the form of student sized dry erase boards with exposed particleboard surfaces.

The t-tests were not significant whether by or across seasons and SD with respect to selection of alternative versus standard interior finish materials, i.e., RC A versus RC B, respectively. By or across RCs, however, at an alpha of 0.10 there were significant differences in the mean concentrations of the target compounds by season, except CH_3CHO in RC B, as values in the cooling season exceeded those in the heating season. These results supported the assertion emissions of compounds from interior finish materials in RCs declined with age, a process enhanced by ventilation.

By and across seasons and SD, there were significant differences in the means of measured concentrations of HCHO and CH_3CHO depending on which HVAC operated; values during standard HVAC system operation weeks exceeded those during IDEC operation weeks. These results further supported a key finding of this dissertation--

Table 3.2.1.7.1: Summary of t-tests of means, LBNL RCS, cooling season (fall 2001) and heating season (winter 2002).

season	school district (SD)	compound	class variable	variable stratified by	no. of obs.	mean	std. dev.	Prob > absT
cooling	3	HCHO	RC A	SD	8	17.4	10.4	0.339
			B		8	22.3	9.5	
		CH_3CHO	RC A	SD	8	7.0	3.7	0.457
			B		8	8.4	3.6	
	4	HCHO	RC A	SD	8	29.2	10.3	0.039
			B		8	18.1	9.1	
		CH_3CHO	RC A	SD	8	13.5	5.8	0.563
			B		8	11.9	5.3	
	3 and 4	HCHO	RC A	n/a	16	23.3	11.7	0.416
			B		16	20.2	9.2	
		CH_3CHO	RC A	n/a	16	10.3	5.8	0.952
			B		16	10.1	4.7	
	3 and 4	HCHO	HVAC-B	n/a	15	30.2	6.9	0.0001
			I		17	14.2	6.6	
		CH_3CHO	HVAC-B	n/a	15	13.5	3.7	0.0002
			I		17	7.3	4.7	
	3 and 4	HCHO	SD 3	n/a	16	19.8	9.9	0.306
			SD 4		16	23.7	11.0	
		CH_3CHO	SD 3	n/a	16	7.7	3.6	0.005
			SD 4		16	12.7	5.4	
	3 and 4	HCHO out	SD 3	n/a	16	3.2	0.7	0.0001
			SD 4		16	5.9	1.4	
		CH_3CHO out	SD 3	n/a	16	3.0	1.8	0.0007
			SD 4		16	5.6	1.9	
heating	3	HCHO	RC A	SD	8	10.2	5.9	0.727
			B			9.3	4.6	
		CH_3CHO	RC A	SD	8	5.1	2.7	0.717
			B			4.7	1.6	
	4	HCHO	RC A	SD	9	19.6	13.8	0.857
			B			18.6	10.2	
		CH_3CHO	RC A	SD	9	8.3	7.0	0.5316
			B			10.4	7.2	
	3 and 4	HCHO	HVAC-B	n/a	17	21.4	10.6	0.0001
			I		17	8.0	2.9	
		CH_3CHO	HVAC-B	n/a	17	10.6	6.3	0.0004
			I		17	3.9	1.4	
	3 and 4	HCHO	SD 3	n/a	16	9.8	5.1	0.006
			SD 4		18	19.1	11.8	
		CH_3CHO	SD 3	n/a	16	4.9	2.2	0.018
			SD 4		18	9.3	7.0	
	3 and 4	HCHO out	SD 3	n/a	16	3.0	0.9	0.083
			SD 4		18	2.4	0.9	
		CH_3CHO out	SD 3	n/a	16	2.3	0.8	0.057
			SD 4		18	2.9	1.2	

Table 3.2.1.7.2: Summary of t-tests of means, LBNL RCS. Unless noted, data from both seasons were used.

school district (SD)	compound	class variable	variable stratified by	no. of obs.	mean	std. dev.	Prob > absT
3 and 4	HCHO	season-C	n/a	32	21.7	10.5	0.0079
		season-H		34	14.7	10.3	
	CH_3CHO	season-C	n/a	32	10.2	5.2	0.03
		season-H		34	7.2	5.7	
3 and 4	HCHO	season-C	RC A	16	23.3	11.7	0.0558
		season-H		17	15.2	11.6	
		season-C	RC B	16	20.2	9.2	0.0714
		season-H		17	14.2	9.2	
	CH_3CHO	season-C	RC A	16	10.3	5.8	0.086
		season-H		17	6.8	5.5	
		season-C	RC B	16	10.1	4.7	0.20
		season-H		17	7.7	6.0	
3	HCHO	RC A	SD	16	13.8	8.9	0.5536
		B		16	15.8	9.8	
	CH_3CHO	RC A	SD	16	6.0	3.3	0.6739
		B		16	6.5	3.4	
4	HCHO	RC A	SD	17	24.1	12.9	0.146
		B		17	18.4	9.4	
	CH_3CHO	RC A	SD	17	10.7	6.8	0.8733
		B		17	11.1	6.2	
3 and 4	HCHO	HVAC-B	n/a	32	25.6	10.0	0.0001
		I		34	11.1	6.0	
3 and 4	CH_3CHO	HVAC-B	n/a	32	11.9	5.4	0.0001
		I		34	5.6	3.8	
3 and 4	HCHO	SD 3	n/a	32	14.8	9.3	0.014
		SD 4		34	21.2	11.5	
3 and 4	CH_3CHO	SD 3	n/a	32	6.3	3.3	0.0005
		SD 4		34	10.9	6.4	
3 and 4	HCHO out	SD 3	n/a	32	3.1	0.8	0.021
		SD 4		34	4.0	2.1	
3 and 4	CH_3CHO out	SD 3	n/a	32	2.6	1.4	0.0008
		SD 4		34	4.2	2.0	

adequate ventilation, improved in the case of the IDEC, reduced measured concentrations of pollutants, bioeffluents, and odors in school classrooms, and may be more important than source control through selection of interior finish materials, furnishings, and teaching and cleaning supplies.

Results of the Pearson correlation coefficient (R) analysis for the LBNL RCS are presented in Table 3.2.1.7.3 and Table 3.2.1.7.4 for the fall 2001 cooling season and the winter 2002 heating season, respectively. For HCHO, the variables " HCHO out" and SD were not significantly correlated in the cooling season but only the former was not significantly correlated in the heating season. SD may have been significantly correlated with HCHO in the heating season due to the introduction of sources, i.e., student art projects, in SD 3 RC A as described with the descriptive statistics. For CH_3CHO, the variables "CH_3CHO out" and SD were significantly correlated across seasons, supporting the argument outdoor sources of this compound were important to understanding IEQ in these RCs, given its nature as a primary and secondary pollutant. Furthermore, across seasons for outdoor concentrations of target aldehydes, the variable SD was significant at an alpha of 0.10; in the cooling season, results were significant at an alpha of 0.05, likely because outdoor concentrations were relatively higher. Overall, these results confirmed SDs were different for the likely reasons previously discussed.

Across seasons and target pollutants, the variable RC was not significantly correlated. This result supported a main finding of this dissertation, which was source control through interior finish materials and furnishings may be relatively less important than other factors like ventilation, especially given uncertainties related to frequency, amount, and duration of use of introduced teaching materials and cleaning compounds.

For both target aldehydes, across seasons, HVAC was significantly and highly correlated; the negative values reflect the fact the improved continuous ventilation of the IDEC reduced measured concentrations relative to those measured during standard HVAC system operation weeks. These results supported the t-test results and thus the importance of adequate, even improved, ventilation for school classrooms.

Related to HVAC operation and thus ventilation were the T and RH measurements. In the cooling season, for both target aldehydes, T values in the AM and PM across sampling days were significantly and highly correlated, as expected, with R-values higher for afternoon T. In addition, across SD, the variable HVAC was significantly correlated with "T_PM" and "RH_PM;" the R-value was negative for T and positive for RH due to the IDEC technology, which cooled the indoor air but added moisture. Implications of this fact for occupant thermal comfort will be discussed in the next section. In the heating season, for both target aldehydes, RH values in the AM and PM were significantly correlated. The HVAC systems were used to increase the indoor T in the winter, which acted to decrease the indoor RH. This appeared more clearly in the mornings since demand was greater. Furthermore, teachers did not use the standard HVAC system HVAC units throughout the school day. This may be why only the "T_Tu PM" variable was significantly correlated with measured aldehyde concentrations in the heating season. The measured RH were likely due to ambient influences and occupant respiration and perspiration based on attendance and occupant activities, especially during standard HVAC system operation weeks when the HVAC operated intermittently or not at all. The next section presents measured indoor air T and RH in the LBNL RCS.

Table 3.2.1.7.3: Summary of Pearson correlation coefficient R analysis, LBNL RCS, cooling season (fall 2001).

		statistically significant R				*not significant, but of interest*			
school district (SD)	compound	parameter	no. of obs.	R	Prob > absR	parameter	no. of obs.	R	Prob > absR
3 and 4	HCHO	HVAC	32	-0.774	0.0001	HCHO out	32	0.279	0.1221
						SD code	32	0.187	0.3064
						RC	32	-0.149	0.4155
		T_AM	32	0.583	0.0005	RH_AM	32	-0.079	0.6683
		T_PM	32	0.718	0.0001	RH_PM	32	-0.263	0.1463
		T_Tu AM	12	0.688	0.0135	T_Wed AM	4	0.616	0.3842
		T_Tu PM	12	0.723	0.0079	T_Wed PM	4	0.800	0.2000
		T_Th AM	14	0.666	0.0093				
		T_Th PM	14	0.722	0.0036				
		RH_Wed PM	4	-0.913	0.0869	RH_Wed AM	4	-0.575	0.4247
3 and 4	CH3CHO	HVAC	32	-0.599	0.0003				
		CH3CHO out	32	0.592	0.0004				
		SD code	32	0.486	0.0048	RC	32	-0.011	0.9523
		T_AM	32	0.641	0.0001	RH_AM	32	-0.239	0.1879
		T_PM	32	0.737	0.0001	RH_PM	32	-0.177	0.3319
		T_Tu AM	12	0.719	0.0084	T_Wed AM	4	0.696	0.3040
		T_Tu PM	12	0.739	0.0060	T_Wed PM	4	0.852	0.1477
		T_Th AM	14	0.588	0.0270				
		T_Th PM	14	0.766	0.0014				
		RH_Wed PM	4	-0.967	0.0304	RH_Wed AM	4	-0.675	0.3252
		RH_Th AM	14	-0.468	0.0919				
		RH_Th PM	14	-0.504	0.0660				
3 and 4	HCHO out	SD code	32	0.781	0.0001				
3 and 4	CH3CHO out	SD code	32	0.570	0.0007				
3 and 4	HVAC	T_PM	32	-0.512	0.0027	T_AM	32	-0.287	0.1117
		RH_PM	32	0.304	0.0910	RH_AM	32	-0.023	0.9017
		RH_Wed PM	4	0.932	0.0676	RH_Wed AM	4	0.584	0.4160
		T_Th AM	14	-0.467	0.0924	T_TuAM	12	-0.386	0.2155
		T_Th PM	14	-0.672	0.0084	T_Tu PM	12	-0.471	0.1218
						T_Wed AM	4	-0.602	0.3983
						T_Wed PM	4	-0.776	0.2237

Table 3.2.1.7.4: Summary of Pearson correlation coefficient R analysis, LBNL RCS, heating season (winter 2002).

		statistically significant R				*not significant, but of interest*			
school district (SD)	compound	parameter	no. of obs.	R	Prob > absR	parameter	no. of obs.	R	Prob > absR
3 and 4	HCHO	HVAC	34	-0.664	0.0001	HCHO out	34	0.265	0.1299
		SD code	34	0.460	0.0062	RC	34	-0.049	0.7828
		RH_AM	34	0.423	0.0126	T_AM	34	0.084	0.6347
		RH_PM	34	0.419	0.0135	T_PM	34	0.185	0.2947
		T_Tu PM	14	0.608	0.0211	T_Tu AM	14	0.192	0.5108
		RH_Tu AM	14	0.558	0.0379	RH_Tu PM	14	0.310	0.2814
		RH_Wed AM	4	0.984	0.0163				
		RH_Wed PM	4	0.987	0.0134				
3 and 4	CH3CHO	HVAC	34	-0.604	0.0002				
		CH3CHO out	34	0.504	0.0023				
		SD code	34	0.399	0.0194	RC	34	0.084	0.6378
		RH_AM	34	0.376	0.0285	T_AM	34	0.143	0.4207
		RH_PM	34	0.399	0.0194	T_PM	34	0.148	0.4040
		T_Tu PM	14	0.542	0.0455	T_Tu AM	14	0.115	0.6956
		RH_Tu AM	14	0.540	0.0462	RH_Tu PM	14	0.363	0.2020
		RH_Wed AM	4	0.951	0.0488				
		RH_Wed PM	4	0.946	0.0543				
3 and 4	HCHO out	SD code	34	-0.301	0.0839				
3 and 4	CH3CHO out	SD code	34	0.326	0.0596				
3 and 4	HVAC	T_AM	34	0.381	0.0263	T_PM	34	-0.048	0.7873
		RH_AM	34	-0.294	0.0916	RH_PM	34	-0.088	0.6202
		RH_Tu AM	16	-0.458	0.0995	RH_ Tu PM	16	-0.016	0.9544

3.2.2 Indoor Air T and RH

Tables 3.2.2.1 and 3.2.2.2 for indoor air T in °F, and 3.2.2.3 and 3.2.2.4 for indoor RH as %, summarized the fall 2001 cooling season and the winter 2002 heating season, respectively. Data were presented as arithmetic mean and minimum and maximum six-minute logged averages for each RC, by HVAC system, for four time periods. The time periods were weekday AM (8:30-12:24 in SD 3 and 7:42-11:30 in SD 4), weekday PM (12:30-16:00 in SD 3 and 11:36-15:00 in SD 4), weekday overnight, and the weekend covering after Friday PM to the following Monday AM. Weekday AM and weekday PM included times teachers may have worked alone or in meetings inside or outside the RCs.

In the cooling season, during the PM with characteristic higher cooling demands, the mean T were nearly the same in the SD 3 RCs during both HVAC operation scenarios; during IDEC operation weeks, however, maximum six-minute T averages were lower, with AM and PM values similar. In SD 4, a warmer climate zone, the mean T were slightly higher than in SD 3, especially during standard HVAC system operation weeks. In addition, during IDEC operation weeks in SD 4, the maximum six-minute averages in the PM were less than or about equal to the AM values. Across SD, indoor mean and maximum six-minute T averages during unoccupied periods were similar to the PM occupied periods which, given occupants provided thermal mass, demonstrated the potential role of mechanical and natural ventilation in provision of comfort and thus enhancement of IEQ. Overall, compared to the ASHRAE 55 (1992) thermal comfort envelope provided in section 3.1.4, cooling season mean T across HVAC systems were usually below the lower bound of the range. The exceptions were SD 4 RC A during standard HVAC system operation weeks and IDEC operation weeks in the afternoon, and RC B in both SD as well as SD 3 RC A during standard HVAC system operation weeks in the afternoon. These results may be due to teacher T set point preferences.

In the heating season, across SD and RCs, the mean T suggested the IDEC, due to continuous ventilation even after heating demand was met, nearly maintained indoor T in the area of the teacher's desk throughout school hours; in SD 4 RC B, where the difference was 1°F, the teacher was observed not to operated either HVAC continuously. At the same time, the maximum six-minute T averages during IDEC operation weeks, and during standard HVAC system operation weeks except SD 3 RC A, confirmed occupant heating demand was higher in the mornings as expected. On the other hand, during standard HVAC system operation weeks across SD and RCs, the mean T and minimum six-minute T averages were higher in the afternoons because the HVAC was likely not operated or operated intermittently, and occupant thermal mass and warming ambient conditions were influences. Compared to school hours, unoccupied periods, across SD and RCs, had relatively lower mean T and minimum six-minute T averages, but similar maximum six-minute T averages, due to the lack of the aforementioned influences. Overall, compared to the ASHRAE 55 (1992) thermal comfort envelope values provided in section 3.1.4, mean T and maximum six-minute T averages were within this range with some exceptions. Those exceptions were mean AM and PM T during standard HVAC system operation weeks in three of the four RCs and mean AM and PM T during IDEC operation weeks in SD 3 RC B. These results may be due to teacher T set point preferences as well as HVAC system operation behaviors.

Table 3.2.2.1: Seasonal summary for cooling season, fall 2001, indoor air temperature (degrees F), LBNL RCS

SD 3 (CUSD) RC A, Room 31

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	70.4	73.4	72.4	73.2
	min	61.5	66.3	61.5	61.5
	max	76.6	80.1	82.2	85.8
IDEC weeks	mean	69.4	70.6	66.0	67.9
	min	53.9	65.6	51.8	56.0
	max	78.0	78.0	80.8	80.1

SD 3 (CUSD) RC B, Room 31

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	69.6	73.3	70.6	71.2
	min	60.8	67.7	60.8	61.5
	max	76.6	82.2	78.7	83.7
IDEC weeks	mean	67.7	70.7	66.8	66.6
	min	52.5	65.6	51.8	56.0
	max	76.6	78.0	80.8	78.0

SD 4 (MCS) RC A, Room 28

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	73.4	75.2	75.3	76.1
	min	64.9	69.7	65.6	67.0
	max	78.7	79.4	83.0	85.8
IDEC weeks	mean	71.1	73.7	74.0	71.8
	min	60.1	70.4	60.1	63.5
	max	77.3	77.3	82.2	81.5

SD 4 (MCS) RC B, Room 29

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	69.9	73.5	73.8	73.8
	min	62.2	67.0	62.2	65.6
	max	77.3	78.7	81.5	83.7
IDEC weeks	mean	69.4	71.8	72.3	71.0
	min	60.1	66.3	61.5	59.4
	max	78.0	75.9	82.2	82.2

Table 3.2.2.2: Seasonal summary for heating season, winter 2002, indoor air temperature (degrees F), LBNL RCS

SD 3 (CUSD) RC A, Room 31

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	64.1	67.6	57.7	55.5
	min	57.3	62.4	45.9	44.7
	max	70.3	74.4	73.3	75.2
IDEC weeks	mean	69.1	68.3	63.3	64.4
	min	60.9	63.8	46.2	52.5
	max	80.0	73.7	74.7	73.8

SD 3 (CUSD) RC B, Room 31

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	64.3	67.3	56.6	54.0
	min	46.9	62.2	45.0	43.2
	max	74.4	72.7	74.0	74.5
IDEC weeks	mean	66.5	66.7	62.6	61.0
	min	57.5	61.5	50.0	50.4
	max	76.2	72.7	74.0	77.3

SD 4 (MCS) RC A, Room 28

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	69.8	71.1	62.3	56.2
	min	51.2	68.9	50.2	44.7
	max	75.5	74.1	72.5	75.9
IDEC weeks	mean	70.5	70.4	68.5	64.2
	min	61.2	66.8	60.4	56.7
	max	76.3	74.1	74.4	72.5

SD 4 (MCS) RC B, Room 29

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	66.1	67.6	59.7	54.3
	min	50.2	64.5	51.2	42.5
	max	72.3	72.0	71.4	71.8
IDEC weeks	mean	68.3	69.4	64.5	59.0
	min	54.4	66.1	55.6	45.4
	max	75.1	74.0	72.8	71.1

Table 3.2.2.3: Seasonal summary for cooling season, fall 2001, indoor relative humidity (%), LBNL RCS

SD 3 (CUSD) RC A, Room 31

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	58.2	50.8	53.0	48.6
	min	36.8	26.7	24.7	24.7
	max	70.2	63.5	74.0	63.6
IDEC weeks	mean	58.1	63.9	60.1	58.4
	min	23.4	26.0	23.8	35.3
	max	82.7	79.4	84.8	91.8

SD 3 (CUSD) RC B, Room 31

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	61.9	56.9	56.6	51.4
	min	44.8	30.9	26.3	27.1
	max	73.2	77.1	71.3	61.8
IDEC weeks	mean	61.6	62.3	59.7	62.5
	min	23.6	24.9	23.6	46.5
	max	82.7	82.2	84.8	91.8

SD 4 (MCS) RC A, Room 28

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	47.3	48.3	44.0	41.7
	min	34.5	28.4	24.9	30.7
	max	60.0	62.2	69.1	68.6
IDEC weeks	mean	53.4	55.5	47.5	48.2
	min	34.1	29.2	28.8	36.9
	max	69.2	72.2	69.8	67.6

SD 4 (MCS) RC B, Room 29

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	49.7	47.8	46.1	45.0
	min	28.5	26.6	29.5	27.3
	max	64.5	62.0	70.0	69.6
IDEC weeks	mean	54.2	57.9	51.7	50.2
	min	29.4	27.9	30.9	36.1
	max	74.1	77.1	77.8	72.2

Table 3.2.2.4: Seasonal summary for heating season, winter 2002, indoor relative humidity (%), LBNL RCS

SD 3 (CUSD) RC A, Room 31

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	41.8	36.4	39.9	46.1
	min	28.5	28.2	27.8	23.5
	max	52.2	46.8	50.1	61.8
IDEC weeks	mean	39.5	44.4	43.1	39.2
	min	25.1	25.2	24.0	23.5
	max	59.3	62.0	68.8	64.2

SD 3 (CUSD) RC B, Room 31

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	39.4	36.8	42.7	47.9
	min	25.8	26.2	26.9	23.7
	max	58.6	49.6	52.9	61.8
IDEC weeks	mean	42.7	44.7	44.6	42.7
	min	26.3	26.7	23.9	23.8
	max	62.9	63.0	69.1	61.3

SD 4 (MCS) RC A, Room 28

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	39.3	45.1	44.1	48.4
	min	25.8	30.3	26.7	30.3
	max	56.3	60.2	60.9	66.3
IDEC weeks	mean	37.7	37.3	37.8	38.6
	min	25.9	25.4	24.2	23.7
	max	52.8	51.7	56.4	54.6

SD 4 (MCS) RC B, Room 29

		Weekday AM	Weekday PM	Weekday overnight	Weekend (F PM - M AM)
conventional HVAC weeks	mean	44.1	49.7	48.6	51.8
	min	32.7	37.8	39.0	38.0
	max	61.9	64.1	61.9	67.1
IDEC weeks	mean	44.2	47.0	49.6	47.6
	min	30.4	31.2	35.0	23.7
	max	67.3	61.4	64.6	60.0

In the cooling season, across SD and RCs, the mean indoor RH and maximum six-minute RH averages were higher during IDEC operation weeks in the PM, characterized by higher cooling demand, and in the AM in SD 4, but in the AM in SD 3 were similar to values during standard HVAC system operation weeks. In addition, during IDEC operation weeks in the PM, mean RH across SD, and maximum six-minute RH averages in SD 4, were higher than in the AM. These results were likely due to the IDEC technology, which intrinsically added moisture to the air in providing air conditioning. Occupants were also an influence on measured indoor RH, especially upon return to the RCs after recess or physical education classes, e.g., SD 3 RC B and SD 4 RC A six-minute RH averages in the PM. When AM RH measures were higher than PM RH values during standard HVAC system operation weeks given this HVAC system's intermittent operation if on, these data suggested ambient conditions and occupants likely were larger influences. During occupied and unoccupied periods, RH measures in SD 3 exceeded those in SD 4, an expected result given the California climate zones in which they were located. Minimum six-minute RH averages, however, were similar across SD, RCs, and HVAC systems during unoccupied and occupied periods. Minimum six-minute RH averages were usually higher in the AM than in the PM. With the exception of SD 3 RC B during standard HVAC system operation weeks, RH values in the PM and most unoccupied period RH values across SD were below the ASHRAE 55 (1992) thermal comfort envelope of 30-60% RH. Indoor RH measures during unoccupied periods were influenced by variable ambient conditions and the IDEC if left on in "auto" mode. The ASHRAE thermal comfort envelope was exceeded in the cooling season by maximum six-minute RH averages across SD, RCs and HVAC systems. In SD 3, the mean PM RH in RC A during IDEC operation weeks, as well as in RC B in the AM and during IDEC operation weeks in the PM, also exceeded the upper bound. These results were consistent with the technologies and potential influences already described.

In the heating season in SD 3, during IDEC operation weeks the mean RH was higher in RC A than in RC B. In addition, across HVAC systems and RCs, the mean RH and the maximum six-minute RH averages were higher in the PM than in the AM due to the AM heating demand; operation of HVAC systems warmed and dried the indoor air. Given the standard HVAC system did not operate continuously, ambient conditions appeared to have a relatively stronger influence during standard HVAC system operation weeks than during IDEC operation weeks, since RH measures were similar or lower. During standard HVAC system operation weeks, the mean RH was higher in RC B than in RC A, likely because the teacher was observed to use the HVAC system relatively less often so the influence of occupant respiration was relatively larger.

In the heating season in SD 4 during standard HVAC system operation weeks, mean RH across RCs were higher in the PM than in the AM, and values were higher than in SD 3 RCs. A relatively higher early AM heating demand in SD 4, based on known differences between climate zones, was consistent with these data. During IDEC operation weeks in SD 4, the maximum six-minute RH averages were higher in the AM than in the PM; ambient influences may have been stronger than HVAC system operation meeting the heating demand. The higher RH measures during unoccupied periods relative to occupied school hours supported this interpretation. Drier, warmer ambient conditions and continuous 100% outdoor air ventilation from the IDEC, coupled with the influence of occupant respiration, maintained similar RH measures during school hours in these RCs. The slightly elevated RH measures in the PM in RC B were consistent with observations of the RC B teacher using the IDEC less consistently than the RC A teacher. Across SD, RCs and HVAC systems during the heating season, only minimum six-minute RH averages were below the ASHRAE 55 (1992) thermal comfort envelope, except for in SD 4 RC B. Again, the observed less consistent use of HVAC systems by this teacher allowed the influence of occupant respiration to be relatively greater.

Table 3.1.4.3 compared observed thermostat T recorded on the "classroom checklist," typical classroom T set points reported by the head custodian during the "O&M" interview questionnaire, and average measured AM and PM T for the LBNL RCS. Data were stratified by SD, RC, HVAC system, room type and season. During IDEC operation weeks, the measured mean AM and PM indoor air T were within the ranges observed by the technician except for in the PM in SD 3 RC B. During standard HVAC system operation weeks, the measured mean AM and PM indoor air T were within the ranges observed by the technician for SD 4 RC B, but near or above the upper bound in SD 4 RC A and in SD 3 RCs. The head custodian reported HVAC thermostat T settings were given as "per teacher preference." Technician observations recorded on the "classroom checklist" during the LBNL RCS were during unoccupied classroom times including recess and lunch but, except SD 3 RC B, teachers were present before and after school. The wide range of observed T reflected changes in occupant preferences, perceptions and HVAC system operation behaviors based on ambient conditions and activities as well as the technologies; the teachers controlled the thermostat linked to each HVAC system. The result was variability in thermal comfort parameters during a school day, over each week, and over each season by SD and RC. Refer to Appendix A.4.7.1-A.4.7.16 about T and RH data for the LBNL RCS.

Figures 3.2.2.1 and 3.2.2.2, and 3.2.2.3 and 3.2.2.4, were typical profiles of diurnal and weekly variation in T and RH measured with the HOBO H8 Pro and BoxCar software for SD 3 RC A and SD 4 RC B, respectively. Figure 3.2.2.1 suggested the IDEC was operated during school hours, and even the overnights in between, but not on the weekends (e.g., 9/21 evening-9/24 morning) in the cooling season. While T and RH trends followed ambient conditions on the weekend, during school hours RH was maintained consistently above but T usually within the ASHRAE thermal comfort envelope; variations to maximum and minimum measurements were likely caused by ambient conditions in unoccupied periods. Figure 3.2.2.2 suggested absent or intermittent ventilation from the standard HVAC system in the cooling season led each day to a similar range of RH measures within the ASHRAE thermal comfort envelope, though maximum and minimum T were outside the range; both parameters increased and decreased steadily each day due to ambient conditions and occupancy. Figure 3.2.2.3 described how operation of the standard HVAC system in the mornings to meet the occupant heating demand resulted in measured T above the lower bound of the ASHRAE thermal comfort envelope. With respect to RH, only school day minimum measures were outside the range. Figure 3.2.2.4 depicted how continuous ventilation during IDEC operation could result in consistent indoor T and RH within the ASHRAE thermal comfort envelope on school days (2/14-15 and 19-20/02). Figure 3.2.2.5, for one school day, showed similar findings though minimum RH values were below the lower bound. These observations would be relevant to the complete quantitative and subjective assessment following ASHRAE standard 55 (1992), which will be presented elsewhere (Shendell et al, 2002b).

In conclusion, indoor T and RH measured near the teacher's desk across SD and RCs in the LBNL RCS were influenced by factors which included afternoon cooling and morning heating demands on HVAC system operation; attributes of the HVAC system technologies; occupants; ambient conditions; and, teacher T set point preferences.

Figure 3.2.2.1: Typical profile of T and RH data with HOBO H8 Pro and BoxCar v.3.5/4.0 programs, cooling season with IDEC, SD 3 RC A, LBNL RCS

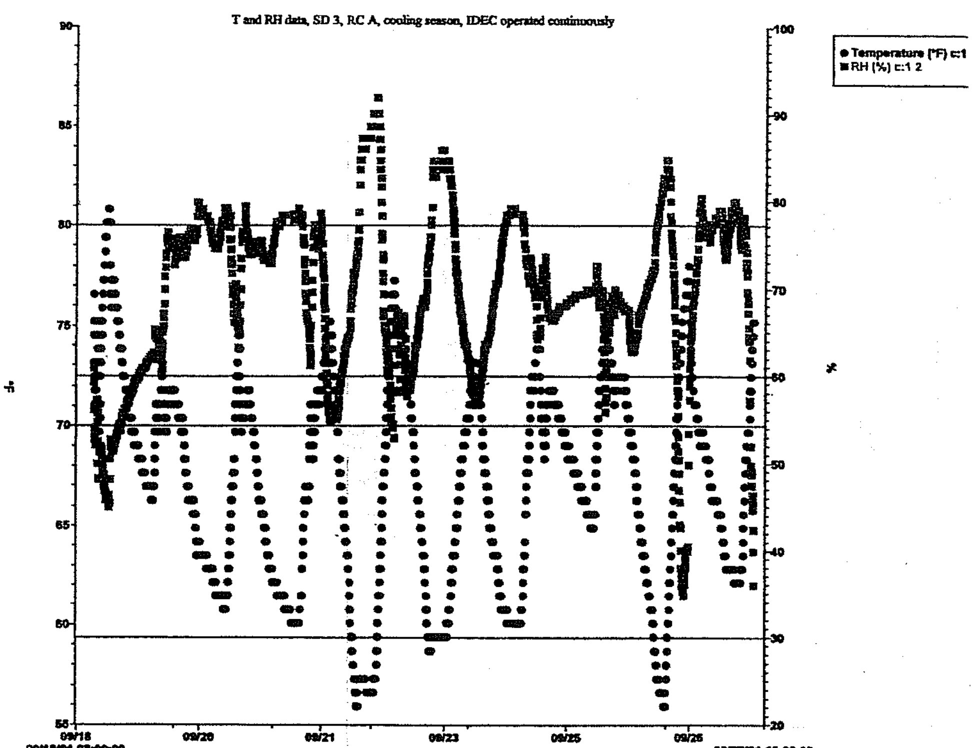


Figure 3.2.2.2: Typical profile of T and RH data with HOBO H8 Pro and BoxCar v.3.5/4.0 programs, cooling season with Bard, SD 3 RC A, LBNL RCS

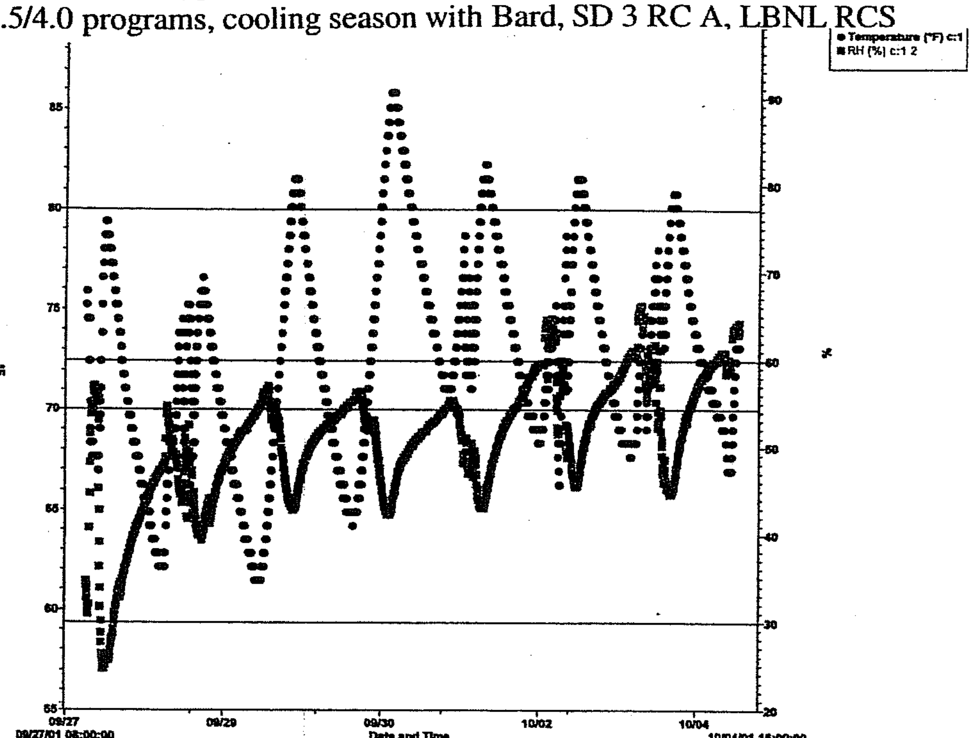


Figure 3.2.2.3: Typical profile of T and RH data with HOBO H8 Pro and BoxCar v.3.5/4.0 programs, heating season with Bard, SD 3 RC A, LBNL RCS

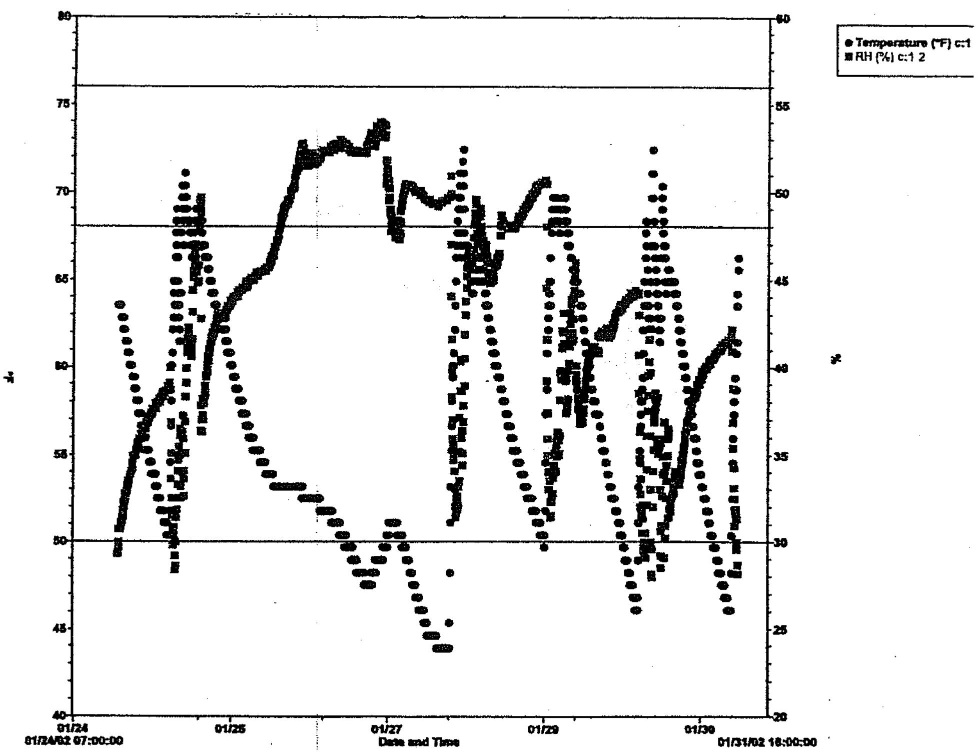


Figure 3.2.2.4: Typical profile of T and RH data with HOBO H8 Pro and BoxCar v.3.5/4.0 programs, heating season with IDEC, SD 4 RC B, LBNL RCS

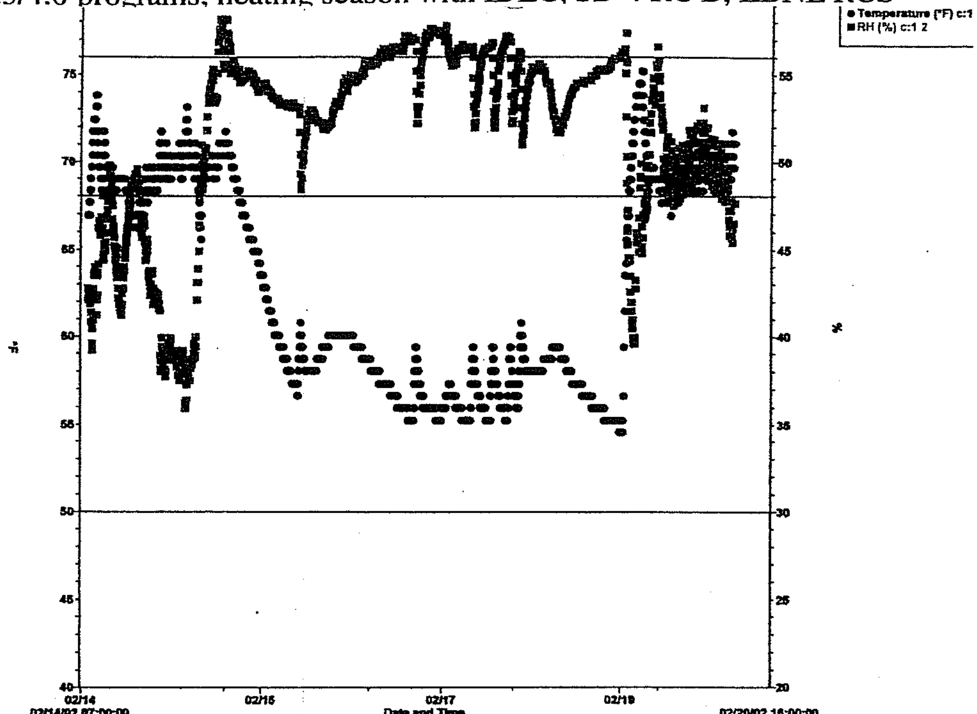
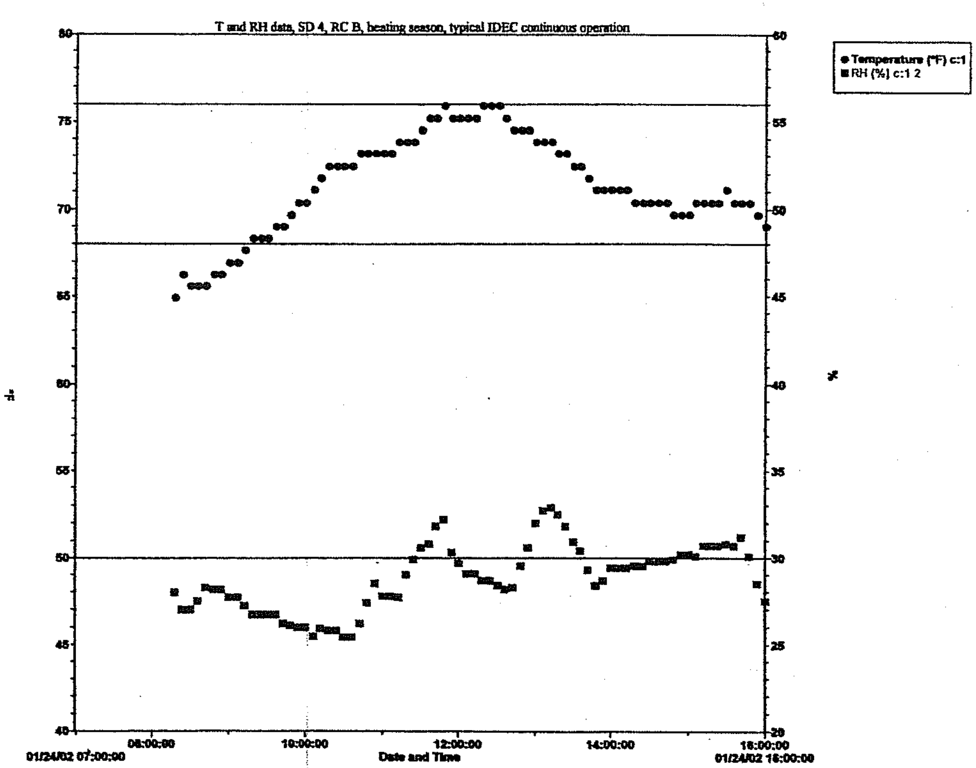


Figure 3.2.2.5: Typical profile of T and RH data over one school day with HOBO H8 Pro and BoxCar v.3.5/4.0 programs, heating season with IDEC, SD 4 RC B, LBNL RCS



3.3 UCLA PCS and LBNL studies

3.3.1 Descriptive Results, "Classroom Checklist"

Table 3.3.1.1 documents of field observations collected using the UCLA "Classroom Checklist" in the UCLA PCS, the LBNL RCS, and the OEHHA study. The number of SD, schools and classrooms of any type included in each study were two, seven and twenty for the UCLA PCS, two, two and four for the LBNL RCS, and three, ten, and 65 for the OEHHA study. Sample sizes by question were noted in parentheses after responses, which were given by sampling event or season or for the individual study overall.

Across studies, room types, and seasons, lights were left on or were being used by only the teacher, given technician visits were before and after school and during recess and lunch times, between 30% and 64% of the time. Every fixture was activated 70-100% of the time and during other times half of the fixtures were on or only one fixture was off. Lighting and daylighting through windows and skylights have recently been studied in relation to physical development and academic performance (Hathaway, 1995; Heschong Mahone Group, 1999), though to date results are suggestive not conclusive.

Across studies, room types, and seasons, the main doors were open only 17-22% of the time, and back or side doors were opened only 6-17% of the time, which likely reflected security concerns especially if the teacher was not present. Similarly, any number of operable windows were only observed open 4-16% of the time, and of the 16% from the OEHHA study 77% had half or fewer of the windows open. Previously, Landrus et al (1987) conducted a pilot case study to assess the installation of operable windows in a previously "sealed" school in relation to perceived and measured indices of

IAQ, health, absenteeism, and energy consumption. The LBNL RCS incorporated continuous door and window use monitoring with sensors and linear displacement potentiometers, respectively (Shendell et al, 2002a), to better understand the impacts on IEQ of door and window use for natural ventilation. These data were not part of this dissertation.

With respect to mechanical HVAC system operation for ventilation and thermal conditioning, the conventional HVAC or heat only systems, mounted on an outside wall or suspended from the ceiling, were found on 22% of the time during the OEHHA study and 27% of the time during the UCLA PCS. In the UCLA PCS, however, the HVAC system or wall heater was on more frequently in SD 1 in the cooling season (38%) than in SD 2 either during the cooling season (14%) or the heating season (19%). SD 1 was located in northeast LA County whereas SD 2 was located to the west near the coast, a cooler area on average. In the LBNL RCS, where observations spanned an entire school day once a week in each season, a HVAC system was found on 46% of the time, and more often in both SD during the heating season compared to during the cooling season. While findings were similar between SD in the heating season, 56% in SD 3 and 58% in SD 4, the HVAC system was found on in SD 4 nearly 10% more often than in SD 3 in the cooling season. SD 3 was located in a transitional climate zone and SD 4 was located in the hotter, drier northern Central Valley. Furthermore, regardless of season or SD, during IDEC weeks the HVAC system was found on more often than during standard HVAC system weeks, especially in the heating season. This may be related to anecdotal evidence which suggested teachers do not like the noise associated with conventional

HVAC systems. Shendell et al (2002b-c) designed and conducted quantitative assessments of exposure to noise appropriate for public schools in the LBNL RCS classrooms, in addition to HVAC operations parameters; these data were not part of this dissertation.

Table 3.3.1.1: Summary of results from field observations collected using the UCLA "Classroom Checklist" of physical environment quality and energy use indicators.

Study	UCLA "Portable Classrooms Pilot Study"				CalEPA-OEHHA and LBNL "East Bay School Children's Respiratory Health Study"	LBNL, DEG and CEC Relocatable Classroom IEQ and Energy Efficiency Demonstration Study				
Season	Entire Study, SDs 1-2	Cooling Season, early June	Cooling Season, Sept-early October	Heating Season, late Feb-early March	Entire Study spring 2001	Entire Study, SDs 3-4	SD 3 (CUSD) Cooling Season, Sept-Oct 2001	SD 4 (MCS) Cooling Season, Sept-Oct 2001	SD 3 (CUSD) Heating Season, Jan-Mar 2002	SD 4 (MCS) Heating Season, Jan-Mar 2002
QUESTION	SAMPLE SIZE, N, IN PARENTHESES				SAMPLE SIZE, N, IN PARENTHESES	SAMPLE SIZE, N, IN PARENTHESES				
Lights left on or in use by occupants? (as % of observations when classrooms visited)	48% (n=237)	56% (n=102)	64% (n=36)	34% (n=99)	30% (n=87)	50% (n=275)	42% (n=64)	59% (n=75)	38% (n=64)	58% (n=72)
If lights were on, how many fixtures? (as %)	84% every fixture on 96% had >94% on	70% every fixture on 94% had >94% on	96% every fixture on 4% half of fixtures on	100% every fixture on	92% every fixture on 100% had >90% on	96% every fixture on 4% half fixtures on	96% every fixture on 4% half of fixtures on	100% every fixture on	83% every fixture on 17% half of fixtures on	98% every fixture on 2% half of fixtures on
Main door was open?	22% (n=237)	18% (n=102)	50% (n=36)	15% (n=99)	22% (n=87)	17% (n=275)	17% (n=64)	16% (n=75)	25% (n=64)	11% (n=72)
Back or side door was open, to the outside or to an adjacent portable?	17% (n=237)	13% (n=102)	22% (n=36)	20% (n=99)	6% (n=87)	RCs had only main doors	RCs had only main doors	RCs had only main doors	RCs had only main doors	RCs had only main doors
<u>Windows</u>-- of various sizes and heights up the walls-- <u>found open</u>? (*survey could not quantify how open*)	4% (n=237)	0% (n=102)	28% (n=36), with 6-83% of windows open	0% (n=99)	16% (n=87), of which 77% had less than half the windows open	6% (n=275), one RC in each SD in different seasons	0% (n=64)	20% (n=75), one RC, of which all open 38%, half open 31%	5% (n=64), one RC, only smaller back window opened	never (n=72)
<u>Mechanical HVAC</u>-- Bard, Eubanks, Wm. Scotsman-- <u>on by sound</u>?	27% (n=237)	38% (n=102)	14% (n=36)	19% (n=99)	22% (n=87)	**46% (n=275)^**	30% (n=64)*	39% (n=75)**	56% (n=64)***	58% (n=72)****
Classroom had computers?	93% (n=88)	93% (n=88)	N/A	N/A	49% (n=87)	100%	100%	100%	100%	100%
If yes, how many computers for teacher and students?	20% one, 41% two, 13% three, 26% five or more (n=82)	20% one, 41% two, 13% three, 26% five or more (n=82)	N/A	N/A	54% one, 16% two, 16% three, 12% four, 2% five (n=43)	RCs had one, two, three or six desktop	one RC with one, other RC with two	one RC with six, other RC with three	one RC with one, other RC with two	one RC with six, other RC with three
Were computers and/or monitors left on or in use by occupants?	62% all off, 15% all on, 23% some on (n=82)	62% all off, 15% all on, 23% some on (n=82)	N/A	N/A	84% all off, 7% all on, 9% some on (n=43)	14% (n=275)	9%, of which 83% all were on	17%, of which 54% only one on (teacher's)	22%, of which 64% all were on	8%, of which 67% only one on (teacher's)
Window blinds open?	N/A	N/A	N/A	N/A	47% (n=87)	front 72%, back 72% (n=255)	front 44%, back 54% (n=57)	front 81%, back 68% (n=62)	front 83%, back 88% (n=64)	front 79%, back 78% (n=72)
Window blinds up?	N/A	N/A	N/A	N/A	47% (n=87)	front 33%, back 36% (n=255)	front 40%, back 49% (n=57)	front 39%, back 32% (n=62)	front 55%, back 67% (n=64)	front once, back never (n=72)

^ = if Bard system, 27% (n=129), and if IDEC system 62% (n=146)

* = if Bard system, 13% (n=30), and if IDEC system, 44% (n=34)
** = if Bard system, 42% (n=31), and if IDEC system, 36% (n=44)
*** = if Bard system, 21% (n=34), and if IDEC system, 97% (n=30)
**** = if Bard system, 32% (n=34), and if IDEC system, 82% (n=38)

3.3.2 Descriptive Results, "Operations and Maintenance" Questionnaire

Table 3.3.2.1 summarizes responses to the UCLA "O&M" questionnaire for public school head custodians or plant managers. Seven, two, and ten head custodians or night plant managers were interviewed in the UCLA PCS, the LBNL RCS, and the OEHHA study, respectively. The ages of the portables and main buildings ranged from nearly 50 years to new. The last major renovation projects included roof repairs, painting indoors and outdoors, and the "Leroy Green Renovation Program" which funded asbestos removal and new ceiling tiles and lighting fixtures. About 65% of the main buildings and 95% of the portables in the UCLA PCS had thermostats in the rooms controlled by the teachers, though in the main buildings teachers sometimes could control T but not HVAC system operation. Across studies, 95% of interviewees reported the current HVAC system air filter was not the original, though the reported inspection and changing frequencies by the SD or the head custodian ranged from 1-12 months; the general manufacturer and CA OPSC recommendations were every 1-2 months. Only about half of the respondents reported training at the start of the job or during each school year. Furthermore, across studies, 74% or 84% of the respondents did not know of a protocol or a manual, respectively, for O&M of the HVAC systems of portables, though 68% reported the existence of a maintenance log in the main office or with the head custodian. This maintenance log, however, usually consisted of a compilation of copies of work orders sent or called in to the SD. No interviewee could answer the question, "'What is the (outdoor) air intake rate (for ventilation), on average, of the mechanical HVAC system in each portable classroom?"

Overall, these results suggested the need for improved and more regular communication between SD officials from facilities, property management, and/or O&M offices and individual school head custodians and principals. Expected outcomes should include the initiation or improvement of existing school facility O&M programs for general cleaning and HVAC systems. Müller (2002) stated though different standards existed for cleaning interior surfaces versus the air, and different methods of cleaning were possible, provision of good facility operations and maintenance was important. In a pilot study in Minneapolis of four main building classrooms (Ramachandran et al, 2002), across seasons there were no statistically significant differences between the old and new schools with respect to measured IAQ parameters, possibly due to good O&M practices. Anderson and Anderson (1999) ran bioassay ASTM-E-981 with air samples from one classroom at each of six schools in the New England region on mice to assess potential effects of toxic air irritants on respiratory rate. Air from one school's kindergarten class resulted in a 36% decrease in test animal respiratory rates, but this effect was not observed after repeating the protocol three months after interventions located and mitigated pollutant sources and increased the ventilation rate. Routine O&M of school HVAC system components such as scheduled air filter inspection and replacement may enhance IAQ. Souto and de Oliveira Fernandes (2000) conducted a series of experiments to characterize HVAC filters and sources of chemical, microbiological and sensory pollution. Their results suggested filters were a cause of or exacerbated indoor air pollution, with the age of the filter a relevant parameter. Provision of thermal comfort for occupants may also be improved. Shaughnessy et al (1997) reported from their school intervention study concerning IAQ, ventilation and energy about initial inspections of the HVAC units serving two classrooms in each of two schools. In one school, the adjacent older main building classrooms had cooling coils completely obstructed with dirt, which negatively impacted HVAC system efficiency during cooling due to lower heat transfer and restricted air flow. At the other school with adjacent, newer portables, however, they found cleaning the wall-mount HVAC system and the auxiliary, manually operated window air conditioner had no impact on indoor T.

Table 3.3.2.1: Summary of results from the UCLA "Operations and Maintenance (O&M) Questionnaire" for public school head custodians or plant managers.

Study	UCLA "Portable Classrooms Pilot Study"	CalEPA-OEHHA and LBNL "East Bay School Children's Respiratory Health Study"	LBNL, DEG and CEC Relocatable Classroom IEQ and Energy Efficiency Demonstration Study	Three Field Studies Together
QUESTION	SAMPLE SIZE, N, IN PARENTHESES (n=7)	(n=10)	(n=2)	(n=19)
Age of portable classrooms and HVAC, i.e., when sited at school? (reported as range)	1986-summer 1999; mid-1950s-early 1960s (concrete "bungalows")	1990-91 school year to summer 2000; 1958 (concrete "bungalows")	~ 08/01/2001	mid-1950s to 08/01/2001
Age of main building, i.e., school (reported as range)	1936-1963	1946-1977	1963	1936-1977
Date of last major renovation project to main buildings (reported as range, as indicator of available funding for renovation and modernization)	1992-1999; one school, built by 1961, reported none	by 1995-96 school year to 1997-98 school year, two schools built by 1951 and 1964, reported none (until 2002 for one)	1985-86, 1998-99	
Types of renovation reported	MB roof redone or repaired (4) painting (1) plumbing (1)	Leroy Green Renovation Program: asbestos removal, and new tiles or lights (4), MB roof redone or repaired (3), new school-- modular (1)	indoor/outdoor painting (2) main office remodeling (1) new carpets, a few rooms each summer (1) new MB HVAC units on roofs (1) new MB wing (1)	
Time mechanical HVAC turned on in general (reported as range) by custodian, central control, or teacher	6:00-8:00	40% 7:00-8:00, 10% 12:00, and 50% on all day and night	7:30, 7:45	6:00-8:00, in general
Time mechanical HVAC turned off in general (reported as range) by custodian, central control, or teacher	10:00-21:00	50% 15:00-17:00, and 50% on all day and night	16:00, 20:00	10:00-21:00, in general
Location of thermostat: A.) central main office; B.) individual teacher control of HVAC operation; or, C.) other: In portables	A. and C.) none, B.) 100%	A. and C.) none, B.) 100%	A.) 50% (on/off), B.) 100%, 50% only T (2-5 deg rang	B.) 95%, 5% only T range
In main building classrooms	A.) 14%, B.)71%, C.) 14%	A.) 40%, B.) 50%; 10% not known	A.) 100% (on/off), B.)100%, 50% only T (2-5 deg ran	A.) 35%, 10% only on/off, B.) 60%, with 5% only T range
Heat turned on: reported temperature range, reported months	<65 to <75, Oct-Nov and Jan	<60 to <72, Sept-Jan	<68, Oct or <65, Dec	<60 to <75, Sept-Jan
Heat turned off: reported temperature range, reported months	>65 to 75-80, Feb-May	>68 to >72, Feb-April	>72, Feb or >67-68, Mar	>65 to 75-80, Feb-May
A/C turned on: reported temperature range, reported months	>65 to >72, April-May	>60 to >71, Mar-Apr and Aug	>70, May or >75, May	>60 to >75, Mar-May and Aug
A/C turned off: reported temperature range, reported months	64 to <72, May-June, end Aug	<60 to <70, June and end Aug	70, Oct or in 60s per teacher preference, Oct	64 to <72, May-Jun and end Aug-Oct

Table 3.3.2.1 (continued): Summary of results from the UCLA "Operations and Maintenance (O&M) Questionnaire" for public school head custodians or plant managers.

Study	UCLA "Portable Classrooms Pilot Study"	CalEPA-OEHHA and LBNL "East Bay School Children's Respiratory Health Study"	LBNL, DEG and CEC Relocatable Classroom IEQ and Energy Efficiency Demonstration Study	Three Field Studies Together
QUESTION	SAMPLE SIZE, N, IN PARENTHESES			
	(n=7)	(n=10)	(n=2)	(n=19)
Current HVAC air filter was not original	83% no, 17% yes/do not know	100% no	100% no	95% no
When HVAC air filter was last changed (reported as range)	11/15/99-8/28/2000	8/31/2000-4/15/2001	8/15/2001, 2/15/2002	
Frequency, during school year, of changing HVAC air filter	1-12 months, one not known	1-12 months, one not known	6 months, 1-2 months	1-12 months
Person changing HVAC air filter	SD building engineer (O&M)	90% SD O&M, 10% sr. custodian	SD HVAC person, head custodian	SD or head custodian
Size of custodial/maintenance staff, both full-time and part-time staff	2 to 5; one high school had eight night part-time staff	2 to 3	3, 6	2 to 6
Custodial staff receives training about operation, maintenance, and cleaning of portables and the mechanical HVAC (range of reported frequency):				
When start job	43%	50%	100%, by SD and/or peers	52%
At start of school year	none	10%	50%, on new products and equipment	16%
Two or more times a year	43%	60%	none	47%
Existence of standardized written protocol or manual at school for:				
Operation of portables HVAC	29% yes, 57% no, 14% not known	20% yes, 80% no	no, no	74% no
Maintenance of portables HVAC	14% yes, 71% no, 14% not known	10% no, 90% yes	no, no	84% no
Existence of maintenance log at school, kept with custodian or at main office	71% yes, 29% no; if yes, at min. copies of work orders	70% yes, 30% no	no, yes-- only HVAC filters: sizes, when changed	68% yes
Average outdoor air ventilation intake rate of the mechanical HVAC	No custodian interviewed could answer this question, even after further clarification. Each custodian recommended calling the SD office of O&M (HVAC person or building engineers), or Central Shops/Facilities, to acquire the answer. This finding, and the other data presented here, suggest the need for improved and more regular communication between appropriate school district officials and head custodians, and between the principal, head custodian, and teachers.			

3.4 Comparisons and Contrasts, Including Seasonal, Between Field Study Sites

3.4.1 HCHO and CH_3CHO Concentrations Inside Classrooms

Table 3.4.1.1 and Table 3.4.1.2 provide measured indoor air concentrations of HCHO and CH_3CHO by HVAC system in operation and overall for the fall 2001 cooling and winter 2002 heating seasons, respectively, in the LBNL RCS. These data were representative of new portables built by one manufacturer with standard and/or alternative interior finish materials. These results can be compared and contrasted with data from Los Angeles County portables of varying age and manufacturers. Concentrations measured in UCLA PCS portables were given in Tables 3.1.1.2.1 for HCHO and 3.1.1.3.1 for CH_3CHO.

In the LBNL RCS, HCHO data appeared normally distributed; the maximum measured concentrations, during standard HVAC system operation weeks, skewed data slightly to the right. Overall, mean and median values across RCs and during IDEC operation weeks were below the eight-hour CalEPA/OEHHA acute non-cancer REL, 33 $\mu g\ m^{-3}$, whereas maximum values during standard HVAC system operation weeks in both seasons exceeded this guideline. Across RCs, SD, seasons and room types, no measured concentrations in either the LBNL RCS or the UCLA PCS exceeded the CARB IAQ guideline of ~60 $\mu g\ m^{-3}$ for HCHO. Measured concentrations during standard HVAC system operation weeks in the LBNL RCS were relatively higher than in the UCLA PCS where portables had a standard HVAC system or comparable mechanical wall-mount HVAC unit, or no HVAC system at all. The ranges of measured concentrations across studies, however, were similar. This was likely because the ages of portables in the

UCLA PCS ranged from about one to 40-50 years old whereas LBNL RCS portables and thus interior finish materials were new. In addition, in both studies, measured concentrations in the cooling season were higher than in the heating season. Ventilation, i.e., AER, T and RH were influences; in the LBNL RCS, measured outdoor concentrations were also lower in the heating season.

In the LBNL RCS, CH_3CHO data also appeared normally distributed, though during standard HVAC system operation weeks and in the heating season maximum measured concentrations skewed data slightly to the right. Overall, measured CH_3CHO concentrations in the cooling season were greater than in the heating season, likely because emissions from interior finish materials and original furnishings in these RCs declined with time, a process hastened by improved ventilation, e.g., values during IDEC operation weeks were lower than during standard HVAC system operation weeks. Moreover, ambient CH_3CHO concentrations measured at the school sites were lower during the heating season. In the UCLA PCS, measured concentrations in portables were also lower in the heating season in SD 2 relative to the cooling season in both SD. In addition, in SD 1, measured SWIA concentrations declined ~40-50% between cooling season sampling events. Measured concentrations in the heating season overall, and during IDEC operation weeks in the LBNL RCS, were below the CalEPA/OEHHA chronic non-cancer REL of 9 $\mu g\ m^{-3}$. In the cooling season across RCs, mean, median and maximum concentrations, and mean and maximum concentrations across seasons during standard HVAC system operation weeks, exceeded this guideline. Even after outdoor concentrations were subtracted as a correction for LBNL RCS data, maximum concentrations measured during standard HVAC system operation weeks across seasons and during IDEC operation weeks in the cooling season, and the mean concentration during standard HVAC system operation weeks in the cooling season, still exceeded this guideline. In the UCLA PCS, in both SD across seasons, mean and median SWIA and SDIA concentrations were below this guideline. As observed with HCHO, these comparisons were likely related to the ages of the portables; ambient CH_3CHO concentrations also varied by SD.

In summary, measured concentrations of HCHO and CH_3CHO in portables assessed in the UCLA PCS and in the LBNL RCS supported the conclusion adequate or even improved ventilation were important for good IEQ. Indeed, ventilation may be more important to the enhancement of IEQ than source control through selection of interior finish materials and furnishings. Nevertheless, introduction of teaching materials, cleaning compounds, and particleboard-based products, for varying periods of time and in varying quantities, influenced measured concentrations indoors and added uncertainty to these school IEQ studies.

Table 3.4.1.1: Summary of measured formaldehyde (HCHO) concentrations-- by HVAC system in operation and overall-- for the fall 2001 cooling (September 5-October 25) and winter 2002 heating (January 8-March 7) seasons, school districts (SD) 3 (CUSD) and 4 (MCS), LBNL RCS

			STUDY, SD 3 and 4, in ug m^{-3}		
Parameter	Season	Statistics	four RCs	during advanced (IDEC) HVAC operation	during conventional (Bard) HVAC operation
indoor	cooling	mean	21.7	14.1	30.4
		stdev (SD)	10.5	6.6	6.9
		median	19.9	14.1	31.0
		min	7.0	7.0	15.0
		max	40.0	29.5	40.0
indoor	heating	mean	14.4	7.9	21.0
		SD	10.3	2.9	10.7
		median	11.9	7.2	30.3
		min	4.2	4.2	6.7
		max	45.2	13.2	45.2
indoor-outdoor	cooling	mean	17.2	9.6	25.7
		SD	10.1	6.1	6.4
		median	15.7	7.1	27.1
		min	3.4	3.4	9.7
		max	34.2	23.5	34.2
indoor-outdoor	heating	mean	11.9	5.5	18.3
		SD	10.0	2.6	10.4
		median	9.2	5.0	15.1
		min	2.1	2.1	4.4
		max	41.4	10.2	41.4

Table 3.4.1.2: Summary of measured acetaldehyde (CH_3CHO) concentrations-- by HVAC system in operation and overall-- for the fall 2001 cooling (September 5-October 25) and winter 2002 heating (January 8-March 7) seasons, school districts (SD) 3 (CUSD) and 4 (MCS), LBNL RCS

			STUDY, SD 3 and 4, in ug m^{-3}		
Parameter	Season	Statistics	four RCs	during advanced (IDEC) HVAC operation	during conventional (Bard) HVAC operation
indoor	cooling	mean	10.0	6.9	13.7
		stdev (SD)	5.0	4.1	3.7
		median	9.8	6.6	12.6
		min	2.6	2.6	7.2
		max	20.3	17.5	20.3
indoor	heating	mean	7.1	3.8	10.4
		SD	5.7	1.4	6.3
		median	5.4	3.8	7.6
		min	1.4	1.4	3.7
		max	24.0	6.7	24.0
indoor-outdoor	cooling	mean	5.7	2.7	9.3
		SD	4.2	2.8	2.7
		median	5.6	1.9	8.6
		min	-0.4	-0.4	4.7
		max	13.2	9.3	13.2
indoor-outdoor	heating	mean	4.5	1.4	7.6
		SD	5.2	0.8	5.8
		median	2.5	1.4	5.9
		min	-0.3	-0.3	1.5
		max	20.3	3.3	20.3

Cavallo et al (1993) investigated IAQ in main building classrooms and special purpose rooms in the winter season in ten K-12 schools in Milan, Italy characterized by natural ventilation. Four of the schools were pre K- K and six of the schools served 1st-12th grades; four indoor samples and one outdoor sample were taken at each school. The measured HCHO concentrations were not normally distributed. The median (range) HCHO concentrations for pre K-K and 1st-12th grade school rooms were 80.0 $\mu g\ m^{-3}$ (10.2-168.0 $\mu g\ m^{-3}$) and 82.0 $\mu g\ m^{-3}$ (8-210 $\mu g\ m^{-3}$), respectively, with corresponding outdoor concentration values of 28.0 $\mu g\ m^{-3}$ (7.0-75 $\mu g\ m^{-3}$) and 17.0 $\mu g\ m^{-3}$ (7.0-220.0 $\mu g\ m^{-3}$), respectively. Although the ranges of measured indoor air concentrations in the UCLA PCS and in the LBNL RCS across seasons fell within these reported ranges, the levels observed and maximum concentrations measured in the Italian study were higher, due to the higher outdoor concentrations and lack of mechanical ventilation.

Smedje and Norback (1999) led a 1993-95 investigation of 181 main building school classrooms, 2-5 per school, in 57 different buildings at 39 of 40 randomly selected public elementary schools and nine secondary schools in the county of Uppsala, Sweden. Among the quantitative one-day exposure measurements conducted, the median (25th-75th interquartile range) HCHO concentrations were < 5 $\mu g\ m^{-3}$ (<5-10 $\mu g\ m^{-3}$). These concentrations were lower than those observed in the UCLA PCS and in the LBNL RCS, though data from each study were below existing IAQ guidelines. The Swedish schools were older, and thus there were likely lower emissions from construction and interior finish materials. Nevertheless, HCHO concentrations were predicted to be higher in classrooms with more fabrics ($p < 0.05$) and more open shelves ($p < 0.001$), which supported the idea of interior furnishings as potential sources and sinks in classrooms.

Fontana et al (2000) reported on measurements conducted for three days during occupied hours in an USEPA school demonstration study on IAQ Four indoor sites and one outdoor location per school, at five public schools across the United States, were included; one school was in California in a mild, dry climate zone. Integrated HCHO measurements were included, which involved an active sampling protocol nearly identical to the LBNL RCS except the sample duration was 8-10 hours instead of 7-8 hours. The mean ± SD (range) integrated indoor concentrations at the California school, in ppb, were 7.5 ± 0.5 (7.1-8.3). These values in $\mu g\ m^{-3}$ were 9.2 ± 0.6 (8.6-10.1). These HCHO concentrations were generally lower than those measured in the UCLA PCS and in the LBNL RCS across SD, seasons, and HVAC systems. The differences in the studies were likely due to ambient influences, differences in HVAC system operation, and sample durations.

Nikolic (2000) reported on a study of IAQ over 20 consecutive winter days in main building classrooms of two primary schools in Nis, Yugoslavia; "school 1" was located in an industrial zone near a busy street, and "school 2" was situated away from major outdoor pollution sources and enclosed by vegetation. The mean ± SD (range) integrated daily indoor HCHO concentrations, in $\mu g\ m^{-3}$, at "school 1" and "school 2," respectively, were 0.8 ± 9.3 (0-27.6) and 0.03 ± 7.6 (0-0.1). The author associated these low concentrations with the lack of new construction materials and furnishings. Measured concentrations in "school 1" were relatively higher than in "school 2" possibly due to relative proximity to primary and secondary ambient sources of HCHO. The maximum measured HCHO concentration in "school 1" was within the ranges of indoor HCHO concentrations measured in the UCLA PCS and in the LBNL RCS.

In the pilot study of the French Permanent Survey on IAQ (Kirchner et al, 2002a), two main building classrooms in each of nine schools were assessed; the main field study in 2003-04 will assess two classrooms in each of 80 schools. The reported range of measured integrated indoor HCHO concentrations was 13-67 $\mu g\ m^{-3}$. These data were similar to, but the range wider than, measurements conducted during the UCLA PCS and the LBNL RCS.

In an IAQ assessment at a Texas public high school (Petronella et al, 2002), where windows and doors were kept closed and HVAC systems run on normal daily cycles, among targeted VOCs only measured HCHO concentrations exceeded current federal occupational guidelines. Interpretation was difficult since data and a detailed discussion were not provided; results may have been linked to a specific source or problem. Maintenance staff inspections, however, found 16 of 19 classrooms had ventilation rates out of compliance with ASHRAE 62 (1999). Though indoor concentrations appeared higher than those measured in the UCLA PCS and in the LBNL RCS, ventilation again seemed important.

3.4.2 Indoor Air T and RH

Overall, as expected, T and RH measures in the UCLA PCS were higher in the cooling season than in the heating season across SD, room types and time periods. In comparison to the ASHRAE Standard 55 (1992) acceptable comfort ranges for activity scenarios relevant to school classrooms, results suggested adequate ventilation and associated conditioning of indoor air for occupant comfort were not always provided to these classrooms. Again, the range for RH was 30-60% across seasons, while the ranges for T in the cooling and heating seasons were 73-74°F to 78-81°F and 68-69°F to 74-76°F , respectively. Mean and median T and RH were usually within season-specific ranges, but minimum and maximum measured T and RH were usually not.

In the cooling season, LBNL RCS mean T, regardless of which HVAC system operated, were usually below the lower bound of the ASHRAE comfort envelope. The exceptions were SD 4 RC A, RC B in both SD, and SD 3 RC A in the PM during standard HVAC system operation weeks, as well as in SD 4 RC A in the PM during IDEC operation weeks. The ASHRAE thermal comfort envelope was exceeded in the cooling season by maximum six-minute RH averages across SD, RCs and HVAC systems. In SD 3, the mean RH in the PM in RC A during IDEC operation weeks, as well as in RC B in the AM and during IDEC operation weeks in the PM, also exceeded the comfort envelope.

In the heating season, LBNL RCS mean T and maximum six-minute T averages were within the ASHRAE comfort envelope except mean morning and afternoon T during standard HVAC system operation weeks in three of the four RCs and mean AM and PM T during IDEC operation weeks in SD 3 RC B. Minimum six-minute RH averages were usually lower in the PM than in the AM. Across SD, RCs and HVAC systems during the heating season, the minimum six-minute RH averages were below the lower bound of the ASHRAE comfort envelope. The lone exception was SD 4 RC B, where the observed less consistent use of HVAC systems allowed the influence of occupant respiration to be relatively greater. Except for SD 3 RC B during standard HVAC system operation weeks, across SD the PM RH values and most unoccupied period RH values were also below the lower bound of the ASHRAE comfort envelope.

Results across studies were likely due to a combination of factors including less than continuous use of the standard HVAC systems; characteristics of the HVAC system technologies; teacher T set point preferences; and, occupants as thermal mass and due to respiration and perspiration. Indoor T and RH during unoccupied periods were influenced by variable ambient conditions and, in the LBNL RCS, the IDEC if it was left on in "auto" mode.

Braganza et al (2000) reported on indoor air T and RH data from one of the USEPA school demonstration studies on IAQ. They conducted one set of measurements for three consecutive days (Tuesday-Thursday) during occupied hours at four indoor sites and one outdoor location per school at eight public schools across the United States prior to energy efficiency retrofits and IEQ interventions, e.g., USEPA *Tools for Schools*. Two of the schools were in California: "school 1" was located in a cooler, drier climate zone; "school 2" was situated in a warmer climate zone with moderate RH. T at four heights, and RH, were monitored continuously with instrumentation similar to the HOBO used in the UCLA PCS and in the LBNL RCS near the teacher work area out of student reach and sight. Internal loggers stored data as five-minute averages. Braganza et al measured vertical indoor air T difference as an indicator of thermal comfort because the ASHRAE Standard 55 (1992) required simultaneous T measurements at three heights where an occupant worked. The average (range) T and RH data for "school 1" were 22°C (19-24°C) and 28% (19-40%), respectively; the average outdoor T and RH% were 16°C and 24%, respectively. The average (range) T and RH data for "school 2" were 23°C (21-26°C) and 45% (41-58%), respectively; the average outdoor T and RH% were 31°C and 47%, respectively. These T data were similar to UCLA PCS results; average T was within the ASHRAE 55 (1992) acceptable comfort range, but the minimum and maximum values were near to, or exceeded, the lower and upper bounds, respectively. LBNL RCS mean and maximum six-minute T averages in the cooling season across RC and SD were similar to "school 2." LBNL RCS mean RH data during standard HVAC system operation weeks in SD 4 in the cooling season, and in SD 4 RC B across HVAC systems in the heating season, were similar to "school 2." Otherwise, T and RH measures in the UCLA PCS and in the LBNL RCS were higher in the cooling season, lower in the heating season, and distributed over a wider range. "School 2" was most similar to the southern California climate zone covered by the UCLA PCS, though in general SD 1, being farther from the Pacific Ocean coastline, experienced higher afternoon ambient T than SD 2. "School 2" was also most similar to the northern California climate zone which included SD 3 of the LBNL RCS. "School 1" was roughly similar to SD 4 of the LBNL RCS, though the northern Central Valley climate zone was likely warmer and drier in the cooling season. Therefore, differences in the three data sets were likely determined by variations in ambient conditions over space and time, school facilities, and HVAC systems.

In the Thorstensen et al (1990) study in greater Copenhagen, Denmark which included selective quantitative short-term monitoring over a five-day period for 10-120 minutes in one of 2-9 main building classrooms at each of ten schools in March 1989, the mean (range) indoor air T and RH were 21.6 °C (19.5-23.5 °C) and 36% (27-44%), respectively. Smedje and Norback (1999) led a 1993-95 investigation of 181 main building school classrooms, 2-5 per school, in 57 different buildings at 39 of 40 randomly selected public elementary schools and nine secondary schools in the county of Uppsala, Sweden. Among the quantitative one-day exposure measurements conducted, the median (25^{th}-75^{th} interquartile range) indoor air T and RH were 23.0 °C (22.0-23.5 °C) and 36% (30-41%), respectively. Across seasons, SD and room type, mean T and minimum five-minute and six-minute RH averages during the UCLA PCS and the LBNL RCS, respectively, were similar. Otherwise, differences between data sets were likely because colder and damper ambient conditions for more of the school year in northern Europe increased HVAC system use for heating.

3.4.3 Checklist, Survey, Questionnaire

Results from the UCLA "Classroom Checklist" and "O&M" interview questionnaire for public school head custodians and plant managers were compared and contrasted during summarization of results in sections 3.3.1 and 3.3.2, respectively, including Tables 3.3.1.1 and 3.3.2.1, respectively. Other studies which conducted walk-through surveys in school and day-care settings can be highlighted for context and further comparisons.

A study in Finland of 30 schools including 41 individual buildings (Koivisto et al, 2002) used trained personnel and a standardized walk-through survey for a moisture damage assessment; parameters included age, predominant building materials, location of moisture damage, and presence of mold and/or mold odor.

Turk et al (2002), based on the USEPA's *IAQ Tools for Schools*, developed checklists for schools on topics such as air cleaning, cleaning management, and moisture and mold; checklists were pilot tested in Albuquerque, New Mexico.

In the previously described study by Smedje and Norback (1999) in the county of Uppsala, Sweden, surveys were conducted to collect data on building age, construction and interior finish materials including open shelves and fabrics, the type of HVAC system, and smells and signs of dampness. For example, 15% of the main building classrooms were observed to have signs of building dampness or moisture damage.

In an IAQ risk assessment of a school building in Finland, Pettinen et al (2000) reported the walk-through assessment discovered a leaking water pipe, which caused significant moisture damage; microbial contamination of surfaces was later quantified. In the LBNL RCS, the "classroom checklist" helped the technician identify a small leak within the IDEC hydronic loop after recognizing a damaged, slightly discolored, damp ceiling tile. The technician and a LBNL mechanical engineer completed repairs and replaced the ceiling tile within one week. As a result, proper, efficient IDEC heating and prevention of mold growth were ensured.

An effort to implement a school IAQ assessment and management program has been ongoing in the states of Washington and Idaho since the 2000-01 school year (Prill et al, 2002). In the first year, 156 schools, including 3801 classrooms, were visited by IAQ and building science specialists from the state government who conducted standardized walk-through assessments; findings sometimes led to more detailed monitoring or interventions. Relevant to "classroom checklist" findings of this dissertation, 10% of the 180 portables at these Washington and Idaho schools had no mechanical HVAC system, and during school hours 25.5%, or 28.4% of those with mechanical HVAC systems, were found with the HVAC systems off. Thus, the problem of inadequate ventilation appeared to be common across studies.

In a study of 56 main building classrooms in 25 schools in a Finnish city (Pasanen et al, 2002), most of the 69% of 619 teachers who responded to a questionnaire reported the main IEQ nuisances were noise and stuffy, dry air. The sources of those problems were believed to be related to HVAC system temperature control, inadequate ventilation, and classroom overcrowding.

A pilot experimental study on effects of mechanical ventilation on IAQ of urban apartments (Kirchner et al, 2002b) found optimal placement of the air inlet was at the less exposed location, i.e., where occupants spent the least time and away from adjacent outdoor sources. This recommendation could apply to the placement of new portables with wall-mount mechanical HVAC units on school sites. In the UCLA PCS, the outdoor air intake vents of the HVAC systems of some portables faced areas where trucks delivering supplies at times remained in idle.

In summary, well-structured qualitative surveys can be useful for conducting or enhancing school IEQ assessments in situations where quantitative measurements may be impossible or limited, respectively, due to limited resources.

3.5 Known Limitations of Study Design

Two basic limitations of the monitoring methodology created for the UCLA PCS, previously described, related to comprehensiveness: no quantitative biological sampling, and no integrated particle concentration measurements. Statistical limitations of the data resulted from necessary methods of recruitment. Other limitations of the study design and sampling methodology were imposed by limited resources, e.g., no monitoring of outdoor air concentrations, and the short amount of time allowed in the elementary school classrooms. These issues applied to the LBNL RCS as well.

A primary goal of this dissertation was to develop a non-invasive, non-intrusive, non-disruptive sampling protocol, with samplers out of reach and sight of students and out of the teacher's organizational and functional space. This methodology required no personal sampling; elimination of personal passive samplers and student and teacher questionnaires also prevented the need for approval by the UCLA and LBNL/UC-Berkeley Institutional Review Boards. The measured concentrations in the portable or main building classrooms, however, were indirect measurements of personal exposure. Exposure is contact between a physical, chemical, or biological agent and a target, e.g., child or adult. Since public elementary school students and their teachers spent most of the school day inside a designated classroom, contact with indoor air by multiple routes was a safe assumption. Personal sampling with passive VOC and aldehyde badges during school hours to separate classroom, cafeteria and playground exposures from exposures received at home and in other activities, e.g., transit to school by school bus, city bus, car, or walking, would have been ideal. In addition, the field studies described in this dissertation involved neither active nor passive sampling of personal particle and/or aerosol exposures. Indoor and outdoor particle counts were continuously measured in the LBNL RCS (Apte et al, 2002; Shendell et al, 2002b) but these data were not part of this dissertation. Personal particle samplers would have involved small pumps, battery packs, and sampling head cassettes with Teflon filters, a cumbersome system and an excessive responsibility for most 5-9 year old boys and girls.

With passive samplers and limited resources, the UCLA PCS could not take direct measurements of concentrations of toxic air compounds inside portables during late afternoon and overnight periods. This fraction, however, was interpolated using the SWIA and SDIA data (see Appendix A.4.3). With active sampling systems for aldehydes, data from the LBNL RCS represented the 7.5 hour school day period, but not the 17.5 hour late afternoon/overnight period, one day per week for eight and nine weeks in the cooling and heating seasons, respectively.

With the exception of indoor air T and RH data, and wintertime CO data in UCLA PCS SD 2 portables, measurements of quantitative parameters in this dissertation resulted in integrated averages over defined time periods. Due to available financial resources and sensitivities with respect to the study populations, the methodology developed required passive samplers in the UCLA PCS and small, relatively quiet, pumps with programmable timers and a calibrated flow rate for active aldehyde sampling in the

LBNL RCS. Thus, no continuous, time-resolved organic compound concentration data or AER measurements were possible.

The LBNL RCS included no direct, quantitative measurements of air exchange, i.e., ventilation, rates like the PFT and CAT system technique used in the UCLA PCS. The LBNL RCS, however, measured continuous CO_2 concentrations inside and outside the classroom (Apte et al, 2002; Shendell et al, 2002b). Incorporating classroom attendance data and data from door sensors and window linear displacement potentiometers (Shendell et al, 2002b), LBNL estimated ventilation rates and assessed the efficacy and impact on IAQ of the advanced versus conventional HVAC systems tested (e.g., Hodgson et al, 2002; Shendell et al, 2002d). These data analyses were not part of this dissertation.

As previously mentioned, the LBNL RCS monitored the opening and closing of doors and windows, including how far windows were open if left ajar. The UCLA PCS, however, did not have these instruments, which were built into the prototype RCs, and would have provided quantitative data on the influence of occupant activities and behaviors on estimated or measured AER through provision of natural ventilation. Therefore, in the UCLA PCS, measured AER may have included mechanical and natural ventilation components. In both field studies, some small amount of unintentional air infiltration through the building envelope occurred.

Another known limitation with respect to assessing HVAC system function was no mechanical engineering tests to measure the flow rates of the outdoor air intake and through ceiling supply air diffusers were conducted in the UCLA PCS. In the LBNL

RCS, LBNL and DEG measured these flows as well as T when commissioning the HVAC systems. In both field studies, however, a "classroom checklist" developed for this dissertation recorded conditions each time the technician visited the classroom, which included the state of doors, windows, and HVAC systems. Therefore, integrated AER measurements provided semi-quantitative, descriptive assessments of HVAC system function.

The UCLA PCS calculated average AER for IAQ purposes, named the effective ventilation rate (Leaderer et al, 1985; Sherman and Wilson, 1986; Sherman, 1989) to distinguish it from the average ventilation rate calculated for energy use purposes (D'Ottavio et al, 1988; Sherman, 1990). In reality, over long measurement time periods of a week to months, ventilation rates may vary in homes and schools, leading to negative bias, i.e., underestimation, of average ventilation rates (Leaderer et al, 1985; Sherman and Wilson, 1986; Sherman, 1989). The magnitude of this negative bias, estimated at 3-6% in a well-defined environmental chamber study (Leaderer et al, 1985), was also related to ambient weather, construction details, and inadequate mixing if multiple zones, were considered (Sherman, 1989).

As a result, adherence to and validity of certain assumptions about the type of passive PFT system used in the UCLA PCS were important. The room, or zone, was perfectly well mixed, which meant the PMCH concentration was uniform, other fluid properties were homogeneous, and any outside air or PFT injected instantaneously dispersed within the zone. The assumption was valid if uniform concentration was considered within +/-10% (D'Ottavio et al, 1988), and a finite time, e.g., 24-48 hours or more, but less than the monitoring time, e.g., one school week, was required for the air to be well-mixed; these criteria were satisfied. Hodgson et al (2000) also made the analogy between this well-mixed zone and the ideal, continuous stirred tank reactors at near steady-state conditions, which was relevant to the next assumption, a system at steady-state during the measurement period. Even typical ventilation flow variations of 50-100%, if the measurement period was 1-10 weeks, would result in only 5-10% error in calculated AER (D'Ottavio et al, 1988). In study classrooms, and especially portable classrooms, doors and windows were usually closed during occupancy and closed and locked overnight. As a result, large short-term variations were limited.

The final assumption was "the zone only communicated with the outside," (Sherman, 1990) defined as an area whose tracer gas concentration was not effected by the zone under study, e.g., ambient air. Tracer gas experiments demonstrated only simple residential and commercial buildings, e.g., one-family one-floor homes, were considered single, well-mixed zones (D'Ottavio et al, 1988; Wallace, 2001). Most portable classrooms also fit this description. Main building classrooms, however, did not fit this description unless they were one-story buildings and were physically separated from adjacent classrooms, i.e., the one or two doors led only to ambient air. If a main building control classroom did not meet these criteria, part of the PMCH likely exited the classroom for the hallway as well as outside; the potential measurement error was likely differential in nature. Again, during UCLA PCS first samplings, only two elementary schools and the senior high school in SD 2 may have been subject to such error, and these data were excluded from statistical analyses; the senior high school was not included in the second seasonal sampling for reasons stated.

Monitoring of outdoor concentrations of target organic compounds and of T and RH (SD 2 only) in the UCLA PCS were not conducted due to limited resources; active sampling outdoors was conducted in the LBNL RCS. No direct quantitative focus was given to the impact of local outdoor sources, e.g., industries, freeways. If high concentrations of compounds emitted from known outdoor sources were measured in selected classrooms at a participating school, future studies could examine the relative impact of indoor and neighboring outdoor sources in a more rigorous, quantitative manner. The "Technician Walk-Through" survey only qualitatively identified potential outdoor sources of target indoor toxic and odorous air contaminants. Outdoor T and indoor/outdoor T differentials have been shown to affect calculated AER values (Dietz and Cote, 1982; Wilson et al, 1996; Wallace et al, 2002), but magnitudes were relatively small. Seasonal and geographical effects were observed with data from California homes (Wilson et al, 1996), where warmer weather may have increased calculated AER and increased the slope of the AER distributions. Residential AER distributions were found to be approximately log-normal in various studies, which included Southern California and specifically Los Angeles area homes from probability sampling (Murray and Burmaster, 1995; Wilson et al, 1996; Pandian et al, 1998; Weisel et al, 2002). The UCLA PCS attempted to investigate similar T and seasonal associations for school AER measurements in Los Angeles County. The data, however, based on small sample sizes after grouping data by SD, season, room type and/or sample type, and generally similar means and medians, were assumed approximately normally distributed; the few specific high values were previously explained.

Neither the UCLA PCS nor the LBNL RCS measured other compounds of interest to acute and chronic children's respiratory health outcomes, e.g., ozone, nitrogen dioxide, oxides of sulfur, sulfates and nitrates, polycyclic aromatic hydrocarbons. These were considered primarily ambient pollutants, given schools in California were non-smoking environments. Furthermore, these were not environmental epidemiology studies of health and productivity of teachers, students, and staff.

CHAPTER 4.-- CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

4.1.1 UCLA PCS

Across room types, school districts, seasons and sample types, none of the measured formaldehyde concentrations exceeded the CARB indoor air guideline of ~60 $\mu g\ m^{-3}$ and likely not the one-hour CalEPA/OEHHA acute non-cancer REL of 94 $\mu g\ m^{-3}$. No measured daily-integrated concentrations were above the eight-hour CalEPA/OEHHA acute non-cancer REL of 33 $\mu g\ m^{-3}$. Across school districts, weekly-integrated and daily-integrated acetaldehyde concentrations were higher in portables than in main building classrooms. These data suggested the main sources of aldehydes in UCLA PCS classrooms 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.

The four most prevalent VOCs measured in the UCLA PCS were toluene, m-/p-xylene, a-pinene, and d-limonene. Their measured daily-integrated concentrations were higher than weekly-integrated concentrations, which suggested the importance of school day activities as sources. Their likely indoor sources in the school classroom environment were commercially available personal, teaching, and cleaning products. Concentrations of these compounds were relatively lower in main building classrooms than in portables, which may be due to differences in the frequency, duration and amounts of indoor source products used or the presence of other sources in the portables.

Across school districts, room types, and samples types, measured air exchange rates (AER) were low, and median daily-integrated values were higher than weekly-integrated values, demonstrating the influences of occupant behavior with respect to the use of doors, windows and/or HVAC systems during school hours. The activities of night custodians were expected to have short-term, limited influences on measured AER. A comparison of measured AER with ASHRAE Standard 62 (1999), 15 ft^3 min^{-1} person $^{-1}$, assuming 20 students and one teacher occupied a classroom given class size reduction initiatives for K-3rd grades, suggested across seasons inadequate ventilation occurred in study classrooms except for in one.

4.1.2 LBNL studies

Across relocatable classrooms (RCs), measured indoor and indoor minus outdoor formaldehyde concentrations were higher during standard HVAC system operation weeks than in advanced HVAC system (IDEC) operation weeks, and values in school district (SD) 4 exceeded those in SD 3 in part due to higher outdoor background concentrations driven by upwind line sources, especially in the cooling season. Variation in HVAC system operation behaviors, and introduced sources, also influenced measured concentrations. In general, acetaldehyde concentrations measured during standard HVAC system operation weeks were higher than in IDEC operation weeks, and were higher in SD 4 than in SD 3 partially due to the higher outdoor background concentrations; subtracting the outdoor concentrations from the indoor concentrations, however, made no difference. LBNL RC study aldehyde data suggested ventilation, especially continuous ventilation with 100% filtered outdoor air as provided by the

IDEC, may be more important than the control of indoor sources (with alternative interior finish materials, cleaning and teaching products) or the influence of local ambient sources.

In the LBNL RCS, across school districts and RCs, indoor temperature (T) and relative humidity (RH) measured near the teacher's desk were influenced by several factors. These included afternoon cooling and morning heating demands on HVAC system operation; attributes of the HVAC system technologies; occupants as thermal mass and due to respiration and perspiration; ambient conditions; use of the door and windows; and, teacher temperature set point preferences.

4.1.3 Overall, Across Study Sites in Southern and Northern California

In summary, measured concentrations of formaldehyde and acetaldehyde in portables assessed in the UCLA PCS and in the LBNL RCS supported the conclusion adequate or even improved ventilation were important for good IEQ. Indeed, ventilation may be more important to the enhancement of IEQ than source control through selection of interior finish materials and furnishings. Nevertheless, introduction of teaching materials, cleaning compounds, and particleboard-based products without lamination, for varying periods of time and in varying quantities, influenced measured concentrations indoors and added uncertainty to these school IEQ studies.

As expected, indoor T and RH were higher in the cooling season than in the heating season across SD, room types and time periods considered. In comparison to ASHRAE Standard 55 (1992), the results suggested sufficient ventilation, both natural and mechanical, and/or associated conditioning of indoor air for occupant comfort were not always provided to school classrooms.

4.2 Recommendations for Future Research

Future research in schools should attempt larger sample sizes and cover larger geographical areas but continue to assess multiple IAQ and environment parameters during occupied hours with quantitative and qualitative instruments. Well-structured qualitative surveys can be useful for conducting or enhancing school IEQ assessments in situations where quantitative measurements may be impossible or limited, respectively, due to limited resources. When toxic and odorous VOCs are measured, the list of target VOCs should emphasize those associated with newer interior finish materials, cleaning compounds, and microbial VOCs, particularly in situations when concerns of moisture build-up on or behind walls and ceiling tiles, and subsequent mold growth, arise after walk-through surveys.

Good analytic and overall precision for the methodologies employed in the UCLA PCS and in the LBNL RCS were demonstrated. An additional finding from the UCLA PCS, however, was the overall precision analysis and field data for measured school day hours average concentrations of aldehydes in portables on multiple weekdays provided support for future development of the DNSH PAKS. Modifications and further laboratory and field validation assessments would benefit personal and microenvironmental exposure assessment in educational and occupational settings for HCHO, CH_3CHO, and other carbonyls of health importance, e.g., acrolein.

The UCLA PCS conducted measurements of AER integrated over different time periods due to the method employed, available resources, and practical limitations. AER, as well as T and RH, however, may vary, especially during the school day, due to HVAC system operation, use of doors and/or operable windows, and occupant time-activity patterns. Therefore, future studies on ventilation in school classrooms should include integrated and continuous measurements of T, RH, and AER with appropriate tracer gas methods, and other airflow measures.

4.3 Implications: Recommendations for Public School Districts Regarding Portable Classrooms and Maintenance and Operations

Results of the "Operations and Maintenance" interview questionnaire suggested the prevalence of insufficient training and limited communication between custodians and SD offices concerning HVAC systems, especially for portables. Therefore, efforts are needed to educate teachers, custodians, and other SD staff on the importance of adequate, even improved, continuous ventilation with filtered outdoor air, even when cooling or heating may not be desired, to help reduce concentrations of pollutants and human bioeffluents including carbon dioxide and odors.

APPENDIX A.1

Instruments, Databases, and Results of School District and School Recruitment

A.1.1. To Maintain Confidentiality, Information Maintained by Author

Targeted School Districts and Schools Recruitment Database: Results and Inventories of Portable/Relocatable and Main Building Classrooms

A.1.1.1 *UCLA PCS*
A.1.1.2 *LBNL RCS*
A.1.1.3 *OEHHA study*

«date»

«name»
«office_of_the_superintendent»
«school district name»
«street address»
«city, state, zipcode»

Dear Superintendent «name»,

I am a doctoral candidate in the UCLA School of Public Health in the professional track Environmental Science and Engineering program. I hold a BA from Dartmouth College and a MPH from the Yale University Department of Epidemiology and Public Health, School of Medicine. My proposed dissertation is an assessment of organic compound exposures and heating, ventilation, and air conditioning system functioning in public school portable classrooms in Los Angeles County, CA. I would work with mentors at UCLA as well as from the state agency hosting my doctoral internship. The field work on school grounds would occur during the 2000-2001 academic year.

Teachers and parents in a number of California school systems (e.g., Saugus Union School District in Santa Clarita) have reported health effects like asthma symptoms of, to date, unknown origin due to the use of portables. It is important to establish a scientific foundation for effective, timely public health intervention strategies concerning this rapidly escalating problem because children are a relatively more susceptible subpopulation.

My specialty, based on my training to date, is multimedia exposure assessment and its relevance to law and policy. My U.S. EPA STAR Graduate fellowship is in health risk assessment with a focus on children.

I would like to receive your formal, written permission by letter or e-mail to continue, i.e., to contact principals at all eligible schools concerning their interest and participation.

Thank you for your time and attention to this present and significant public health concern in our children's school environment. Please call (310) 825-3161 or e-mail shendell@ucla.edu with any questions.

Sincerely,

Derek G. Shendell, MPH
University of California, Los Angeles School of Public Health
Environmental Science and Engineering Program doctoral candidate
University of California Chancellor's fellow

May 11, 2000

Office of Research and Evaluation
Los Angeles Unified School District
450 North Grand Avenue
Los Angeles, CA 90012

Dear staff members,

I am a doctoral candidate in the UCLA School of Public Health in the professional track Environmental Science and Engineering program. I hold a BA from Dartmouth College and a MPH from the Yale University Department of Epidemiology and Public Health, School of Medicine. My proposed dissertation is an assessment of organic compound exposures and heating, ventilation, and air conditioning system functioning in public school portable classrooms in Los Angeles County, CA. I would work with mentors at UCLA as well as from the state agency hosting my doctoral internship. The field work on school grounds would occur during the 2000-2001 academic year.

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My specialty, based on my training to date, is multimedia exposure assessment and its relevance to law and policy. My U.S. EPA STAR Graduate fellowship is in health risk assessment with a focus on children.

I would like to receive your formal, written permission by letter or e-mail to continue, i.e., to contact principals at all eligible schools concerning their interest and participation. This letter was originally sent to the Region C Superintendent on May 10; Reneé Jackson, Assistant Superintendent, called with an immediate reply and instructions to contact your office.

Thank you for your time and attention to this present and significant public health concern in our children's school environment. Please call (310) 825-3161 or e-mail shendell@ucla.edu with any questions.

Sincerely,

Derek G. Shendell, MPH
University of California, Los Angeles School of Public Health
Environmental Science and Engineering Program doctoral candidate
University of California Chancellor's fellow

CONTACT/ADMINISTRATOR NAME
SCHOOL DISTRICT NAME
ADDRESS
CITY, STATE ZIP CODE

DATE

DEAR MR. /MRS. ________________,

Lawrence Berkeley National Laboratory (LBNL), in collaboration with the Pacific Gas and Electric Company's Premium Efficient Relocatable Classroom (PERC) Program, and funded by the California Energy Commission (CEC), is conducting a study of energy efficiency and indoor environmental quality (IEQ) in relocatable classrooms (portables). We will study a new classroom with a cost-effective design intended to simultaneously improve energy efficiency and indoor environmental quality. The project will focus on comparing the effectiveness of a standard versus an advanced technology for heating, ventilation, and air conditioning (HVAC) systems. W e will use established techniques to identify and implement practical methods to reduce indoor sources of volatile organic compounds considered indoor air pollutants.

We are actively searching for school districts for the 2001-02 school year to place two to four portables for our study. We have arranged to collaborate with the following classroom manufacturers: American Modular Systems, Meehleis Modular Buildings, Enviroplex, and/or MSI, Inc.

The project has advantages for school district administrators, individual schools, and LBNL and CEC. LBNL views the project as high quality applied field research with respect to environmental engineering and energy efficiency. California school districts, due to limited resources, increasing student populations, class size reduction policies, and short-term time scales, will need to buy and/or lease many portables over the next 5-10 years. Improved energy efficiency and IEQ are key issues in producing the next generation of school housing.

LBNL/PERC portables are energy efficient while ensuring compliance with current minimum ventilation standards set by the State. Our project will be in full compliance with state and federal guidelines for design, construction, and operation of portables. The cost of the classrooms would only be the manufacturer's normal price; we will pay incremental costs in the design, construction, and installation by providing the improvements above the standard product. During our study we will monitor energy use, indoor environmental quality, and thermal comfort in the classrooms for about two months each during the cooling and heating seasons. Monitoring will be non-intrusive with most measurement equipment built into the classroom, however some monitoring sessions with instruments placed in the classroom will be necessary. These procedures are designed to be conducted unobtrusively, with set up and takedown of instruments outside class hours.

For more information, please contact LBNL at your earliest convenience. Please call Dr. Michael Apte at 510-486-4669, myself at 510-486-6404, or Bill Fisk at 510-486-5910.

We look forward to working in collaboration.

Sincerely,

Derek G. Shendell, MPH (D.Env. candidate, UCLA)
Senior Research Associate
Indoor Environments Program, Environmental Energy Technologies Division

Summary of LBNL/CEC Portable Classroom Project:
Increased Energy Efficiency, Improvements in Thermal Comfort, and Indoor Air Quality Benefits

Improvements in energy efficiency for public school portable classrooms (portables) would lead to lower energy bills for schools already facing limited resources, providing a relatively larger percentage of tight budgets for other educational and teacher training priorities. Energy efficiency can be gained through improved performance and/or selection of lighting fixtures, bulbs, heating, ventilation and air conditioning units (HVAC), insulation, and consumer education. Furthermore, energy efficiency gains can be closely linked to human performance improvements, e.g., teaching efficacy, staff productivity, and student learning. The bridge between energy efficiency and improved educational outcomes is indoor environmental quality, and most importantly higher sustained ventilation rates and moderated temperature and relative humidity. Given that school districts have limited resources, short-term time frames, rapidly rising student populations, and class size reduction programs, the demand for and use of portables will likely remain elevated over the next decade. Thus, the importance of energy efficient, comfortable, clean portables for elementary and new schools is evident.

The Lawrence Berkeley National Laboratory (LBNL), with funding and collaboration from the California Energy Commission (CEC), has a project to evaluate advanced technologies and building materials for improved ventilation, source reduction for lower volatile organic compound emissions, and temperature control. The items are on the market but not all are used specifically for school classrooms. The technology will likely work best in climates with hot, dry summers. The four classrooms will be on the campuses of one or two Northern California school districts, with monitoring and calculations for energy use and costs, thermal comfort, and indoor air quality to take place in the 2001-02 school year during the cooling and heating seasons. There will be no extra financial burden for the schools; LBNL and CEC will cover all incremental costs. There are no known health risks, only potential benefits.

August 2001

SCHOOL NAME Elementary School, CITY, CA

Dear parents of students, teachers, and staff,

Lawrence Berkeley National Laboratory (LBNL), located in the hills above the University of California-Berkeley is conducting a project with California Energy Commission (CEC) funding and collaboration from the Davis Energy Group. We will examine and quantify differences in energy efficiency, increased ventilation, lower electricity use and costs, and improvements in thermal comfort and indoor air quality between standard and advanced technologies for heating, ventilation, and air conditioning (HVAC) systems. We are focusing on public school relocatable classrooms (RCs) due to a combination of factors including class size reduction policies, student population growth, and limited resources for new school buildings. The demand for and use of RCs will likely remain elevated during this decade. The importance of energy efficient, comfortable, and environmentally sound RCs to public schools is evident.

We are actively collaborating with *your* school district (SD) facilities, property, and/or operations and maintenance administrators, their architects, school and materials manufacturers, and PRINCIPAL NAME. An interested superintendent's office has granted permission.

Energy efficient lighting, HVAC units, and construction can reduce energy costs. Adequate RC ventilation rates maintain indoor air quality; however, ventilation requires extra energy. HVAC designs reduce energy use can be used to offset the cost of adequate ventilation.

Our project evaluates advanced technologies and building material options to improve ventilation and temperature control and lower volatile organic compound emissions from materials. The items are on the market but not all are used specifically for school classrooms. Monitoring with two new RCs on this school campus will be conducted in the 2001-02 school year during the cooling and heating seasons.

Schools have <u>no financial burden; we covered incremental costs</u>. There are <u>no known risks, only potential benefits</u>.

We are committed to executing this project by conducting high quality environmental health science and engineering research, development and demonstration, while still involving the local knowledge and experience of public and private sector stakeholders, **including your SD.**

Education and energy supply as well as safe and healthy schools are foremost on our minds as California residents. We believe this project has significant potential value to school districts, legislators, and consumers.

Sincerely,

____________	____________	____________	____________
Derek G. Shendell, MPH	Dr. Michael G. Apte	Alfred T. Hodgson	William J. Fisk
Sr. Research Associate	Scientist	Scientist	Scientist, Dept. Head

APPENDIX A.1

Instruments, Databases, and Results of School District and School Recruitment

A.1.3. Letters to Principals for Recruitment and Retention of Schools, UCLA PCS

A.1.3.1 Sample of letter sent to principals in recruited school districts
A.1.3.2 Self-addressed stamped reply post card given to potential schools in the LAUSD to indicate if and when interested to participate

«date»

«name»
Office of the Principal
«school name»
«street address»
«city, state, zipcode»

Dear Principal «name»,

I am a doctoral candidate in the UCLA School of Public Health in the professional track Environmental Science and Engineering Program. I hold a BA from Dartmouth College and a MPH from the Yale University Department of Epidemiology and Public Health, School of Medicine. My proposed dissertation is an assessment of organic compound exposures and heating, ventilation, and air conditioning system (HVAC) functioning in public school portable classrooms in Los Angeles County, CA. I would work with mentors at UCLA as well as from the state agency hosting my doctoral internship. To coincide with my current field research and project management efforts for a multicenter study of fine particles and toxic air compounds, I have chosen to select schools from the same four communities' target areas.

The field work involves samplings in up to two seasons, each one school week long, during late August or September 2000 and late November or December 2000, respectively. No sampling would occur during Thanksgiving or Christmas/New Year's vacations.

The proposed environmental exposure measurement protocol includes passive samplers inside the classroom for volatile organic compounds, formaldehyde, and air exchange rate; indoor temperature and relative humidity with data logging sensors; a technician walk-through questionnaire; and a questionnaire for facilities' staff about HVAC operations and maintenance. There will be neither personal sampling of teachers and students nor disruption of the learning process; teachers and staff may be asked questions about daily class activities inside and outside the portables. Three visits, each about 20-40 minutes long, are required to complete the sampling-- Thursday or Friday after school, the following Monday before school, and then on Friday afternoon at the end of school. I would like to include one or two portable classrooms and one main building classroom in the study.

Please fill out the enclosed, self-addressed stamped post card stating your interest and willingness to participate as well as preferences for sampling dates.

Thank you for your attention to a present and significant public health concern in our children's school environment. Please call (310) 825-3161 or e-mail shendell@ucla.edu with any questions.

Sincerely,

Derek G. Shendell, MPH

UCLA Portable Classrooms Study

____ **Yes**, we are interested and
will participate!
Our <u>preferences (mark 1, 2)</u> for dates
for the sampling are:
__ September 7 or 8 and 11-15
__ September 14 or 15 and 18-22
__ September 21 or 22 and 25-29
__ September 28 or 29 and October 2-6

SCHOOL NAME ______________
____ No, although the study is endorsed
by the LAUSD, we decline participation.

THANK YOU FOR YOUR RESPONSE!

UCLA Portable Classrooms Study

____ **Yes**, we are interested and
will participate!
Our <u>preferences (mark 1, 2)</u> for dates
for the sampling are:
__ September 7 or 8 and 11-15
__ September 14 or 15 and 18-22
__ September 21 or 22 and 25-29
__ September 28 or 29 and October 2-6

SCHOOL NAME ______________
____ No, although the study is endorsed
by the LAUSD, we decline participation.

THANK YOU FOR YOUR RESPONSE!

UCLA Portable Classrooms Study

____ **Yes**, we are interested and
will participate!
Our <u>preferences (mark 1, 2)</u> for dates
for the sampling are:
__ September 7 or 8 and 11-15
__ September 14 or 15 and 18-22
__ September 21 or 22 and 25-29
__ September 28 or 29 and October 2-6

SCHOOL NAME ______________
____ No, although the study is endorsed
by the LAUSD, we decline participation.

APPENDIX A.1

Instruments, Databases, and Results of School District and School Recruitment

A.1.4. Approval of Proposal, UCLA PCS

A.1.4.1 Proposal submitted to LAUSD Program Evaluation and Research
A.1.4.2 Approval letter, LAUSD (Dr. S. Cantrell)
A.1.4.3 Memo of support to targeted schools, LAUSD (Dr. S. Cantrell)

Derek G. Shendell, MPH shendell@ucla.edu
(310) 476-9326 home, (310) 825-3161 work, (310) 206-3358 FAX

RESEARCH PROPOSAL FOR SUBMISSION TO THE COMMITTEE ON RESEARCH STUDIES, PROGRAM EVALUATION AND RESEARCH BRANCH, LOS ANGELES UNIFIED SCHOOL DISTRICT (CA)
[Supplement and follow-up to a letter sent previously to the Office of the Superintendent, answered by the Assistant superintendent, forwarded to your office, and responded to with an e-mail by Dr. Steven Cantrell]

1.0 REQUIRED ELEMENTS

1.1 RESEARCHER'S STATUS

I am a graduate student pursuing a professional-track doctoral degree (D.Env.) in the Environmental Science and Engineering Program, Department of Environmental Health Sciences, University of California, Los Angeles. This research has two mechanisms of financial support: a research fellowship grant from the Center for Environmental Risk Reduction at the University of California, Los Angeles (UC Toxic Substances Research and Training Program); my allowance for research supplies and travel under my U.S. EPA STAR Graduate fellowship in human health risk assessment. I receive mentoring and support from my graduate advisors, Dr. Arthur Winer and Dr. Steven Colome. They provided constructive criticism on the sampling protocol and will participate in the analysis and interpretation of the data. They are highly experienced and internationally recognized for their atmospheric chemistry/air pollution and exposure assessment/modeling research, respectively.

1.2 TITLE OF PROJECT

Assessment of Organic Compound Exposures and HVAC System Functioning in Public School Portable Classrooms in Los Angeles County, CA

1.3 STATEMENT OF PURPOSE

This comprehensive, multidisciplinary exposure assessment will incorporate passive monitoring devices for volatile organic compounds (VOCs) in the indoor microenvironment of public school portable classrooms as well as continuous measurements of temperature and relative humidity and an integrated calculation of the air exchange, i.e., ventilation, rate. Two questionnaires, a "Technician Walk-Through Questionnaire" and an "Operations and Maintenance Questionnaire" (see attachments), will evaluate physical attributes of the portable and control (main building) classrooms, the routine activities of the teacher and students inhabiting them, and the activities and knowledge of the custodial staff. I will also record observations upon the set-up and take-down of the passive monitoring devices including use of classroom lighting; operation of the heating, ventilation, and air conditioning system; the smell and intensity of noticeable odors; and, whether doors and windows are opened or closed.

My doctoral program stresses the integration of knowledge across the various natural and social sciences dealing with the state of the environment and human interactions with it. The proposed study would give me additional professional research and project management experience to apply all of my acquired skills before moving on full-time to a state or regional position in children's environmental health research and policy.

My advisors and I have already had discussions with the California State Department of Health Services (CADHS). CADHS, and the California EPA/Air Resources Board (ARB), due to their increasing interest in the areas of indoor air quality and personal exposure assessment, share mutual interest in portables. Our evaluation of the portable classrooms issue, and current exposure assessment, is approximately 12-18 months ahead of the agency efforts. Therefore, my project would constitute a pilot study at the county and city level, to serve as a potential model for a statewide study. My subsequent doctoral internship would not only include completing this project as my doctoral dissertation, but working with CADHS, ARB, and the Office of Environmental Health and Hazard Assessment with the statewide assessment foreseen for the 2001-2002 school year. In summary, my proposed project will help answer questions relevant to epidemiology, children's health, structural and mechanical engineering, chemistry, environmental sciences, and public policy.

1.4 INSTITUTIONAL SUPPORT

The signed letters of sponsorship will be sent to LAUSD separately by mail.

1.5 RESEARCH QUESTIONS/HYPOTHESES

The three major hypotheses of this study are the following: Teachers and students receive exposures to VOCs and aldehydes due to building materials and/or the influence of outdoor sources such as traffic as a function of ventilation; Any improper ventilation in portable school classrooms is due to a lack of, or limited use of, windows and/or poorly maintained or poorly operated HVAC systems; Meteorological parameters (T°, RH%), and their seasonal variation, influence potential chemical and biological exposures inside portable and main building classrooms.

The present assumption is portable classrooms are similar across communities in Los Angeles County, CA because they come from the same few manufacturers.

Brief Statement of the Theoretical Basis for this Research and Previous Findings

Due to recent state and federal policy initiatives concerning public school class size reductions at the lower grade levels (K-3, ages 4-9), and severe resource restraints for capital projects, the prevalence of prefabricated, portable school classrooms (portables) is rising. This is especially true in California's most populated counties (e.g., Los Angeles, San Diego), where children (U.S. citizens) of Spanish-speaking and Asian immigrants will be entering the school system in large numbers over the next several years. Teachers and parents in a number of California school systems (e.g., Saugus Union School District in Santa Clarita) have made complaints about health effects of, to date, unknown etiology (like occupational "Sick Building Syndrome"), such as asthmatic symptom prevalence and severity, due to the use of portables. Portables have one door, windows (sometimes), carpets, and heating, ventilation, and air conditioning (HVAC) systems. Although manufactured to existing specifications, HVAC systems may not function properly due to lack of maintenance, lack of understanding of operations instructions on the part of schools' maintenance staffs, age, vandalism, etc. The materials used to construct portables may off-gas VOCs and formaldehyde (H2CO) as a function of age, temperature, and relative humidity. Based on location on school grounds, portable classroom floors may be subject to water damage (i.e., potential breeding ground for mold spores and bacteria). Portables also may not provide adequate space for teacher(s) and students to move in, a consideration due to the students' ages and developmental stage. Assessments were done by private consultants trained in toxicology and microbiology—hired by the Saugus Union School District between February and August of 1999 (for their reports and a CADHS advisory on portable classrooms, see http://www.cal-iaq.org). Their research provided no definitive conclusions on potential risks from biological or chemical contaminants since the exposure assessment was not comprehensive. Measurements were taken over only one day, in uninhabited rooms during vacation periods, with neither air exchange rate calculations nor any questionnaires evaluating the characteristics of the classrooms or the teachers and students using them.

1.6 SAMPLE ("STUDY POPULATION"), METHODS, ANALYSES

Selection of Target Areas and Schools Within LAUSD

The target population consists of all K-12 public schools serving the West Los Angeles area which have portable and main building classrooms. All these schools lie within the 90064 and 90066 zip codes and are close to or about 0.5-1.0 kilometers away from the I-405 and I-10 freeway intersection. Thus, the schools serve the same target communities chosen for another UCLA project, the "Relationship Among Indoor, Outdoor, and Personal Air Concentrations" study (RIOPA) of fine particles and toxic air compounds. I constructed a list of all schools and their facilities based on phone conversations conducted with assistant principals, secretaries, and other school administrative staff members in December 1999. The numbers of portables and main building classrooms were determined. Schools with no portables, or temporary ones only for main building repairs, were excluded. The resulting elementary schools are Overland Elementary, Richland Elementary, Beethoven Elementary, Grand View Elementary, Mar Vista Elementary, and Walgrove Elementary. The high school is Venice Senior High School. There are no junior high schools with portable classrooms in the target areas.

Following the letters to the Office of the Superintendent and the Program Evaluation and Research branch of the LAUSD, if the project is approved, I will send an introductory letter to the principals of the named seven schools including notice of my proposal's acceptance by LAUSD. Among consenting schools, three or four will be selected at random. One or two portables (one newer, one older) and one main building control classroom will be selected randomly at each school.

It was determined whether school grounds are, on average, upwind or downwind of a major freeway. Geographic location and meteorology were considered in target area selection and analyses following field data collection.

Monitoring Inside Classrooms

Three visits will be required to carry out the monitoring protocol. The first visit, on a Thursday or Friday before the sampling, will occur after the school day ends. The following tasks will be accomplished. A "Technician Walk-Through" survey will assess characteristics of the portable classroom and the surrounding environment, as well as basic activities of the teacher and students. I will set out two perfluorocarbon (perfluoromethyl cyclohexane) tracer blocks (PFTs), so the non-toxic gas permeates and achieves equilibrium before the capillary absorption tube containing packed activated charcoal is set out on the second visit. These items comprise the air exchange rate (AER), i.e., ventilation, calculation system. I will also reconfirm meeting times with buildings and grounds staff for the questionnaire and entry into the classrooms

The second visit will be on the Monday or Tuesday morning of the sampling week. I will deploy samplers and instruments (refer to Table 1). I will also conduct the "Operations and Maintenance (O&M)" questionnaire with buildings and grounds staff to assess HVAC system function, operation parameters and maintenance, as well as the age of the portable classroom and the level of staff training.

The final visit is on Friday afternoon of the sampling week immediately after school ends. I will take down instruments and cap passive samplers and then return to UCLA to process the samples and download the field data. If necessary, the "O&M" questionnaire will be completed.

In summary, all three visits occur before or after the official school day, and monitoring occurs without batteries or pump-operated equipment, to eliminate disturbing the learning process and/or authority of the teacher.

Analyses of Air Samples, Meteorological Data, and Questionnaire Responses

Validated, precise, and sensitive chemical analyses will be conducted by the same academic institutions that collaborate with UCLA on RIOPA. The three universities are the University of Texas-Houston School of Public Health for VOCs; the Environmental and Occupational Health Sciences Institute at Rutgers University for aldehydes; and the Harvard University School of Public Health for AER. They will be compensated for their services and expect to report back results within 1-3 months of receiving the samples.

Descriptive statistics for all measured compounds and AER will be calculated, including mean; median; maximum; minimum. Descriptive statistics will be prepared on HVAC system parameters for operation and maintenance with an evaluation of their relationship to AER. Correlation between AER and pollutant concentrations will be computed. The correlation of temperature and/or relative humidity data with AER and pollutant concentrations as a function of their physicochemical properties will be evaluated. Seasonal variation for measured variables will be assessed. There will also be a qualitative evaluation based on data from the questionnaires on potential biological exposures and impacts on learning activities in portable classrooms.

1.7 INSTRUMENTS

A. Microenvironment passive samplers

TABLE 1: Samplers and instruments to be used in measurements

Apparatus	**Compounds Assessed**	**Attributes of sampler**
3M 3500 organic vapor monitor (OVM) badge	volatile organic compounds (VOCs)	Small, orange plastic clip-on badge contains adsorbing surface and protective white film
DNSH treated passive cartridge/badge	aldehydes (e.g., formaldehyde, acetaldehyde)	small, white and clear colored cartridge sits in clip-on badge
Perfluorocarbon tracers (PFTs) and capillary absorption tube (CAT) system, 2:1 ratio used	Air exchange rate (hr −1), i.e., amount of ventilation provided by HVAC system	PFTs emit non-toxic gas which equilibrates in 24-48 hours, then CAT (with activated charcoal) collects it during sampling
HOBO data loggers	Temperature, relative humidity	small, durable grey case encloses sensors; download data to PC; samples every 5 min.

B. Questionnaires

As introduced above in section 1.3 and 1.6, I wrote, edited, and used in Baldwin Park, CA two questionnaires for this study: the "Technician Walk-Through Questionnaire" and the "Operations and Maintenance Questionnaire (O&M)." Copies were sent by mail as attachments. The questions and classroom diagram inform specific goals of our assessment of the classrooms' physical environment, the indoor air quality, the impact of outdoor pollution and sources, and possible biological contamination (no quantitative assessment of mold and bacteria in this study).

C. Other written field and project management instruments

I created chain-of-custody forms, to be used when sending samples to collaborating institutions for analyses, and field data sheets for this project. A complete set of the blank field data sheets was sent by mail as an attachment to this proposal.

2.0 LEGAL AND ETHICAL RISKS

2.1 LEGAL OBLIGATIONS

This research project does adhere to federal regulations regarding family and pupil rights, their privacy and protection. Confidentiality is maintained. The three aforementioned collaborating universities which will perform the laboratory analyses will only receive the samples, the sample ID numbers, and the "duration of sampling" values, in minutes. They will receive no information regarding the name and address of the school, the names of the teachers, principal or head custodian, or the telephone and FAX numbers.

This research clearly adheres to federal guidelines regarding the protection of human subjects because there are no human subjects. We do not ask K-3 schoolchildren or their teachers and principals to directly participate in the microenvironment assessments; there will be no personal passive or active sampling. We will only assess the air quality, the physical environmental characteristics, and the HVAC systems of portable and main building classrooms.
Therefore, we do not need to obtain written parental consent for these minor students. We will follow previous letters to the Office of the Superintendent and the Office of Program Evaluation and Research for LAUSD with letters to the principals of the targeted schools as described.

2.2 PROTECTION OF HUMAN SUBJECTS

This topic does not apply to the proposed project. Please refer to sections 1.3, 1.5, 1.6, and 2.1.

2.3 ETHICAL PRINCIPALS

The doctoral student serving as principal investigator for this project (Derek G. Shendell) has and will continue to abide by all known ethical principles in his multidisciplinary field which includes public health as well as environmental health, assessment, epidemiology, law, policy, and management.

Comment on "informed consent"

In the development of the letters to the superintendents and principals as well as the "O&M" Questionnaire, I used language reasonably understandable to research participants and the technicians to gain their support, informed consent, and answers to the questions. Letters and questionnaires were well received for their clarity and sophistication in the Baldwin Park Unified School District in June 2000. I have a record of all contacts with superintendents' offices, school administrative offices, and district officials between December 1999 and June 2000 by phone, letter, or electronic mail. These contacts were made to inventory the number of portables and main building classrooms at each K-12 public school in the original list of (five) target communities and to discuss and/or confirm schools' participation in the study.

Comment on "minimizing intrusions on privacy"

This project makes a sincere, concerted effort to minimize intrusions on the privacy of principals, school administrative staff, custodians, teachers, and most importantly, the young students. I conducted several rounds of editing on both questionnaires. The schedule for the three visits required in the sampling methodology was created as a function of the typical school day to complete all tasks before and after the children arrived to their classrooms.

All quantitative and qualitative information collected in the study within the LAUSD will be discussed only for appropriate scientific or professional purposes and only with persons clearly concerned with the issues of children's environmental health, exposure assessment, and portable classrooms. Since the proposed work inside the LAUSD would be part of my doctoral dissertation, my advisors, a faculty committee, LAUSD officials, and specific collaborators at other universities and state agencies would have such privilege.

3.0 ANTICIPATED BENEFITS OF RESEARCH

3.1 "TOPICS OF INTEREST TO LAUSD" ADDRESSED BY PROPOSED PROJECT

This project addresses two topics of primary interest to the LAUSD. First, the quantitative and qualitative data collected inside and around the outside of the classrooms will provide a better understanding of the physical school environment and the influence of anthropogenic and natural sources of chemical and biological contaminants. Therefore, this project will help improve the management of the school environment. Second, by improving the indoor air quality and condition of the classroom, and overall school environment, this project should lead to improvements in academic achievement for students of all socioeconomic and ethnic backgrounds. Overall, from a health perspective, young children with developing lungs and immune systems will be the principal project beneficiaries. The secondary beneficiaries will include their teachers and caregivers (parents, relatives, school nurses). Regarding risk management and policy, other benefactors include interested scientists and the private and local government sectors that must assess and address the problem, if one exists, on a larger scale.

4.0 BURDEN ON RESEARCH SUBJECTS

4.1 NUMBER OF PARTICIPANTS, SCHOOLS AND CLASSROOMS

No teachers or students will have direct, active participation in this study. One custodial staff member, likely the head custodian, will be required to complete the "O&M" questionnaire with me. I hope to include three or four schools and therefore 6-9 classrooms (3-6 portable and 3-4 in the main building) for sampling in each of two seasons, i.e., late summer/early fall and late fall/early winter.

4.2 AMOUNT OF TIME REQUESTED, AND WHEN INTERACTION WILL OCCUR, PER PARTICIPANT, CLASSROOM, AND SCHOOL

Approximately 10-15 minutes will be asked of the member of the custodial staff to complete the "O&M" questionnaire as well as 5 minutes for each of the second and third visits to open classrooms doors for me. To complete tasks, I will need approximately 15 minutes during the first and second visits and approximately 10 minutes during the third visit in each classroom (all outside normal classroom hours). These estimates are based on field experience in Baldwin Park in June 2000.

I would like to conduct the study in two different seasons in each classroom at each school. I propose to come to the schools in late August and September 2000 as the late summer/early fall sampling and in late November through mid-December 2000 for the winter sampling.

4.3 RATIONALE FOR SAMPLE SIZE, NUMBER OF CONTACTS, AND TIME REQUIRED

The proposed sample sizes in section 1.6 and 4.1, the number of contacts specified in sections 1.6 and 4.2, and the time requirements proposed in section 4.2 are based on several criteria. First, my field experience conducting the first sampling in Baldwin Park in June 2000. Second, a careful consideration of the available resources, e.g., grant money and fellowship allowances, personnel, and time, for this project. Finally, to ensure the best possible science, we want to assess spatiotemporal variation regarding meteorology, sources and pollutants in our analyses and interpretation. The schools also vary in their proximity to freeway traffic.

4.4 STATEMENT OF PARTICIPANT/SCHOOL COMPENSATION

There will be no financial compensation of any kind given to principals, custodians, or facilities staff members who help in any way with the execution of this project. The principal from each school will, however, receive a "Summary of Sampling Results" report, on UCLA letterhead, for each season's assessment. This letter will include average temperature; average relative humidity; concentrations, with specified units, of formaldehyde and a comparison to the CalEPA/Air Resources Board guideline for indoor air quality (see attachment mailed separately); concentrations, with specified units, of selected VOCs; and air exchange rate. The "Summary of Sampling Results" letter has not been created, but will be modeled after the form created by D. Shendell et. al for the RIOPA study (see attachment mailed separately).

July 13, 2000
Derek Shendell
RIOPA Project, CA Site
School of Public Health
650 Charles Young Drive, S, 61-295 CHS
Los Angeles, CA 90095
Dear Mr. Shendell,

The Committee on Research Studies has approved your request to conduct your study of the organic compound exposures and HVAC functioning in LAUSD portable classrooms. Your research may be conducted at the Los Angeles Unified Schools that you have mentioned as your sample. These schools include Overland Elementary, Richland Elementary, Beethoven Elementary, Grand View Elementary, Mar Vista Elementary, Walgrove Elementary, and Venice High School.

This approval by the committee is in no way a requirement for district personnel to participate. All participation must be completely voluntary. The anonymity of all data sources must be maintained.

At the conclusion of your study, please send an abstract of your findings to my attention.

Sincerely,

Steven M. Cantrell, Ph.D.
Chair, Committee on Research Studies

Inter-Office Correspondence
Program Evaluation and Research Branch

DATE: July 20, 2000

TO: Principal
Overland Elementary, Richland Elementary, Beethoven Elementary, Grand View Elementary, Mar Vista Elementary, Walgrove Elementary, and Venice High School.

FROM: Steven M. Cantrell, Ph.D.
Chair, Committee on Research Studies

SUBJECT: APPROVAL TO CONDUCT RESEARCH AT SELECTED LAUSD SITES

The Program Evaluation and Research Branch has granted approval to Derek Shendell to conduct research at your site. Mr. Shendell is researching health and exposure issues related to the use of portable classrooms throughout the district. This research has been deemed important, timely, and relevant to district interests in maintaining safe facilities for all children. Although we strongly urge your cooperation, the approval by this branch is not a mandate for district personnel to participate. Your participation is voluntary.

Any questions you may have regarding the Program Evaluation and Research Branch's approval of Mr. Shendell's study may be directed to me at 310.215.9392. Our criteria for the acceptance of research studies within the district are available at the following URL: http://www.lausd.k12.ca.us/lausd/offices/perb/resprop.htm . Mr. Shendell will contact each school directly to schedule dates for his field research.

APPENDIX A.1

Instruments, Databases, and Results of School District and School Recruitment

A.1.5. Letters to Participant Schools, UCLA PCS

- A.1.5.1 Sample of letter sent to participating schools with confirmation of participation, study details, and first seasonal sampling schedule
- A.1.5.2 Sample of letter sent to participating elementary schools to reestablish contact, give a project update, and propose the second sampling schedule
- A.1.5.3 Sample of letter sent to participating elementary schools to remind staff of the schedule for the second seasonal sampling
- A.1.5.4 Sample of letter sent to participating schools to reestablish contact and propose dates to share sampling results
- A.1.5.5 Sample of letter sent to participating schools to reestablish contact and accompany summary of sampling results forms

May 21, 2000 *(BPUSD; or, August/September 2000 for LAUSD)*

Principal NAME
SCHOOL NAME
ADDRESS
CITY, STATE   ZIP CODE

Dear Principal LAST NAME,

This letter serves as a formal confirmation of the times agreed upon during our phone conversation DAY, DATE concerning your school's participation in the UCLA Portable Classrooms Study.

The schedule appears below. Please share it with teachers from these classrooms as well as the custodians whom I will need to talk with for 15 minutes on DAY, DATE.

Thursday (or Friday), MONTH __, 2000	_: __ AM – _: __ AM
Monday, MONTH __, 2000	_: __ AM – _: __ AM
Friday, MONTH __, 2000	_: __ PM – _: __ PM

I would appreciate it if you and one facilities staff member could stay an extra 10-15 minutes, approximately, on DATE OF FIRST VISIT. On DATE OF SECOND VISIT and DATE OF THIRD VISIT, it should take me about 10-15 minutes to complete each classroom. I will make a sincere effort to be timely and efficient.

At random, I have chosen the following classrooms for the assessment:
Portables # __, __
Main building classroom #__
Library, i.e., the District constructed portable *(BPUSD, one school only)*

Please contact me with any questions at (310) 825-3161 or at shendell@ucla.edu

I look forward to meeting with you in MONTH. Thank you for your cooperation.

Sincerely,

Derek G. Shendell, MPH
UCLA Environmental Sciences and Engineering Program, D.Env. candidate
UCLA Portable Classrooms Study, principal investigator

December 1, 2000

Principal NAME
SCHOOL NAME
ADDRESS
CITY, STATE ZIP CODE

Dear Principal LAST NAME,

Greetings. I hope you, as well as your staff, students, and families, enjoyed a Happy Thanksgiving. I assume the fall semester has progressed well. Projects at the UCLA School of Public Health remained busy and exciting, and my new work up at the Lawrence Berkeley National Laboratory, as part of my doctoral candidacy internship, is providing worthwhile experiences concerning energy efficiency and indoor environmental quality at schools.

This letter serves two important purposes: to reestablish communication regarding first seasonal sampling results of my UCLA Portable Classrooms Study; and present the schedule for the previously discussed second seasonal sampling. I have taken your academic calendars into full consideration.

To participating schools in your district, I will return on Friday, February __, Monday February __, and Friday, February/March __. Please note the second seasonal sampling schedule was already discussed with and approved by your school district. The schedule for your school, similar to before, appears below. Surveys are not conducted this time.

Friday, February __, 2001 _:__ AM – _:__ AM

Monday, February __, 2001 _:__ AM – _:__ AM

Friday, February/March __, 2001 _:__ PM – _:__ PM

I will send another letter reminding you of these times in late January; a summary of the main results from the first seasonal sampling will accompany it. I will be happy to answer any questions you have by phone or in person on a Friday listed above. District staff will receive copies of the results as well.

Please contact me as soon as possible to confirm receipt of this letter, and with any questions, at (510) 486-6404 or at shendell@ucla.edu. Please leave a message if I am away from my desk.

Thank you for your cooperation. I look forward to our further collaboration.

Sincerely,

Derek G. Shendell, MPH
UCLA D.Env. candidate/Lawrence Berkeley National Laboratory
UCLA Portable Classrooms Study, principal investigator

MONTH __, 2001

Principal NAME
SCHOOL NAME
ADDRESS
CITY, STATE ZIP CODE

Dear Principal LAST NAME,

Greetings. I hope you, as well as your staff, students, and families, enjoyed a wonderful holiday season and have started the year 2001, as well as the new millennium, off well.

This letter serves to present and provide you with the final schedule for the previously discussed second seasonal sampling. I have taken your academic calendars into full consideration.

To participating schools in your district, I will return on Friday, February __, Monday February __, and Friday, March __. Please note the second seasonal sampling was already discussed with and approved by your school district. The schedule for your school, similar to before, appears below. Surveys are not conducted this time.

Friday, February __, 2001 _:__ AM – _:__ AM

Monday, February __, 2001 _:__ AM – _:__ AM

Friday, March __, 2001 _:__ PM – _:__ PM

I will be happy to answer any questions you have by phone or in person on a Friday listed above. Your staff and school district administrative staff will receive summary copies of the results.

Please contact me as soon as possible to confirm receipt of this letter, and with any questions, at (510) 486-6404 or at shendell@ucla.edu and DGShendell@lbl.gov. Please leave a message if I am away from my desk.

Thank you for your cooperation. I look forward to our further collaboration. See you in a few weeks.

Sincerely,

Derek G. Shendell, MPH
UCLA D.Env. candidate/Lawrence Berkeley National Laboratory
UCLA Portable Classrooms Study, principal investigator

MONTH __, 2001

Principal NAME
SCHOOL NAME
ADDRESS
CITY, STATE ZIP CODE

Dear Principal LAST NAME,

Greetings. I hope you, as well as your staff, students, and families, enjoyed a wonderful holiday season and have started the year 2001, as well as the new millennium, off well.

This letter serves to present and provide you with the final schedule for the previously discussed second seasonal sampling. I have taken your academic calendars into full consideration.

To participating schools in your district, I will return on Friday, May/June __, Monday June __, and Friday, June __. Please note the second seasonal sampling was already discussed with and approved by your school district. The schedule for your school, similar to before, appears below. Surveys are not conducted this time.

Friday, May/June __, 2001 _:__ AM – _:__ AM

Monday, June __, 2001 _:__ AM – _:__ AM

Friday, June __, 2001 _:__ PM – _:__ PM

I will be happy to answer any questions you have by phone or in person on a Friday listed above. Your staff and school district administrative staff will receive summary copies of the results.

Please contact me as soon as possible to confirm receipt of this letter, and with any questions, at (510) 486-6404 or at shendell@ucla.edu and DGShendell@lbl.gov. Please leave a message if I am away from my desk.

Thank you for your cooperation. I look forward to our further collaboration. See you in a few weeks.

Sincerely,

Derek G. Shendell, MPH
UCLA D.Env. candidate/Lawrence Berkeley National Laboratory
UCLA Portable Classrooms Study, principal investigator

May 18, 2001

Principal NAME
SCHOOL NAME
ADDRESS
Baldwin Park, CA 91706

Dear Principal LAST NAME,

Greetings from Northern California. I hope you, as well as your staff, students, and families had a good spring break and then a successful standardized testing season. Summer vacation is "around the corner!"

This letter serves as an important reminder of the final schedule for the previously discussed second seasonal sampling for the "UCLA Portable Classrooms Study (part of my dissertation). I have taken your academic calendars into full consideration.

To participating schools in your district, I will return on Friday, June 1 and Monday June 4 through Friday, June 8. Please note the second seasonal sampling was already discussed with and approved by your school district. The schedule for your school, similar to before, appears below. Surveys are not conducted.
It is important I gain access to the classrooms(________) as promptly as possible with the custodians.

Friday, June 1, 2001	____ AM – ____ AM
each day Monday-Friday, June 4-8, 2001	____ AM – ____ AM
each day Monday-Friday, June 4-8, 2001	____ PM – ____ PM

I will be happy to answer any questions you have by phone or in person on a Friday listed above. Your staff and school district administrative staff will receive summary copies of the results.

Please contact me as soon as possible to confirm receipt of this letter, and with any questions, at (510) 486-6404 or at shendell@ucla.edu and DGShendell@lbl.gov. Please leave a message if I am away.

Thank you for your cooperation. I look forward to our further collaboration. See you in a few weeks. I hope you have a good Memorial Day weekend.

Sincerely,

Derek G. Shendell, MPH
UCLA D.Env. candidate/Lawrence Berkeley National Laboratory
UCLA Portable Classrooms Study, principal investigator

November 9, 2001

Principal NAME
SCHOOL NAME
ADDRESS
CITY, STATE ZIP CODE

Dear Principal LAST NAME,

Greetings again from Northern California. We have been affected, in different ways, by the events on and proceeding the September 11 attacks so close to the start of the public school year. Nevertheless, I sincerely hope you, your colleagues, and your students have had an enriching, enjoyable fall term.

As promised, I wish to contact you with regard to our collaborative school environment and indoor air quality project, the pilot "UCLA Portable Classrooms Study." We have completed chemical analyses, calculations, quality assurance/quality control procedures, data management, and primary data analysis.

I am preparing to share the key results, and my recommendations, for the sampled classrooms at participating elementary schools.

I would like to set-up a brief meeting, approximately 30-45 minutes, on a Thursday or Friday afternoon after school this late November—after Thanksgiving-- or December, convenient for your staff's schedule. Teachers, the head custodian, and secretaries are highly encouraged to join us. My only preference is to make one trip for your school district to the Los Angeles area from Berkeley.

I look forward to speaking and working again with you.

Sincerely,

Derek G. Shendell, MPH
UCLA D.Env. candidate/Lawrence Berkeley National Laboratory (IED/EETD), Senior Research Associate
UCLA Portable Classrooms Study, principal investigator

Fall 2002

Principal FIRSTNAME LASTNAME
SCHOOLNAME
ADDRESS
Los Angeles OR Baldwin Park, CA 90066 OR 91706

Dear Principal LASTNAME,

I hope the 2002-03 school year has started well for the staff and students.

As promised, I am contacting you with regard to the school environment and indoor air quality project, the pilot "UCLA Portable Classrooms Study." Attached is a one-page summary of key results for the sampled classrooms, and a general conclusion and recommendation for public schools.

Please share the findings with the teachers from selected classrooms. I also hope you will articulate the general conclusion and recommendation on classroom environments to your teaching and custodial staff.

Thank you for your participation in this pilot study and support of my dissertation. Feel free to contact me with any final questions or comments.

Sincerely,

Derek G. Shendell, MPH
UCLA D.Env. candidate/Lawrence Berkeley National Laboratory (IED/EETD), Senior Research Associate
dgshendell@lbl.gov
(510) 486-6404

APPENDIX A.2

Study Design and Field Studies

A.2.1 Quantitative Field Data Collection Instruments Developed, UCLA PCS

A.2.1.1 First samplings
A.2.1.2 Second samplings

UCLA PORTABLE CLASSROOMS STUDY

SAMPLE INFORMATION FORM

SCHOOL NAME/ID ………………………… **CITY, STATE** ………………………………
FIELD PERSON ……………… **SAMPLING NUMBER ……**
DATE OF SAMPLING PERIOD ………… - …………

AIR EXCHANGE RATE

CLASSROOMS' VOLUME	Length (ft)	Width (ft)	Area (ft²)	Height (ft)	Volume (ft3)	Volume (m³)
Classroom A:……						
Classroom B:……						

COMMENTS:

SOURCE (PFT)

	Classroom A: ……			*Classroom B: ……*		
ID number						
Start Date (mm/dd/yy)						
Starting Time (hh/mm)						
End Date (mm/dd/yy)						
Ending Time (hh/mm)						
Duration (min)						
Location (Floor-Room)						

COMMENTS:

This form was modified from the original created by EOHSI and used in RIOPA Study
EOHSI, Environmental and Occupational Health Sciences Institute, 170 Frelinghuysen Road, POBox 1179, Piscataway, NJ 08€

SAMPLE INFORMATION FORM

SCHOOL NAME/ID .... **CITY, STATE** ....
FIELD PERSON .... **SAMPLING NUMBER** ......
DATE OF SAMPLING PERIOD .... - ....

CAPPILLARY ABSORPTION TUBE	*Classroom A: ......* Sample	Control/ Duplicate	Blank	*Classroom B: ......* Sample	Control/ Duplicate	Blank
CAT Number						
Start Date (mm/dd/yy)						
Starting Time (hh/mm)						
End Date (mm/dd/yy)						
Ending Time (hh/mm)						
Duration (min)						
Location (Floor-Room)						

COMMENTS:

RH% - TEMP. LOGGER (HOBOs)	*Classroom A: ......* Indoor	*Classroom B: ......* Indoor
Unit S/N Number		

START DATE and TIME
END DATE and TIME

COMMENTS:

This form was modified from the original created by EOHSI and used in RIOPA Study

EOHSI, Environmental and Occupational Health Sciences Institute, 170 Frelinghuysen Road, POBox 1179, Piscataway, NJ 08ε

SAMPLE INFORMATION FORM

SCHOOL NAME/ID .... **CITY, STATE** ....
FIELD PERSON .... **SAMPLING NUMBER ......**
DATE OF SAMPLING PERIOD .... - ....

Classroom A: ...... *Classroom B:* ......

VOC SAMPLE	Indoor	Control/ Duplicate (Indoor)	Blank	Indoor	Control/ Duplicate (Indoor)	Blank
Badge #						
Sample ID						
Start Date (mm/dd/yy)						
Starting Time (hh/mm)						
End Date (mm/dd/yy)						
Ending Time (hh/mm)						
Duration (mm)						

COMMENTS:

This form was modified from the original created by EOHSI and used in the RIOPA Study

EOHSI, Environmental and Occupational Health Sciences Institute, 170 Frelinghuysen Road, POBox 1179, Piscataway, NJ (

SAMPLE INFORMATION FORM

SCHOOL NAME/ID .... **CITY, STATE** ....
FIELD PERSON .... **SAMPLING NUMBER** ......
DATE OF SAMPLING PERIOD .... - ....

Classroom A: ...... *Classroom B:* ......

Aldehyde Passive Sample	Indoor	Control/ Duplicate (Indoor)	Blank	Indoor	Control/ Duplicate (Indoor)	Blank
Badge #						
Sample ID						
Start Date (mm/dd/yy)						
Starting Time (hh/mm)						
End Date (mm/dd/yy)						
Ending Time (hh/mm)						
Duration (min)						

COMMENTS:

This form was modified from the original created by EOHSI and used in the RIOPA Study
EOHSI, Environmental and Occupational Health Sciences Institute, 170 Frelinghuysen Road, POBox 1179, Piscataway, NJ 08855

UCLA PORTABLE CLASSROOMS STUDY

SAMPLE INFORMATION FORM

SCHOOL NAME/ID .... **CITY, STATE** ....
FIELD PERSON .... **SAMPLING NUMBER** ......
DATE OF SAMPLING PERIOD .... - ....

AIR EXCHANGE RATE

CLASSROOM VOLUME	Length (ft)	Width (ft)	Area (ft^2)	Height (ft)	Volume (ft3)	Volume (m^3)
Classroom A:......						
Classroom B:......						
Classroom C:......						
Main Building (M.B.) Classroom:......						

COMMENTS:

SOURCE (PFT)	*Portable Classroom A: ......*			*Portable Classroom B: ......*			*Portable Classroom C: ......*			*M.B. Classroom: ......*		
ID number												
Start Date (mm/dd/yy)												
Starting Time (hh/mm)												
End Date (mm/dd/yy)												
Ending Time (hh/mm)												
Duration (min)												
Location (Floor-Room)												

COMMENTS:

This form was modified from the original created by EOHSI and used as part of the RIOPA Study
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UCLA PORTABLE CLASSROOMS STUDY

SAMPLE INFORMATION FORM —

SCHOOL NAME/ID ……………………………… **CITY, STATE** ………………………………
FIELD PERSON ……………… **SAMPLING NUMBER** ……
DATE OF SAMPLING PERIOD ………… - …………

		Portable Classroom A: … …			*Portable Classroom B: … …*			*Portable Classroom C: … …*			*Main Building Classroom: … …*		
SAMPLE TYPE	CAPPILLARY ABSORPTION TUBE	Indoor	Control/ Duplicate (Indoor)	Blank	Indoor	Control/ Duplicate (Indoor)	Blank	Indoor	Control/ Duplicate (Indoor)	Blank	Indoor	Control/ Duplicate (Indoor)	Blank
Weekly Integrated Sample	CAT Number												
	Location (Floor-Room)												
	Start Date (mm/dd/yy)												
	Starting Time (hh/mm)												
	End Date (mm/dd/yy)												
	Ending Time (hh/mm)												
	Duration (min)												
	COMMENTS:												
School Day Integrated Sample	CAT Number												
	Location (Floor-Room)												
	START DATE = / /0												
	Monday: Start Time												
	Monday: End Time												
	Tuesday: Start Time												
	Tuesday: End Time												
	Wednesday: Start Time												
	Wednesday: End Time												
	Thursday: Start Time												
	Thursday: End Time												
	Friday: Start Time												
	Friday: End Time												
	END DATE = / /0												
	Total Sampling Duration (min)												
	COMMENTS:												

This form was modified from the original created by EOHSI and used as part of the RIOPA Study

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UCLA PORTABLE CLASSROOMS STUDY

SAMPLE INFORMATION FORM

SCHOOL NAME/ID ……………………………… CITY, STATE ………………………………
FIELD PERSON ……………… SAMPLING NUMBER ……
DATE OF SAMPLING PERIOD ………… - …………

SAMPLE TYPE	VOC SAMPLE	Portable Classroom A: …… Indoor	Control/ Duplicate (Indoor)	Blank	Portable Classroom B: …… Indoor	Control/ Duplicate (Indoor)	Blank	Portable Classroom C: …… Indoor	Control/ Duplicate (Indoor)	Blank	Main Building Classroom: …… Indoor	Control/ Duplicate (Indoor)	Blank
Weekly Integrated Sample	Badge #												
	Sample ID												
	Start Date (mm/dd/yy)												
	Starting Time (hh/mm)												
	End Date (mm/dd/yy)												
	Ending Time (hh/mm)												
	Duration (min)												
	COMMENTS:												
School Day Integrated Sample	Badge #												
	Sample ID												
	START DATE = / /0												
	Monday: Start Time												
	Monday: End Time												
	Tuesday: Start Time												
	Tuesday: End Time												
	Wednesday: Start Time												
	Wednesday: End Time												
	Thursday: Start Time												
	Thursday: End Time												
	Friday: Start Time												
	Friday: End Time												
	END DATE = / /0												
	Total Sampling Duration (min)												
	COMMENTS:												

UCLA PORTABLE CLASSROOMS STUDY

SAMPLE INFORMATION FORM

SCHOOL NAME/ID ……………………………… **CITY, STATE** ………………………………

FIELD PERSON ……………… **SAMPLING NUMBER** ……

DATE OF SAMPLING PERIOD ………… - …………

		Portable Classroom A: ……			*Portable Classroom B: ……*			*Portable Classroom C: ……*			*Main Building Classroom: ……*		
SAMPLE TYPE	Aldehyde Passive Sample	Indoor	Control/ Duplicate (Indoor)	Blank	Indoor	Control/ Duplicate (Indoor)	Blank	Indoor	Control/ Duplicate (Indoor)	Blank	Indoor	Control/ Duplicate (Indoor)	Blank
Weekly Integrated Sample	Badge #												
	Sample ID												
	Start Date (mm/dd/yy)												
	Starting Time (hh/mm)												
	End Date (mm/dd/yy)												
	Ending Time (hh/mm)												
	Duration (min)												
	COMMENTS:												
School Day Integrated Sample	Badge #												
	Sample ID												
	START DATE = _/_/0_												
	Monday: Start Time												
	Monday: End Time												
	Tuesday: Start Time												
	Tuesday: End Time												
	Wednesday: Start Time												
	Wednesday: End Time												
	Thursday: Start Time												
	Thursday: End Time												
	Friday: Start Time												
	Friday: End Time												
	END DATE = _/_/0_												
	Total Sampling Duration (min)												
	COMMENTS:												

One School Day "Grab" Sample

	Portable Classroom A: … …			*Portable Classroom B: … …*			*Portable Classroom C: … …*			*Main Building Classroom: … …*		
Badge #												
Sample ID												
Monday: Start Time												
Monday: End Time												
Monday ONLY Sampling Duration (min)												
Badge #												
Sample ID												
Friday: Start Time												
Friday: End Time												
Friday ONLY Sampling Duration (min)												
COMMENTS:												

This form was modified from the original created by EOHSI and used as part of the RIOPA Study

EOHSI, Environmental and Occupational Health Sciences Institute, 170 Frelinghuysen Road, POBox 1179, Piscataway, NJ 08855

APPENDIX A.2

Study Design and Field Studies

A.2.2. Field Sheets Developed to Record Pertinent Observations and Measures, LBNL RCS

Field Data Sheet: Particle Counters (MetOne 237B) Flows, Sound Level Meters, Gas Use, HOBOs

SCHOOL NAME/ID: ______________
Circle One: **Bard** **IDEC**

SCHOOL DISTRICT: ______________
Circle One: Cooling Season Heating Season Transitional Period
SAMPLING PERIOD DATES: __________

Particle Counter Flow Rate Measurements				
Classroom/Room #	Date (mmddyy)	Day of Week	Time	Flow Rate (cc/min or L/min)
LBNL RC A = Room #____:......				
LBNL RC B = Room # ____:				
Outdoor PM counter:				

COMMENTS:

AM field technician comments:

PM field technician comments:

HOBO (Temp/RH%), near teacher workstation/desk		
	LBNL RC A = Room #____	LBNL RC B = Room # ____
ID number		
Start Date (mm/dd/yy)		
Starting Time (hh/mm)		
End Date (mm/dd/yy)		
Ending Time (hh/mm)		
Location (Floor-Room)		

COMMENTS:

Gas Meters (Rinnai-IDEC)		
Classroom, # and RC A/B	AM check (time = ____)	PM check (time = ____)
RC A, Rm. 31		
RC B, Rm. 30		

Sound Level Meters	calibration target 94.0 dB(A)	
Classroom, # and RC A/B	AM check	Reading after calibration
RC A, Rm. 31		
RC B, Rm. 30		

(circle one) (HEATING SEASON) COOLING SEASON

(circle one) Bard 10 SEER HVAC (IDEC & hydronic heat coil for HVAC)

Sampling Period = 7:50-15:00 (MCS) / 8:15-15:35 (CUSD) on (circle one) (TUESDAY) WEDNESDAY THURSDAY

Date 2/12/02 Technician DGS+SML

Field Work/SAMPLING Start Time 6:30

NOTE: warm up pumps for 15 minutes. START WARM-UP 7:00 AM END WARM-UP 7:20 AM

Record INDOOR A

Peristaltic Pump ID# VOC #2 / ALD #2

Record Elapsed Time Left Timer 61973.1 Right Timer 629.3

Clock correct (**check**) Left Timer ✓ Right Timer ✓ ✓ Set to "AUTO" (**check**) Left Timer ✓ Right Timer ✓
Programming Correct (**check**) Left Timer ✓ Right Timer ✓ Return to clock (**check**) Left Timer ✓ Right Timer ✓

In **location # 3**, install and record ALD cartridge # C-31-3-021202 (In **location # 4**, install and record dup ALD cartridge #
Lot # W13382L1

In **location #1**, install and record VOC sorbent tube # 449 S-CC-L—MMDDYY--NNN C-31-1-021202-449

In **location #2**, install and record VOC sorbent tube # 464 S-CC-L—MMDDYY--NNN C-31-2-021202-464

Record OUTDOOR

Peristaltic Pump ID# VOC #3 / ALD #3

Record Elapsed Time Left Timer 697.8 Right Timer 7505.1

Clock correct (**check**) Left Timer ✓ Right Timer ✓ ✓ Set to "AUTO" (**check**) Left Timer ✓ Right Timer ✓
Programming Correct (**check**) Left Timer ✓ Right Timer ✓ Return to clock (**check**) Left Timer ✓ Right Timer ✓

In **location # 11**, install and record ALD cartridge # C-OA-11-021202 (In **location #** — install and record dup ALD cartridge #
Lot # W13382L1

In **location #9**, install and record VOC sorbent tube # 798 S-OA-L—MMDDYY--NNN C-OA-9-021202-798

In **location #10**, install and record VOC sorbent tube # ~~456~~ 776 ~~S-OA-L—MMDDYY--NNN~~ ~~C-OA-10-021202-~~ 458 C-OA-10-021202-776

* 456 appears to have broken white packing material sorbent upon final GAOC replaced (DS/SML)

Record INDOOR B

Peristaltic Pump ID# VOC #1 / ALD #1

Record Elapsed Time Left Timer 280.2 Right Timer 736990

Clock correct (**check**) Left Timer ✓ Right Timer ✓ ✓ Set to "AUTO" (**check**) Left Timer ✓ Right Timer ✓
Programming Correct (**check**) Left Timer ✓ Right Timer ✓ Return to clock (**check**) Left Timer ✓ Right Timer ✓

In **location # 7**, install and record ALD cartridge # C-30-7-021202 (In **location # 8**, install and record dup ALD cartridge #
Lot # W13382L1

In **location #5**, install and record VOC sorbent tube # 455 S-CC-L—MMDDYY--NNN C-30-5-021202-455

In **location #6**, install and record VOC sorbent tube # 791 S-CC-L—MMDDYY--NNN C-30-6-021202-791 (circle one) (HEATING SEASON) COOLING SEASON

(circle one) Bard 10 SEER HVAC (IDEC & hydronic heat coil for HVAC)

Sampling Period = approximately 8:~~00~~ 15 to 15:~~00~~ 35 on a (circle one) (TUESDAY) WEDNESDAY THURSDAY

Date 2/12/02 Technician OGS + SML

Field Work/SAMPLING Start Time 6:30

NOTE: DNPH cartridge in **location (Loc) #3(and #4)**, VOC sorbent tube in **Loc #1**, Duplicate VOC sorbent tube in **Loc #**

NOTE: warm up pumps for 15 minutes...START WARM-UP 7:00 AM *END WARM-UP* 7:20 AM

Flow rate measurements

AM measurements START TIME 9:00

INDOOR A ✓ Temp 57.6°F Loc#3 Flowrate 140.9, (Loc#4-dup Flowrate ——),
59.0°F Loc#1 Flowrate ________,
59.5°F Loc#2 Flowrate ________

OUTDOOR ✓ Temp 57.0°F Loc#11 Flowrate 141.7, (Loc#—-dup Flowrate ——),
57.7°F Loc#9 Flowrate ________,
58.5°F Loc#10 Flowrate ________

INDOOR B ✓ Temp 54.2°F Loc#7 Flowrate 139.2, (Loc#8-dup Flowrate ________),
59.9°F Loc#5 Flowrate ________,
59.6°F Loc#6 Flowrate ________

AM measurements END TIME 9:32

VOCs, see attached pages

PM measurements START TIME 14:58

INDOOR A ____ Temp 66.9°F Loc#3 Flowrate 144.8, (Loc#4-dup Flowrate ——),
67.8°F ~2.5-3%↑ Loc#1 Flowrate ________,
68.5°F Loc#2 Flowrate ________

OUTDOOR ✓ Temp 66.7°F Loc#11 Flowrate 143.9, (Loc#—-dup Flowrate ——),
68°F ~1.5%↑ Loc#9 Flowrate ________,
67.8°F Loc#10 Flowrate ________

INDOOR B ✓ Temp 66.9°F Loc#7 Flowrate 144.4, (Loc#8-dup Flowrate ——),
67.8°F ~3.5%↑ Loc#5 Flowrate ________,
67.5°F Loc#6 Flowrate ________

PM measurements END TIME 15:21

All flow Δ good, < 5% (OS)

End of run Elapsed time measurements

INDOOR A Remove and store samples (**check**) ✓ Left Timer 624131 Right Timer 636.7

OUTDOOR Remove and store samples (**check**) ✓ Left Timer 705.1 Right Timer 7945.1

INDOOR B Remove and store samples (**check**) ✓ Left Timer 287.5 Right Timer 74139.0

Loc	Sample Type	Flow, cc/min. (f+i)/2	Sampling Time (f-i), min	Vair sampled, L
1	VOC	5.62	440	2.47
2	VOC	5.63	440	2.48
3	ALD	142.9	444	63.45
4	ALD dup.	—	—	—
5	VOC	5.58	438	2.44
6	VOC	5.64	438	2.47
7	ALD	141.8	440	62.39
8	ALD dup.	—	—	—
9	VOC	5.72	438	2.50
10	VOC	5.47	438	2.40
11	ALD	142.8	440	62.83

APPENDIX A.2

Study Design and Field Studies

A.2.3. Qualitative Data Checklist, Survey, and Questionnaire Developed

A.2.3.1 Final checklist for classroom physical environment, odors, and energy use indicators
A.2.3.2 "Technician Walk-Through" questionnaire developed initially for the UCLA PCS
A.2.3.3 "Operations and Maintenance" survey developed initially for the UCLA PCS

LBNL/CEC Relocatable Classrooms Study

Field Data Spreadsheet-->

Qualitative Assessment by Technician (DGS) of Indoor Physical Environment including lights, doors, HVAC functioning, and odors. Summary of sentence(s) written on data sheets.

SD NAME

SCHOOL NAME — *Circle One:* COOLING SEASON HEATING SEASON — *Circle One:* BARD IDEC

Date (MMDDYY): ______

Day of Week (enter Tu, W, Th): ____

Classroom #: ____

(Technician writes when observations were inventoried)	**(on/off, #;** if on and not all on, _ of _ = %)	**(open/closed;** *if open, estimate if 30/60/90 angle AND write if kept open by door stop or chair?*)	(by sound) **on/off**	**(open/ closed;** *if open, estimate how far, i.e., "a crack," half, or full?*)	**(Technician Comments:** Perfume/cosmetics? Food smells? Musty/"damp basement" smells? Chemical solvent-type odors from cleaning and teaching products? Other?)	**Bard** (off, auto, fan); **IDEC** (off, heat, cool, auto)	**(deg F)**	(Technician Comments-- four categories, use Y or N, plus any key details)	(Technician writes Y or N, and if Y which ones observed)	**Y/N (If Y, # and left on?)**
AM SET-UP, RECESS, LUNCH, END OF SCHOOL, or PM TAKEDOWN	LIGHTING FIXTURES	DOORS	HVAC SYSTEM	WINDOWS	Description of Odors	HVAC System Thermostat Setting	Thermostat Reading	Describe cleanliness (surface dust; tiled wet areas; carpets-soiled,stained?; water damage anywhere?)	Pollutant sources present and/or open? (adhesives/glues; non-H2O based paint; cleaners for carpet, desk, sink/counter; pesticides; other)	Computers & Monitors?

TECHNICIAN WALK-THROUGH QUESTIONNAIRE

(NOTE: some sections adopted from RIOPA study "Technician Walk-Through" questionnaire, itself based on questionnaires used in NHEXAS)

1. A. Name of Interviewer ________________________

   B. Dates of Sampling (Start-to-Finish, MMDDYYYY) __________ - __________

   C. Portable or Permanent Building Classroom #: ________

   D. Name of School ________________________
   E. Address ____________________

   F. City, State ________________________ G. Zip Code ______

   H. Telephone Number (___) ___ - ____

2. AT THE TIME OF THIS SAMPLING

   A. Name of Teacher(s): ____________________________________

   B. Grade Level(s) Instructed: ________

   C. Subjects Instructed: _____________________________________

   D. Number of rooms (DO NOT INCLUDE BATHROOM): __

   E. Number of partitions: __
      F. If partitions, are they retractable or sliding, i.e., temporary?
      Yes No (= permanent wall)

   G. # students (desks) per classroom (NOTE IF > 1 CLASSROOM) _____,_____

3. Is the portable classroom raised above the ground? Yes No D/K

4. What kind of surface is the portable situated on?
CHOOSE BEST ANSWER TO DESCRIBE

A. __ Concrete Slab
C. __ Pavement (i.e., asphalt lot)
B. __ Grass/Field
D. __ Dirt/Soil

5. Are any of the following stationary sources in the classroom's immediate surroundings?
(CIRCLE ALL THAT APPLY; y= yards, m= miles)

< 50 y	A.	Dry cleaners	< 0.5 Km	E.	Dry cleaners
< 50 y	B.	Gas station	< 0.5 Km	F.	Gas station
< 50 y	C.	Industrial facility	< 0.5 Km	G.	Industrial facility
< 50 y	D.	Other sources, specify	< 0.5 Km	H.	Other sources, specify

6. What is the approximate horizontal distance from the classroom to the nearest...?
(MARK ALL THAT APPLY, CIRCLE y= yards or m= miles AND WRITE DISTANCE)

A.	Major thoroughfare (e.g., freeway and/or primary road)	y m
B.	Shipping facility, truck loading/unloading area	y m
C.	Bus depot	y m
D.	Train depot	y m
E.	Other, specify	y m

7. SKETCH OF PORTABLE (USE GRAPH PAPER LIKE IN RIOPA AS PAGE 4)

a.) Measure dimensions to calculate approximate volume of air.

Length= ___ ft. Width= ____ ft. Ceiling Height= ____ ft.

VOLUME = ________ ft^3 = ________ m^3

b.) Indicate with compass diagram North (and other corresponding directions)

c.) USE SYMBOLS [as RIOPA (see attachment)] to draw and designate garbage can(s); storage areas for any cleaning supplies, paints, markers, glues, etc.; light fixtures; vents; bathroom or sinks; doors; ceiling or floor fans; HVAC unit location.

d.) Indicate whether floor is carpeted, wood, or tile. If floor is partially carpeted, indicate specifically where (USE SHADING)

e.) Indicate what borders each of the four sides of the portable classroom building (WITHIN __ FEET):

A. Other portable classroom buildings? ________ ft

B. Permanent main building? ________ ft

C. Fields? ________ ft

D. Parking lot? ________ ft

E. Loading/Unloading area for trucks and/or cars? ________ ft

F. Boarding area for school buses? ________ ft

G. Nothing?

f.) *(BVHC'S)* Indicate **location and type** (e.g., hanging plant, hanging flowers, vines/ivy, plants, flowers, trees, bushes/shrubs) of any **vegetation** inside, and immediately outside, the portable classroom building.

g.) Note the location of the PFT sources, the CAT, and the passive samplers.

NOTE: The following questions will require the interviewer/technician to consult the teacher(s) and/or an appropriate administrator.

8. How many hours are in a typical school day for students in the class(es) inhabiting this portable classroom building? (IN HOURS PER DAY; SPECIFIED BY ROOM, IF NECESSARY)

____

____

9. What is the **length in time** (IN TOTAL HOURS PER SCHOOL DAY, TO NEAREST 30 MINUTE INTERVAL), **on average**, spent in the following scheduled activities <u>outside the portable classroom building</u>?

A. Lunch ________

IF STUDENTS HAVE LUNCH IN PORTABLE, CHECK HERE ____

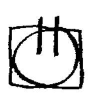
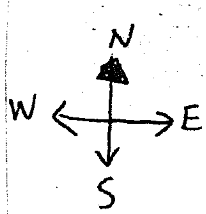
B. Recess ________

C. Classes for other subjects ________

i.) Were those classes in portables? Yes No D/K

ii.) Were those classes in portables and in the main building? Yes No D/K

D. School assemblies ________

-  = window
- (S) = storage area for cleaning agents, solvents, non-waterbased paints
-  = door
- [L] = lighting fixture
- [V] = vent duct
- [HVAC] = heating, ventilation, and air conditioning system duct <u>or</u> unit
- [Desk] = teacher's or library staff member's desk
-  = sink and faucets
- [Thermostat] = control for room temperature
- 

 = directions by compass (Re: wind)
- [Computer] = table with student computers and/or learning stations
- [Garb] = garbage cans/receptacles
- [Recycle] = recycling bins (paper, etc.)

For Technician Walk-Through Survey, p. 4 drawing

OPERATIONS & MAINTENANCE QUESTIONNAIRE

BUILDINGS & GROUNDS / FACILITIES STAFF

1. A. Name of Interviewer ______________________

   B. Name of Interviewee ______________________

   C. Position Title ______________________

   D. Telephone Number (___) ___ - ____, Ext. ____

   E. Name of School ____________________
   F. Address ______________________

   G. City, State ___________________ H. Zip Code ______

2. A. Name of chief/head/supervisor ______________________

   B. Number of staff at school ____

3. A. Classroom Number: Portable(s) studied ____, ____, ____

   B. Permanent building room studied ____

   C. Ages of portable(s) studied, i.e., year built and/or placed at school, respectively:

   ________, ________, ________

   D. When was the main building constructed? ______
   E. Last major renovation? ______

4. A. Age (month/year installed) of current HVAC unit in portable(s) studied , respectively :

_________________, _________________, _________________

B. Time of day the HVAC unit is turned **on for ventilation, "ON"setting** (APPROXIMATE TO 30 MINUTE INTERVAL): ____-____ AM PM

C. Time of day the HVAC unit is turned **off, "AUTO"setting** (APPROXIMATE TO 30 MINUTE INTERVAL): ____-____ AM PM

5. A. Is the original filter in the HVAC unit? Yes No D/K

B. If answer is "No", when was the filter last changed? (MMDDYYYY) __________

C. How often is the filter changed?

Every __ months "Only if necessary" D/K

6. What is the air intake rate in each portable classroom? (VOLUME/TIME, SPECIFY UNITS)

A. On average (i.e., requirement) ___________, ___________, ___________

B. Most recent recorded measurement ___________, ___________, ___________

7. Indoor temperature (SPECIFY UNITS) when **heat** (of HVAC) is **turned on**? ____ F C

When do you start using the heat (from HVAC)?

A. January __	E. May __	I. September __
B. February __	F. June __	J. October __
C. March __	G. July __	K. November __
D. April __	H. August __	L. December __

8. Indoor temperature (SPECIFY UNITS) when **heat** (of HVAC) is **turned off**? ____ F C

When do you stop using the heat (from HVAC)?

A. January __	E. May __	I. September __
B. February __	F. June __	J. October __
C. March __	G. July __	K. November __
D. April __	H. August __	L. December __

9. Indoor temperature (SPECIFY UNITS) when **air conditioning** (of HVAC) is **turned on**?____ F C When do you start using the air conditioning (from HVAC)?

A. January __	E. May __	I. September __
B. February __	F. June __	J. October __
C. March __	G. July __	K. November __
D. April __	H. August __	L. December __

10. Indoor temperature (SPECIFY UNITS) when **air conditioning** (of HVAC) is **turned off**? ____ F C When do you stop using the air conditioning (from HVAC)?

A. January __	E. May __	I. September __
B. February __	F. June __	J. October __
C. March __	G. July __	K. November __
D. April __	H. August __	L. December __

11. Where is the temperature control, e.g., thermostat? __________(MARK ON DIAGRAM)
12. Does the staff receive training

A. ____ At the start of their job?
B. ____ At the start of the school year?
C. ____ Several times a year (i.e., training workshops/seminars)?

D. If Yes, how many? ____
E. At what time interval (i.e., frequency)?
Every ____ WEEKS MONTHS

13. Does a standardized written protocol or manual exist for

A. Operation of the HVAC units for the portable classrooms? Yes No D/K

B. Maintenance of the HVAC units for the portable classrooms (e.g., change filters)? Yes No D/K

C. Does an accurate maintenance log exist for each of the portable classrooms? Yes No D/K

D. For the portable(s) used in our study? Yes No D/K

9. Indoor temperature (SPECIFY UNITS) when **air conditioning** (of HVAC) is **turned on**?____ F C When do you start using the air conditioning (from HVAC)?

A. January __	E. May __	I. September __
B. February __	F. June __	J. October __
C. March __	G. July __	K. November __
D. April __	H. August __	L. December __

10. Indoor temperature (SPECIFY UNITS) when **air conditioning** (of HVAC) is **turned off?** ____ F C When do you stop using the air conditioning (from HVAC)?

A. January __	E. May __	I. September __
B. February __	F. June __	J. October __
C. March __	G. July __	K. November __
D. April __	H. August __	L. December __

11. Where is the temperature control, e.g., thermostat? __________(MARK ON DIAGRAM)
12. Does the staff receive training

A. ____ At the start of their job?
B. ____ At the start of the school year?
C. ____ Several times a year (i.e., training workshops/seminars)?

D. If Yes, how many? ____
E. At what time interval (i.e., frequency)?
Every ____ WEEKS MONTHS

13. Does a standardized written protocol or manual exist for

A. Operation of the HVAC units for the portable classrooms? Yes No D/K

B. Maintenance of the HVAC units for the portable classrooms (e.g., change filters)?
Yes No D/K

C. Does an accurate maintenance log exist for each of the portable classrooms?
Yes No D/K

D. For the portable(s) used in our study? Yes No D/K

APPENDIX A.2

Study Design and Field Studies

A.2.4. Quality Assurance Quality Control: UCLA PCS Chain-of-Custody Forms

UCLA PORTABLE CLASSROOMS STUDY: Chain-of-Custody Form: CATs (Capillary Adsorbent Tube)

sample ID	clean CAT sent			clean CAT received			sample collection date	sample sent			sample received			sample analysis date
	by	location	date	by	locatrion	date		by	location	date	by	location	date	

UCLA PORTABLE CLASSROOMS STUDY: **Chain-of-Custody Form: DNSH Aldehyde**

sample ID	clean cartridge sent			clean cartridge received			sample collection date	sample sent			sample received			sample analysis date
	by	location	date	by	locatrion	date		by	location	date	by	location	date	

UCLA PORTABLE CLASSROOMS STUDY: Chain-of-Custody Form: OVM 3500 BADGES (VOCs)

Sample ID	Badge Number	Date		sample sent by -- location	sample received by -- location	Date	
		sample collected	sample sent			sample received	sample analyzed

APPENDIX A.2

Study Design and Field Studies

A.2.5. AER Calculations Using a Harvard School of Public Health (Boston, MA) Protocol Modified with UCLA, and Protocol for HOBOs--T and RH data

Written by Robert Weker 1999, edits by DGS 12/05/01 and final organization 6/14/02

AIR EXCHANGE MEASUREMENT

I.

1. Scope

This document is intended to provide the necessary details for the determination of indoor/outdoor air exchange rates in relatively small enclosures such as homes, apartments, or small offices (DGS: or portable and relocatable school classrooms). Following the procedure below, **air exchange rates can be quantified over the range 0.10 to 2.5 air changes per hour (ACH). The limit of detection is about 3.0 ACH.**

2. **Introduction**

The measurement of air exchange rate (AER) is accomplished using a tracer gas under steady-state conditions, and a passive sampling technique followed by sample analysis with a gas chromatograph and electron capture detector (GC/ECD).

This method is based upon the technique developed by Dietz et al(1). An inert, non-toxic, tracer chemical, perfluorinated methylcyclohexane (PMCH), is allowed to permeate into the enclosure for 24 hours. During this period a steady-state concentration is theoretically established based upon partly the permeation rate of the PMCH source, the volume and temperature of the enclosure and its average air exchange rate. Now, the passive sampling device, a capillary adsorption tube (CAT), is located in the enclosure and allowed to collect PMCH for a fixed period of time ranging from 12 hours to one week. The PMCH permeation source remains in the enclosure for the duration of the sampling period. The passive sampling device is returned to the laboratory for determination of the amount of PMCH collected. Given the above variables, the collection rate of the CAT, and conversion factors, the average air exchange rate can be calculated. The PMCH source is removed one day after CAT sampling is complete, then it is returned to the lab for post-experimental permeation rate verification.

3. PMCH sources

PMCH sources have a nominal permeation rate of 375 ng/min. **at 24-25 degrees C. and a useful lifetime of about 4-5 years. The permeation rate is proportional approximately to temperature, 3% per degree C. For a batch of sources prepared with the same materials at the same time the permeation rate has an associated relative standard deviation (RSD) less than 3% (DGS: why PFT ng/min values range a bit).**

A. Preparation

Apparatus, Materials, Supplies
22 mm aluminum bullet shells and holder
PMCH (Aldrich Chemical)
50 ml or 100 ml graduated glass beaker
autopipette for transferring 0.4 ml
silicone rubber solid tubing
aluminum plug-cutting tool
silicon high vacuum grease
crimper
7 mm punch
razor blades, single edge
electromechanical vibrating engraver or equivalent
lab tissue paper
disposable rubber gloves
#3 cork borer
polyurethane foam
labels 0.5cmx2.5cm
clear tape 3/4"

Procedure:
1. Engrave an ID on each bullet shell. The ID should be HSPH yy-nnn where yy are the last two digits of the year made and nnn is the next sequential number.
2. Using the punch and hammer, carefully expand the open end of each shell only slightly to facilitate later insertion of the silicone plug. Place the engraved shells sequentially in the shell holder.
3. Lay a piece of silicone rubber solid tubing in the aluminum plug jig and carefully cut fixed length plugs with a razor blade. Cut one plug for each source.
4. Using gloves, apply a very thin layer of silicone grease to the circumferential surface of the plugs being careful not to get grease on the flat surfaces.
5. Calculate the total ml of **PMCH needed**: number of PMCH sources multiplied by **0.4 ml per source.**
6. Transfer the calculated amount of PMCH plus a small additional amount to the graduated glass beaker.
7. **With the autopipette, transfer 0.4 ml PMCH** to 6 shells.
8. Carefully insert/press a rubber plug into each shell until it is just flush with the top edge.
9. Crimp the plugged end of each shell with the special crimper tool.

10. Remove excess grease if any with a piece of tissue and replace the shell in the holder.
11. With a hack saw **cut the polyurethane foam into blocks of 2cm(L) x 3cm(W) x 5cm(H).**
12. Bore two holes: one, straight through the 3cm dimension at 4cm(H); the second hole to be also about 3cm long, but from the center of the just bored hole through the 5cm dimension, but not straight through.
13. Insert a source through the first 3cm hole into the second 3cm hole of the polyurethane plug so that the end of the source with the silicone rubber plug just barely protrudes into the first 3cm hole of the polyurethane plug .
14. Prepare a small label (0.5cmx2.5cm) with the ID of the PMCH source and attach it securely to the polyurethane plug with a piece of clear tape all the way around.
15. Repeat the process until all sources are made. Place them in a box and store beneath another vented hood away from any potential contact of PMCH with CATs.

B. Determination of permeation rate.

Apparatus, Materials, Supplies
PMCH permeation sources
Analytical balance with a readability/accuracy/precision of 0.1 mg.
Plastic tweezers
Worksheet template

Procedure
1. The PMCH source must be at least 3 weeks old prior to any weighing.
2. On the template, record the date, time, and temperature. Record the IDs of the PMCH sources.
3. Make sure the balance pan is clean (gently wipe with a fine artist brush) and rezero the balance.
4. Using the plastic tweezers, carefully extract the PMCH source from its polyurethane block holder and place on the balance pan.
5. Allow the reading to stabilize and record the weight. A new source weighs between 1.8 and 2.0 gm. whereas one at the end of its useful life is usually at or below 1.2 gm.
6. Remove the source from the balance pan and replace it in the polyurethane holder.
7. Check the zero and reset if necessary.
8. Weigh 9 more sources, then reweigh one of the previous nine by random selection.
9. Continue this procedure until all PMCH sources have been weighed and recorded.
10. If the weighing session is the first time the sources have been weighed, then stop here.
11. If this is the second or a subsequent weighing, then the permeation rate may be calculated. For a newer source at least 3 weighing sessions about 2 weeks apart each, are necessary for confirmation of a constant permeation rate. Sources should be weighed twice each, before and after field deployment.
12. The permeation rate is calculated by taking the difference in two weights from different weighing sessions, multiplying by 10^{-9} to convert grams to nanograms, and dividing by the time interval in minutes.

$$R_P = [(W_{Tf} - W_{Ti}) * 10^{-9}\ (ng/gm)] / [(Tf - Ti) \times K] \quad (1)$$

where

R_P = Permeation Rate in ng/ml

W_{Tf} = final weight of permeation source in gm.
W_{Ti} = initial weight of permeation source in gm
Tf = date and time of final weighing
Ti = date and time of initial weighing
K = factor for converting days to minutes (1440 minutes/day)
and/or hours (60 minutes/hour)

13. General example/discussion: a total of 4 weighing sessions, 2 before and 2 after. Assuming the temperature to be 24 degrees C. for the interval between the first two sessions and the last 2 sessions, the permeation rate should reflect the same equilibrium conditions and be the same within experimental error. The permeation rate between the 2nd and 3rd weighing sessions represents the time interval during field deployment. Providing the temperature remained at 24 degrees C. and there was no mishandling of sources, the permeation rate should be the same as that measured in the lab. (Sources returned from the field should be weighed as soon as possible.) Any change in the permeation rate should obviously be consistent with field temperatures.

Permeation rate for the field at other than 24 degrees C. should also be calculated by applying the appropriate temperature correction factor to the lab measured rate, i.e. the rate obtained from the 1st/2nd and/or 3rd/4th session. The corrected rate should be close to the rate calculated for the 2nd/3rd session rate. When using the permeation rate for the AER calculation, select the rate which is most consistent with actual source history. For this one may consider that to reach a new permeation equilibrium at a different temperature, takes only a day or two compared to the 3 week duration needed for newly prepared sources. For homes where there is a diurnal variation in temperature, make the correction based on the average temperature determined by max-min thermometers.

4. Cleaning of CATs

The CAT sampling device consists of a short length of glass tubing (6.35 cm L x 0.6cm OD x 0.4cm ID) containing a small amount of a carbonized adsorbing material which is sandwiched in the middle by stainless steel screens. An identification number (ID) is permanently engraved on each sampler. The ends of the CAT are capped with either a polyurethane cap or a polyethylene cap. **CATs are cleaned by thermally desorbing** any adsorbed compounds from them **at an elevated temperature in an inert nitrogen atmosphere.**

Apparatus, Materials, Supplies:
23 position cleaning rack with attached nichrome heating coils
variable voltage transformer
low voltage, high current transformer
automatic programmable shut off timer (1500 watt)
ultrahighpurity nitrogen gas (tank with pressure regulator and needle valve)
standard lab tubing (rubber or polyethylene) to connect the gas tank/valves to the rack
flowmeter, 500 ml/min
carbon paper and/or activated charcoal tea bags
cleaning worksheet template
resealable plastic bag

Procedure:

1. On worksheet, enter your name, date of cleaning, and IDs of CATs. Note any unusual CATs.
2. Remove the protective caps from 23 CATs and insert the CATS through the coils into the rack's retaining silicone O-rings. The rack is on the upper shelf of the cabinet below the fume hood. Make it protrude a few inches by sliding it toward the operator.
3. Turn on the nitrogen gas tank valve, adjust the pressure regulator to about 10 psi.
4. Attach a flowmeter to any of the 23 CATs; adjust the needle valve for a flow of ~15 ml/min.
5. Check the flow in the remaining 22 CATs to be in the range of 10-100 ml/min.
6. Remove the flowmeter.
7. With the variable voltage transformer set to zero, turn on the timer:
   A. Press the *T1*
   B. Press the *min* button until 25 has registered.
   C. Press *Outlet 1* to activate the outlet, red light on.
   D. Slowly turn the variable voltage transformer dial to a reading of 80. This should produce a just barely visible red-orange glow in the heating coils.
   E. Press *Start* on the timer.
8. After 25 minutes have elapsed, the timer automatically shuts off voltage to the variable voltage transformer. Allow about 15 more minutes for the heating coils to cool.
9. Replace the protective caps on 22 of the 23 CATs.
10. Turn off the nitrogen gas tank main valve, pressure regulator, and needle valve.
11. Remove the 23rd CAT with no cap and recap at both ends.
12. Remove the 22nd CAT and recap the one open end.
13. Proceed in similar fashion until all the CATs have been removed and recapped. Minimize the time spent doing this to reduce the amount of air that can diffuse into the CAT.
14. Place all the CATs in a plastic resealable bag containing protective carbon paper or 2 activated charcoal tea bags.
15. Label the bag: number of CATs, date cleaned, and initials. Store in a labeled drawer.
16. Place the worksheet in the Clean/QC file.
17. Allow the rack to cool down.
18. Replace the rack in its original position.

Safety: Perform this work in the fume hood area with no combustible solvents nearby. Attach a sign in a convenient location to indicate the high temperature hazard.

5. Quality Assurance

Apparatus, Materials, Supplies:

23 cleaned CATs
special gas chromatograph with autosampler and integrator (described below)
silicone grease
disposable latex gloves (non-powdered)

For most projects, all CATs are analyzed before being sent out to the field. For projects with many CATs (>500) each bag of 23 CATs is at least subsampled to check for contamination. The size of the subsample may vary but may never be less than 3 CATs (10%).

Upon QA analysis, CATs must have < 1.0 pl PMCH, or a peak at t_r~1.3 minutes with an area count < ~50000 counts. The actual area count must be determined by first establishing the value for 1.0 pl. This is easily done by determining the area count for a lab blank (=0.0 pl) and a standard PMCH in the range of 2.0 pl. If the CAT has < 5 pl PMCH (as measured from a recent standard curve) then it can be rerun. If the rerun is < 1.0 pl PMCH, then the CAT may be accepted, otherwise it must be recleaned by the usual process. All data and information must be recorded on the cleaning worksheet and the CAT QA worksheet.

Follow the same procedure for CAT analysis (described below).

II. Preparation of Standard CATs (for analysis)

Purpose and Design

A series of CATs are prepared with known amounts of PMCH (and optionally PDCH). Each analytical run of samples is accompanied by a full set of CAT standards covering the range of interest of PMCH. The standards are used to construct calibration curves for calculating the amount of PMCH in unknown samples.

A PMCH generator is used. It consists of a source of inert nitrogen gas flowing over a temperature-controlled PMCH source. Flow is measured by a soap-bubble flowmeter and temperature controlled by a constant temperature water bath. Aliquots of PMCH vapor in nitrogen are removed sequentially with a series of gas-tight syringes of increasing volumes through a T-septum arrangement downstream of the generator.

Apparatus, Materials, Supplies:

Ultrahigh purity nitrogen gas tank with regulator, 20 µm id glass capillary and holder, and connecting tubing.
Cleaned and QA'd CATs
Temperature controlled water bath and copper tubing
20 ml midget impinger
Chronometer or stopwatch
50 ml burette class A
glass T
tubing
soap bubble solution
gas-tight syringes: 10, 25, 50, 100, 250, and 500 µl.
charcoal paper or charcoal tea bags

Procedure:

1. Determine the nitrogen flowrate

Increase the regulator adjustment so that the secondary pressure is about 20 psi which corresponds to a flow of about 30 ml/min. Squeeze the bulb at the bottom of the glass tee to set in motion a soap bubble in the buret. When the bubble intersects the 50 ml line, start the chronometer; when the bubble intersects the 40 ml line, stop the chronometer. Record the elapsed time in seconds. Repeat two more times. Using the average of the 3 time readings calculate the nitrogen flow rate:

F (ml/min) = (10 ml x 60 sec/min) / average time (sec)
(2)

2. Reweigh the standard PMCH source in the midget impinger at least once per month and use equation (1) to calculate the standard PMCH source permeation weight, $r_{p\text{-std}}$ and record all data and information on the standard CAT worksheet.

3. Calculate the concentration of PMCH in the generator:

PMCH (pl/µl) = [$r_{p\text{-std}}$ (ng/min) x (24.45 nl /350 ng) x1000 pl/nl] / [F (ml/min) x 1000 µl/ml]
(3)

where (350 ng/24.45 nl) is a molecular weight-molecular volume conversion factor. When $_{p\text{-std}}$ = 375 and F = 30, then PMCH (pl/µl) = 0.87 pl/µl.

4. Assemble from 1 to 9 sets of cleaned and QA'd CATs. Each set has 9 CATs. Every CAT must have an orange-brown silicone septum on the numbered end and on the plain end a black polyurethane cap or a red polyethylene Caplug, no. #EC-4. Record the CAT IDs on the Standard CATs worksheet.

5. Add the indicated µl of PMCH from the generator to the designated CATS using the syringe shown below:

amount of PMCH to be added:	syringe
0 µl	10 µl syringe
2 µl	10 µl syringe
4 µl	10 µl syringe
10 µl	25 µl syringe
20 µl	50 µl syringe
40 µl	100 µl syringe
100 µl	250 µl syringe
200 µl	500 µl syringe
0 µl	500 µl syringe

A. Check each syringe-needle for blockage by withdrawing the needle to about 80% of syringe volume, placing the needle tip in a beaker of water, and depressing the plunger. Look for air bubbles and remove the needle from the water while still depressing the plunger. Wipe the tip with lab tissue. If there is blockage, determine whether it's in the needle or the polytetrafluoroethylene (PTFE) needle retainer. Clean the former with the supplied wire. Clean the latter with the plunger. Be very careful not to deform, damage, or lose any parts. Use a low-power stereomicroscope if necessary.

B. For each of the "0" CATs pierce the CAT septum with the clean empty 10 μl syringe-needle, remove the needle and return the CAT to its storage position.

C. Repeat B. but with the clean empty 500 μl syringe-needle.

D. For the "2" to "20" CATs, insert the appropriate size syringe/needle into the metal T-septum on the PMCH generator and slowly "pump" the plunger at least 3 times. Set the plunger so that the PTFE tip end intersects the appropriate volumetric marking on the syringe. Withdraw the syringe from the generator septum.

E. Insert the syringe needle through the correspondingly appropriate standard CAT septum until the needle is within 5mm of the SS screen, and slowly depress the plunger all the way.

F. Remove the syringe needle and replace the CAT in its designated location.

G. Repeat D. through F. until all "2" to "20" standard CATs have been prepared.

H. For the "40" to "200" CATs, follow the same procedure as above except first withdraw air from the CAT before introducing the PMCH. This prevents pressure buildup and septum loosening. The amount of air to withdraw is twice the amount of standard PMCH to be introduced, e.g, withdraw 80 μl when preparing 40 μl std. CAT.

I. Place some charcoal paper or charcoal tea bags in the standard CAT box , close, and store for at least 4 hours before using.

J. Make sure information has been recorded and store the worksheet in the file.

III. GC-ECD analysis of CATs

<u>Introduction</u>

The amount of PMCH adsorbed on CATs is determined by GC-ECD analysis. A very complete discussion of the GC (Varian Model 6000) and the technique can be found in Dietz, R. et al. This discussion is strictly limited to the operation of the system at HSPH.

<u>Apparatus, Materials, Supplies:</u>

Varian GC with ECD; GC heavily modified in semi-multi-dimensional configuration for analysis of PMCH.
Hewlett-Packard 3393A integrator
5% H_2 and 95% N_2 carrier gas
Strip chart recorders: 0-1 mv, 0-2 mv, 0-5 mv, and 0-10 mv.
Custom in-house built 23 sample-position autosampler
Chrontrol Lab Timer-Electrical Controller for 1 or 2 circuits.
Silicone grease
Q-tips

Lab supplies/expendables, e.g. tissues gloves, etc.
Analysis worksheets from templates.

Carrier gas is 5% H_2 and 95% N_2. House supplied air is regulated to 30 psi and provides the air pressure necessary for operation of the 4 6-port switching valves integrally located on the GC, and for maintaining a tight seal on the autosampler's 24-port switching valve (op cit).

A Hewlett-Packard 3393A integrator is attached to the integrator signal lead of the GC. The integrator parameters and Basic language have been used to automate data acquisition and preliminary data reduction.
Further signal acquisition is obtained on a strip chart using the GC recorder signal. Also the temperature of the special external Porapak GC column (op. cit.) is monitored by a thermocouple with the signal (0-2 mv)displayed on a stripchart recorder.

See the indicated Appendix below for the settings of all the instrumentation.

Appendix A.	Parameters for GC.
Appendix B.	Parameters for Integrator operational settings.
Appendix C	Program of Integrator data reduction.
Appendix D	Program for Timer which controls the recorder pens.
Appendix E	Recorders' settings.
Appendix F	Autosampler setting.

Procedure:
Autosampler

1. Enter CAT ID data on the GC Analysis worksheet; i.e. autosampler rack position, a number between 1 and 23, the corresponding CAT ID, and the type of CAT, standard (std) or field sample (unknown,). Every run must have all 9 standard CATs necessary to construct a standard curve. Also every one must have at least one(1) lab blank and/or field blank. A Run will have then either 12 or 13 unknown CATs .
2. Remove the cam adjusters and the top plate from the rack
3. Loosen the C-clamps on the bottom plate of the rack
4. Use gloves. Apply a small amount of silicone grease to a Q-tip (or equivalent). Carefully and lightly use the Q-tip to apply the grease to the red silicone O-rings in the bottom plate. Clear any visible excesses. The grease facilitates the insertion of the CATs into the O-rings. The 0-rings on the top plate must be greased only once every week .
5. Remove the cap from the plain unnumbered side of each CAT and insure that the top cap is not very tight
6. Insert the 23 CATs with the ID facing up, through the heating coils into the O-rings according to the sequence on the worksheet. Press firmly but do not force which can cause breakage. Adjust the C-clamps firmly but not too tightly
7. Replace the top plate carefully; line up the top of the CATs with the wells on the top plate and press it firmly down to seat barely the CATs.
8. Insert the cam adjusters holding the arm in the 3 o'clock position. Replace an finger-tighten the nuts on the cam-adjusting screw

9. Rotate the cam-adjusting arms counterclockwise slowly and carefully to set the CATs and seal the O-rings. Use care so as not to break anything.
10. Attach the bungee cord to the cam-adjusting arms to prevent the arms from loosening.
11. Check the autosampler's LED reading for position. If not (00) use the toggle switch on the respective controller to reset it to 0.00

<u>GC Procedure</u>

1. Check the A and B pressures on the right side of the instrument. The gauges should be pointing to the preset marks of 42 psi and 80 psi. The carrier gas pressure must be 80 psi as measured on the tank's regulator gauge
2. Insure that the integrator is in BASIC mode. Press "R" (for run) then "ENTER:. Follow the instruction on the integrator. When it prints "start pending" PROCEED.
3. Place the recorder ON/OFF toggle switch in the ON position. Activate the timer by pressing "CIRCUIT", "1", "ON", PROGRAM ", "1", "ON" .
4. On the left side of the GC, press "SCHEDULE". Set the mode for "SINGLE PASS", if necessary. Repeatedly press "ENTER" to get to line 1 and enter "2" for the method # and "24" for the number of injections. Press the "ENTER: button, then "INSTRUMENT STATUS" A. Finally press "START" to initiate the run.
5. The run will go for about 3.5 hours. Check the progress frequently to make sure the instruments are functioning properly and the area counts for standards and blanks are in the proper range .
6. When the run has been completed, remove the strip chart and the integrator chart and place them in a labeled file folder along with the GC analysis worksheet.
7. Remove the CATs from the autosampler by reversing the procedure above.
8 . Recap the CATs and set them in the bin for cleaning.

IV. Calculations

Standard Curve

There is a spreadsheet template for entering the area counts from the integrator. It is straightforward and produces the calculated data for the unknowns. The replacement equations used in the template are very complex and it is suggested not to alter them. They are designed to produce a point-to-point fit for the standard curve. The curve's shape tends toward a quadratic as long as the amount of PMCH does not exceed about 400 picoliters. Note that the PMCH standard curve is not linear and so linear regression analysis (least squares analysis) cannot be used successfully across the entire range of interest.

Short of the template, one can devise their own spreadsheet as follows. Let the pl of PMCH from the standard CATs be the Y values and the area counts from the integrator be the X values. Enter these values in a spreadsheet which can perform either a quadratic fit or a point-to-point linear fit (sometimes termed a piecewise fit). Cubic may also work. The spreadsheet should be able to draw the standard curve and calculate the values of X for given values of Y.

Preparation of Standard Curve

From the PMCH source permeation rate and the measured nitrogen flow from the PMCH generator, calculate the PMCH concentration(pl/µl) of the standards used as described earlier. Enter this value into the designated cell in the spreadsheet. Enter the corresponding area counts into the designated cell(s) in the spreadsheet.

[Alternatively, multiply the PMCH concentration by the percent of PMCH in the reagent (usually 90%). Multiply this by the volume(µl) of gas used for each standard to get the total amount of PMCH.]

Calculation of PMCH in Unknowns

For the complete run, enter the sample (standard) ID and the corresponding integrator area counts into designated cells in the spreadsheet. **SHOW AN EXAMPLE** Now, the final data appears in the adjoining cells and the standard curve can be seen in the nearby chart

The concentration of PMCH in unknowns is calculated from the unknown area counts, the amount of PMCH in the standard with next least area counts, and the slope for the corresponding area count point on the standard. The slope is obtained either from the point-to-point fit or the quadratic equation.

Organization of Files and Worksheets **SHOW EXAMPLES**

Worksheets
Source Permeation Rates
Cleaned CATs
QA'd CATs
Standard CATs

Files
GC Analyses
Sources
CATs
Clean
QA'd
Computer
Sources
Templates
Clean and Run
Standards
Special Runs
Data and Results

V. Shipping Procedures

Sources
Sources and CATs should never be transported together nor on the same day. Sources should be shipped in resealable plastic bags in a box within a box. Their value is usually listed at $0.50 to $1.00 each. Paper records should be maintained showing what carrier, when, and the airbill or waybill number.

CATs
CATs are in resealable plastic bags with charcoal protection. These bags must be placed with charcoal paper or equivalent in a box within box for shipping. The declared value is $1.00 each.

Boxes for shipping should be adequately cushioned and taped with 3" postal tape or equivalent.

VI. Field Sampling

Introduction
As with any chemical determination, the data are only as good as the sample. PFT AER is a passive technique operating in a possibly heterogeneous sampling theater. So, attention to numbers of sources and CATs as well as careful placement of PMCH sources and CATs are very probably the most important parts of the AER protocol.

Determination of the Number of Sources
The number of sources is determined by rearrangement of Equation

$$AER = (N * R_{Perm} * R_{CAT} * T_{CAT})/(V_{PMCH} * V_{house})$$
$$N = [AER * (V_{PMCH} * V_{house})] / (R_{Perm} * R_{CAT} * T_{CAT})$$

where:

N = number of PFT sources used
R_{Perm} = PFT permeation rate in ng/min, or average permeation rate in ng/min if $N > 1$!
R_{CAT} = CAT collection rate in liters/hr = 0.008308 if one end open during sampling; multiply by two if both ends opened for sampling

T_{CAT} = CAT exposure time in min
V_{PMCH} = picoliters of PMCH found on CAT (GC analysis)
V_{house} = house volume in cubic feet
Conversion factors:
60 min/hr
28.3 lit/cubic foot
1,000,000,000 ng /gm
1000 picoliters/nanoliter
PMCH molecular weight = 350 gm/mole or ng/nmole
PMCH molecular volume = 24.45 lit/mole or nl/nmole

A desirable amount of PMCH to collect on a CAT is in the range of 20-100 µl. The sampling time is determined according to convenience, subjective assessment, and consideration of other simultaneous sampling.

FOR EXAMPLE, to calculate the number of sources needed in a given location, using an estimate of 0.2 air changes per hour and an average R_{Perm} = 300 ng/min and a house volume of 6,048 cubic feet, with an exposure of 24 hours, then to collect 25 pl PMCH,
$N = [AER \bullet (V_{PMCH} \bullet V_{house})] / (R_{Perm} \bullet R_{CAT} \bullet T_{CAT})$ or
N = [0.12 air changes per hour • (25 pl • 6048 cubic feet • (28.3 lit/cubic foot)] / (300 ng/min • {24.5 nl/350 ng}• (1000 pl/nl) • 0.008308 lit/hr •24 hr • 60 min/hr)
N = 2 sources.

Determination of the Number of CATs

The number of CATs to be employed is determined according to the type of information desired. For average air exchange rate, as few as 1 or 2 CATs can be used if optimally placed. For a more accurate measure of average air exchange rate, CATs may be located in every room in the house or building. If one wants to know the AER for a given room, then 2 or more CATs may be placed there as well as a PMCH source. This can get very complex very quickly when one considers that air exchange occurs not only with the outdoors through window areas, but also within the home through the door. In this case it is best to employ another tracer, say PDCH, in a nearby hallway to determine the rate of inflow of air into the target room from the hallway, i.e. some measure of the air exchange between hallway and target room. This should be complemented by placing CATs in the hallway to measure the PMCH and thus get an independent measure of outflow of air into the hallway. Some of these issues are discussed in detail in references 1 and 2.

In addition to the above, there should be at least 10% duplicate CATs and 10% Field Blanks.

Locating Sources and CATs

As can be seen from the immediately preceding paragraph, the optimal positioning of sources and CATs is necessary to obtain the most meaningful AER data. A complete discussion is beyond the scope of this document.

Some general considerations can be stated however. Sources and CATs should be placed in areas which allow relatively free but not forced movement of air. CATs should be as close as reasonably possible to the breathing height for both sitting and standing and be in an area which is representative of where occupants sit or stand, and representative of the AER in that room. This is obviously a very subjective judgement in the absence of additional instrumentation. Sources should be in an area that allows the tracer to disperse evenly and be transported in the dwelling to all locations which influence the AER.

Among the areas to avoid are windows and doors where there are strong drafts or winds, stairways which have increased vertical air movement due to thermal effects, adjacent to walls or or in "cubbyholes", and away from sources of heat or cold, and appliances such as refrigerators and dehumidifiers which contain Freons, a potential interferent in the analysis.

It is good for CATs to be suspended if possible, or placed on a flat surface with the exposed end protruding beyond the end of the surface, e.g. a table or mantle or bookcase or bureau.

<u>Deploying Sources and CATs</u>

The sources are contained in polyurethane blocks and should never be touched or removed. There is one source per block. Sources are sent to the field in resealable plastic bags. They are never shipped or transported together anywhere with CATs particularly regarding the sampling location. Sometimes some charcoal is placed with the sources. The charcoal absorbs the PMCH so that it cannot escape or contaminate anything. Every block has an external ID which matches the source contained within. Sources can be secured by taping (removable type adhesive tape) or tying with a string (using the available hole in the block). Dental floss is a very convenient material for the latter. Orientation, though not the most important issue, should still be considered: try to secure so the ID is in readable position. Record the date, time, and location (include a sketch) on the sample data sheet.

The CAT samplers are packaged 5 to a resealable plastic bag; they should always be protected by charcoal, paper, tea bag, or equivalent. CATs are set out 24 hours or longer after the sources have been deployed. They can be taped (removable type adhesive tape) or secured with a wire or plastic tie, or tied with dental floss. They should never be closer than six (6) feet from a PMCH source. Once the location is selected and the CAT secured, the sampling CAT is "activated" by removing the cap on the numbered end and positioning it by having the open end facing down, to minimize collection of particles. Record the date, time, and location of the CAT on the sample data sheet.

<u>Field Blanks</u>

Field Blanks (CATs) are transported to the sampling location, and treated identically to unknowns except they are opened then immediately closed. They should be protected by charcoal paper or tea bags, replaced in the plastic bag, and left at the house if convenient, otherwise taken to the local field office or equivalent where there is no source of unprotected PMCH.

<u>Duplicates</u>

Duplicate CATs are used to establish precision. They are prepared and treated identically to the main CAT. They should be placed next to the main CAT within about 3-6 inches. Both duplicates and Field Blanks should be recorded on the sample data sheet.

Appendix A. Parameters for GC.

Oven temperature = 130 °C.
Oven temperature limit = 150 °C.
Run time = 8.5 minutes
Inj A temperature = 200 °C.
Inj B temperature = 200 °C.
Ion temperature (ECD) = 250 °C.
TCD temperature = OFF
Detector = 4 (ECD)
Range 10 (only two choices, 1 or 10)
Attenuation = 32 (0.1,1,2,4,8,16,32,64,128,256,512,1024)
AutoZero A ON
AutoZero B ON

Relay Settings:

Time	Relays ON	Relays OFF
0.01	3456	1278
0.25	12	
0.41		5
2.01	7	16
2.02		7
4.01	8	23
4.61	3	8

Appendix B. Parameters for Integrator operational settings.
Appendix C Program of Integrator data reduction.
Appendix D Program for Control Timer which controls the recorder pens.

To reset, the timer-controller should be disconnected from the wall outlet for at least one minute. Then perform the following key entry procedures:
TIME
ENTER
1
ENTER
CIRCUIT
1
OFF
INTERVAL
3
4
5
ENTER
ENTER
ENTER
TIME

To test the timer operation, first set up the program by pressing...

TIME
ENTER
1
ENTER
CIRCUIT
1
ENTER
OFF
INTERVAL

...after INTERVAL press...

0
SEC
5
ENTER
TIME

to set the timer for a 5 second shutdown. To test, press...

CIRCUIT
1
ON

...and the circuit 1 indicator lamp should light.

Then press...

PROGRAM
1
ON

...at which time there should be a barely noticeable blink of the display; after 5 seconds, there should be an audible clicking sound simultaneous with the circuit 1 lamp light extinguishing. If this does not happen, then try reentering the program. When the test is successful, repeat the key entry procedure above entering 345 instead of the SEC 5 after the INTERVAL.

Protocol for HOBO, v.7/2000, by Naomichi Yamamoto and Derek G. Shendell, modified by Derek G. Shendell for UCLA pilot Portable Classroom Study

Launching HOBO

Pre-field: Use boxcar program to set up HOBO.

Use HOBO cord to connect HOBO to computer.

From Start menu, choose Programs, choose Onset Applications, choose Boxcar Pro v.3.5 or 4.0.

In boxcar pro program choose Logger option, choose Launch.

Choose 5-6 min (>14 days).

Choose delayed start function; set date and time to start sampling at 7:00 on first day of a sampling period in the classroom or outside at the school.

The HOBO is now set-up to sample **every 5-6 minutes.**

Field: **Mount the HOBO upside-down and protect from sun/rain, if outside, using roof overhang. Record placement time the first Thursday/Friday morning or afternoon, or Monday morning. Record time of retrieval at the end of the sampling period on Friday afternoon.**

Downloading HOBO

Create three new folders for HOBO raw data, HOBO text data, and Excel data.

Use Boxcar program v.4.0 to download information from HOBO.

Use HOBO cord to connect HOBO to computer.

From Start, choose Programs, choose Onset Applications, choose Boxcar pro Version 4.0.

In boxcar pro program choose Readout option from "Logger" menu.

Save the file in the HOBO raw data folder **for that sampling season** as boxcar data file (.dtf) **using the SD code, school name, and classroom number.**

Exporting to Excel

In boxcar program, chose the export option in the file menu to export file to MS Excel.

Choose following options:

For Date/Time Setting

Date Format: month/day/year

Date/Time Separator: Space

Time Format: Hr Min Sec (Inc. ½ sec.)

For Data Settings

Data Separator: Tab

Highlight the following-

Temp F

Temp C

RH (%)

Hit Export button and save file in HOBO text folder as text file (.txt) using the same name as boxcar file.

Open the text file in Excel, make sure the open file menu has "all files" selected.

The text import wizard will open.

Start import at row 1.

Follow directions and choose the following options:

File origin: Windows (ANSI)

Choose delimited

Delimiters: tab

Text qualifier: "

Column data format: general

Once imported in Excel, format the cells, choose Format Cells option- choose number- choose date or time option- choose 3/4/95 13:30 (m/d/y hr/min) format.

To make sure correct info was exported compare first data points in boxcar by opening boxcar file
To do so, choose View option-file information-show data (use display options to view different points)

Using files in Excel, Saving and Storing Excel Files
Delete both ends of exported data that are not part of the sampling time (the information recorded before placement and after dismantle). If the start of end of the AM/PM/overnight/weekend time period designation is between an interval, keep the data point before and after.

On each worksheet, by week/HVAC operated, day of week and AM/PM/overnight/weekend time period, calculate the arithmetic mean, standard deviation, median, minimum, and maximum.
Save the MS Excel workbook for each SD, with one worksheet per school (2-4 classrooms), per sampling season or event. Store MS Excel files in designated folders on laptop and back up on floppy disks.

Sampling date's season determination:
Cooling season or spring/summer: June-early October
Heating season or winter: January-March

APPENDIX A.2

Study Design and Field Studies

A.2.6. Analytical Standard Operating Procedures (SOP) for Aldehydes

- A.2.6.1 DNSH-PAKS, Sample Preparation and Analysis SOP, Environmental and Occupational Health Science Institute, Rutgers University/UMDNJ, Piscataway, NJ, for passive sampling in the UCLA PCS
- A.2.6.2 DNPH cartridges, Sample Extract Preparation and Analysis SOP, LBNL, Berkeley CA, for active sampling in the LBNL RCS

EOHSI
Environmental and Occupational Health Science Institute

MEASUREMENTS OF ALDEHYDES IN PERSONAL AIR

RIOPA Study

Sampling and Analysis Protocols:

Part 1: Standard Operating Procedures for the Preparation of Passive Aldehydes and Ketones Sampler (PAKS)

Part 2: Standard Operating Procedures for the Personal Sampling with PAKS

Part 3: Standard Operating Procedures for the Extraction of Aldehyde and Ketone-DNSH Derivatives

Part 4: Standard Operating Procedures for the Analysis of Aldehyde and Ketone-DNSH Derivatives Using HPLC System

Part 5: Standard Operating Procedures for the Quality Control and Quality Assurance for the Analyses of Aldehydes and Ketones

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Part 1

Standard Operating Procedures for the Preparation of Passive Aldehydes and Ketones Sampler (PAKS)

(Draft 10/29/99)

1 Chemicals and Apparatus Required

1.1 5-(dimethylamino)naphthalene-1-sulfohydrazide (dansylhydrazine, DNSH), reagent grade.
1.2 Acetonitrile (ACN): HPLC grade, for DNSH sample preparation.
1.3 Acetic Acid: reagent grade, to acidify the DNSH coating solution.
1.4 Nitrogen: zero grade, for cartridge drying.
1.5 Supelclean LC-18 Syringe Cartridge: 6-mL, 0.5g, Supelco Corporation, sampling medium for carbonyls.
1.6 Disposable Pipette: 5-mL volumetric and small pasture, with bulbs and pipetters
1.7 Volumetric Flask: 100-mL, to prepare DNSH coating solution.
1.8 Reagent Bottle: 100-mL or larger, to store DNSH stock solution.
1.9 Sample container: Aluminum can for cartridge storage.
1.10 Syringe: 10-mL syringe, use as many syringes as cartridges you want to coat.
1.11 Polyethylene Cap Plugs: to seal the DNSH-coated cartridges.
1.12 Tiered Syringe Rack: two racks that will fit on top of each other; the bottom rack must fit the vials, the top must fit the cartridges, and must be able to line up with the vials.
1.13 Tygon Tubing: 3/16" I.D., ~5-inches long. You will need 2 pieces.
1.14 Scrubber Cartridge: C_{18} Sep-Pak cartridge coated by DNSH.
1.15 Vacuum Dessicator: Equipped with DNSH coated silica gel and sample tray to hold samples over the drying media. 4 mL conical polystyrene auto-sampler sample cups are also useful as individual holding units for the cartridges. Note: All glassware should be cleaned with deionized water and ACN.
1.16 Caps: Plugs for DNSH cartridge.
1.17 Clip and Tight-band: Clip holder and tight-band for holding the cartridge.
1.18 Labels: 4 labels per cartridge. The labels should have numbers and corresponding bar-codes for sample identification.

2 DNSH Coating Solution

2.1. Weigh 250 mg of dansylhydrazine(1-dimethyl-amnionaphthaline-5-sulfonylhydrazine, DNSH).
2.2. Transfer DNSH into a 25-mL beaker and add about 20 mL of ACN.

2.3. Mix DNSH solution and transfer the DNSH solution to a 250-mL volumetric flask.
2.4. Rinse the 50-mL beaker with 20 mL of ACN and transfer the DNSH solution to 250-mL volumetric flask. Repeat three times.
2.5. Add 0.25 mL of Acetic acid to the flask.
2.6. Stopper the flask and shake to mix.
2.7. Add ACN to the flask up to 250 mL.
2.8. Stopper the flask and shake again to mix until homogenous.

3. Cartridge Coating Procedure

3.1. Place the 6-mL syringe-type cartridges in the double tier syringe rack.
3.2. Clean the cartridge with ACN. Add 6 mL of ACN to each cartridge and allow ACN to drain by gravity into a waste reservoir.
3.3. Displace any air bubbles with a disposable Pasteur pipet.
3.4. Add 4 mL of DNSH solution into each cartridge. Allow the cartridge to drain by gravity into a waste reservoir.
3.5. When DNSH solution has completely drained, wipe off any excess liquid on the ends of the cartridges with a CLEAN tissue paper.
3.6. Drying in a vacuum dessicator (Place a watch glass containing DNSH coated silica gel in the bottom of the dessicator. Connect one piece of Tygon tubing to each end of a DNSH coated C_{18} scrubber cartridge, and then connect the cartridge between the dessicator and the VAC system.
3.7. Place sample tray in dessicator, and arrange auto-sampler sample cups on tray (open end up). Use as many as will fit firmly.
3.8. Place the cartridges one-per-cup in the sample cups. They should be sitting in a vertical position.
3.9. Place the cover on the dessicator.
3.10. Be sure that there is a good seal on the dessicator.
3.11. Turn on the VAC. After about ten seconds, test the vacuum and seal by lifting the lid. If the lid lifts off, there is no seal, make sure the vacuum port in the dessicator is open, allowing the VAC to remove the air.
3.12. If there is still no seal, check to make sure the VAC is operating properly.
3.13. Repeat steps 3.11 and 3.12 until a seal is formed. Note: The resistance to flow between cartridges varies, therefore, the time needed to create a vacuum may vary depending upon the cartridge being used.
3.14. When a good seal is made, leave the cartridges to dry for 48 hrs.
3.15. After 48 hrs, turn off the vacuum and disconnect the piece of Tygon tubing from the VAC unit. The scrubber cartridge will slowly let the air back in while removing any contaminants.
3.16. Once the vacuum has depleted, remove the lid and immediately cap the cartridges.

3.17. Label the cartridges and sample container using the 4 labels designated for each sample. **Note:** Clean the caps with soap water, rinse them with tap water, twice with DI water, and twice with ACN.

3.18. Place the first label around the thick part of the cartridge. Be sure the bar-code is not covered in any way. Wrap each labeled cartridge with aluminum foil.

3.19. Stick one label directly on the sample container and cover with a piece of scotch tape.

3.20. Place the cartridge, clip holder with tight-band and 2 labels of 4 same ones in a sample container.

3.21. These two labels will be used by the field and extraction personnel. Make sure the tape is not stuck to the printed side of these two labels. They should be easy to remove and undamaged.

Note: Make sure all four labels (one on the cartridge and three on the vial) have the same identifying number.

3.22. Place the sample containers in a zip-lock bag. Write the date on the bag (this will be the batch number) and place the bag in a freezer.

3.23. Record the batch number and the respective identifying number of the cartridges.

Note: Each coated cartridge should contain about 0.5 mg of DNSH and should be good for at least one month when stored in a freezer.

Part 2

Standard Operating Procedures for the Personal Sampling with PAKS

(Draft 10/29/99)

1 Identify the individual that will wear the cartridge.
2 Remove the passive sampler from the container and unwrap the sampler.
3 Record the sample code, start time, start date, and participant identification number on the information sheet .
4 Remove the big white cap from the thick end of the cartridge (be sure to leave the thin end sealed) and attach the sampler to the collar of the shirt or direct on the shirt where close to the breathing zone.
5 Tell the participants that the sampling setup should be worn whenever they are awake, be placed near the bed when sleeping (as close as possible to his/her head), and should be in the room while showering but should not get wet.
6 Tell the participants that the open end of the cartridge should never be covered (i.e. with cloth, a jacket, or clothing), and that the open end should never be face down against any surface.
7 Inform the participants that if they forget to wear the sampling setup for any period of time, they should write down the approximate amount of time that the setup is not worn. Also inform the participants to note any problems or occurrences involving the sampling apparatus.
8 Tell the participants when you, or somebody else, will return to recover the sampling apparatus (at least 24 hours of sampling required).
9 At the end of the sampling period, remove the cartridge from the clip and plug the open end with the big white cap provided. Wrap the cartridge in aluminum foil. Place the cartridge and the clip in the original container.
10 Record the ending time and date, and participant identification number on the sample collection sheet.
11 Place the container in the cooler (at temperature of 4°C or cooler) and send the samples back to the lab via overnight carrier.

Part 3

Standard Operating Procedures for the Extraction of Aldehyde and Ketone-DNSH Derivatives

(Draft 10/29/99)

1. Scope and Application

Personal samples have been collected using Passive aldehydes and Ketones Sampler (PAKS). carbonyls react with DNSH present within the cartridges to form hydrazones. The cartridges will be extracted with acetonitrile (ACN) and the extract will then be analyzed by HPLC to determine the carbonyl content. Analysis of these results can be interpreted to yield information pertaining to carbonyl exposure for the individual and the household from which the samples are obtained, such as where the majority of the individual carbonyl exposure occurred. These results can then be further extrapolated to determine the exposure of a population to carbonyls, especially when correlated to the probable source emissions of the carbonyls.

2. Summary of Method

The collected cartridges are extracted using ACN, and the sample extracts are then analyzed by a HPLC.

3. Safety

Each chemical compound should be treated as a potential health hazard. The user should obtain relevant health and safety information from manufacturers. Handle all these chemicals in laminar-flow hoods, wear butyl or nitrile gloves when handling high concentrations of carbonyls during preparation of primary standards. Avoid contact with skin, eyes, and clothing. In case of contact, immediately flush skin or eyes with plenty of water for at least 15 minutes. If eyes are affected, consult a physician.

4. Chemicals and Apparatus Required

4.1 Acetonitrile (ACN): HPLC grade: extraction solvent.

4.2 Disposable pipettes: 5-mL volumetric and small Pasteur pipette, with bulbs and pipettes.

4.3 HPLC auto-sampler vials: 4-mL glass vials, for HPLC analysis.

4.4 Syringe and Cartridge Adapter: 10-mL syringes and adapter for squeezing out any left over ACN within the cartridge with a plunger.

4.5 Labels pre-prepared: label the 4-mL glass vials.

4.6 Two-tiered syringe/vial rack: two racks that will fit on top of each other. The bottom rack must fit the vials, the top must fit the syringe-type cartridges, and the cartridges must be able to line up with the vials.

5. Extraction of DNSH-Coated LC-C_{18} Cartridges

5.1 Prepare 4-mL vials for sample extraction.

5.1.1 Get a number of vials that you will use for cartridge extraction. Place the TEF liner in the cap and label the vials.

5.1.2 Pipet 2 mL of ACN into each extraction vial.

5.1.3 Rinse (shake) the vials with caps on and dump the ACN to the waste.

5.2 Extraction of carbonyl-DNSH samples

5.2.1 Get PAKS from the freezer.

5.2.2 Use pre-prepared labels to label the vials according to the sample IDs and place the vials in the bottom of the two-tiered syringe/vial rack apparatus.

5.2.4 Remove the two caps from two side of cartridge.

5.2.5 Match each cartridge with the label on the vial and place the cartridge into the rack above the vial.

5.2.6 Pipette 2 mL of ACN into each cartridge and allow ACN to drain through the cartridges by gravity.

5.2.7 After all the ACN has passed through, displace any liquid left in the cartridge using the syringe and cartridge adapter.

5.2.8 Cap the cartridges, put the cartridges back into their original bag, and replace the bag to the refrigerator.

5.2.9 Add enough ACN to each extraction vial to fill to the 2-mL mark.

5.2.10 The syringe and cartridge adapter can be reused for all the extraction performed in one day.

5.2.11 Analyze the samples as soon as possible or store the sample extract in the freezer until analysis.

Part 4

Standard Operating Procedures for the Analysis of Carbonyl-DNSH Derivatives using HPLC System

(Draft 10/29/99)

1. Scope and Applicability

The method described is appropriate for the analysis of carbonyl-DNSH (5-(diethyl-amino) naphthalene-1-sulfohydrazide) derivatives using high pressure liquid chromatograph with fluorescence detection, but precision and quality control data presented only for the most commonly found carbonyl compounds including formaldehyde, acetaldehyde, acetone, acrolein, propionaldehyde, crotonaldehyde, benzaldehyde, and hexaldehyde.

2. Summary of Method

The carbonyl-DNSH derivatives dissolved in acetonitrile (ACN) are injected on an HPLC, separated by a C_{18} reverse phase column, and identified and quantified by a fluorescence detector.

3. Interferences

3.1 Method interferences may be caused by contamination from solvents, reagents, glassware, and other sample processing hardware.

3.2 Control of interferences

3.2.1 Wash the glassware with detergent, rinse with tap water and deionized water, and oven dry at 180 °C for at least one hour. Solvent rinses with acetonitrile may be substituted for the oven heating.

3.2.2 Use high purity reagents and HPLC grade solvents.

3.3 DNSH, especially in moist laboratory environments, can react with carbonyls when directly exposed to carbonyls in air. Lower molecular weight carbonyls, such as formaldehyde, acetaldehyde, and acetone, are commonly found in the laboratory and outside air and can cause positive bias by reacting with DNSH. For these reasons, exercise care to reduce the exposure of samples, standard solutions, and DNSH reagent to air, and store DNSH in an explosion proof cabinet.

4. Safety

Formaldehyde has been tentatively classified as a suspected human carcinogen, and the toxicity of other reagents used in this method have not been defined precisely; however, each chemical compound should be treated as a potential health hazard. The user should obtain relevant health and safety information from manufacturers. Handle all these chemicals in laminar-flow hoods, wear butyl gloves when handling high concentrations of carbonyls during preparation of primary standards, and wear nitrile gloves when ACN and carbonyl-DNSH derivatives. If you spill any of the substance on the gloves, remove them immediately and wash your hands; continue the work with new gloves. Avoid contact with skin, eyes, and clothing. In case of contact, immediately flush skin or eyes with plenty of water for at least 15 minutes. If eyes are affected, consult a physician.

5. Apparatus for Carbonyl-DNSH Analysis

- **5.1 HPLC System** A HPLC system equipped with fluorescence detector.
- **5.2 HPLC Column.** Nova-Pak C_{18} column (Waters, 3.9 x 150 mm), or an equivalent column.
- **5.3 Helium.** UHP/Zero-Grade. For solvent degassing.
- **5.4 Data Processor.** To record, integrate, and store chromatograms.
- **5.5 Syringes.** 250-µL or larger size for sample injection. 200, 500, and 1000-µL size, calibrated, for preparation of calibration standards.
- **5.6 Volumetric Flasks.** 10-mL volumetric flask for stock solutions and calibration standards.

6. Reagents: Unless otherwise indicated, all reagents must conform to the specifications established by the Committee on Analytical Reagents of the American Chemical Society. Where such specifications are not available, use the best available grade.

- 6.1 Water. Deionized water filtered with 0.22-µm filter. Mobile phase for HPLC analysis.
- 6.2 Acetonitrile (ACN). HPLC grade. Mobile phase for HPLC analysis.
- 6.3 Carbonyl Standard Materials for Target Compounds. Aldrich, Inc., or equivalent. Obtain purity assay of each purchased standard before use.
- 6.4 Carbonyl Mixture Solution. Prepare 1mg/mL carbonyls stock solution in ACN in a 100-mL volumetric flask and put the flask in the freezer.
- 6.5 Carbonyl-DNSH Stock Solution. Add DNSH coating solution (1000 mg/L DNSH with 1 mL/L acetic acid) to a 10-mL volumetric flask. Then add 50 µL carbonyl mixture solution to the flask. Add DNSH coating solution to the flask up to 10 mL. Shake the mixture for 30 seconds and allow the mixture to react for 60 minutes at 60°C in an oven.
- 6.6 Calibration Standards. Prepare at least five different calibration standards that can bracket the expected average sample concentration using the stock solution.

7. HPLC Analysis

7.1. Analytical Conditions

Column:	Nova-Pak C_{18} column (Waters), 3.9 mm x 150 mm
Mobile Phase Gradient:	Solution A = 32% ACN and 68% water containing 1.6g/L of KH_2PO_4; Solution B = 70% ACN and 30% water containing 1.6g/L of KH_2PO_4; linear gradient from 100% A to 100% B in 20 minutes, then from 100% B back to 100% A in 10 minutes, and then held at 100% A for 10 minutes.
Flow Rate:	1.0 mL/min
Detector:	The fluorescence detector is set at an excitation wavelength of 240 nm and an emission wavelength of 470 nm.
Sample Injection Volume:	20-µL

The retention times for the target compounds tested are listed in Table 1.

7.2 Initial Calibration. Load calibration standards on the HPLC auto-sampler carrousel from low to high concentrations. Inject 20-µL of each of the standards prepared in Section 6.6 into the HPLC and record the response. Repeat the injections for each standard until the response from the two successive injections agree within 5%. Use the mean response for each calibration standard, and prepare a linear least square equation relating the response to the mass of the analyte in the sample. Perform the calibration before analyzing each set of samples.

7.3 Daily Calibration Check. At the beginning of each day, analyze the mid-level calibration standard as described in Section 7.2. The response factor from the daily analysis must agree with the response factor from the initial calibration within 10%. If it does not, the initial calibration must be repeated.

Table 1. Retention Times for the Carbonyl-DNSH *

Compound	Retention Time (min)
Formaldehyde	10.7
Acetaldehyde	12.1
Acetone	14.0
Acrolein	16.6
Propionaldehyde	17.2
Crotonaldehyde	18.8
Benzaldehyde	23.5
Hexaldehyde	25.9

*The retention times may vary when the conditions of the analytic system have been changed. Always run the authentic standards with the samples for the identification of the actual retention times of the target compounds.

7.4 Sample Analysis.

7.4.1 Label the auto-sampler vials according to the sample ID on the vials with sample extract.

7.4.2 Pipette approximately 1.0 mL of sample from each sample vial into the auto-sampler vial. Make sure that the sample ID match on both sets of vials.

7.4.3 Replace the sample vials back into the refrigerator.

7.4.4 Prepare some ACN blank samples.

7.4.5 When load auto-sampler vials on the HPLC auto-sampler carrousel, place an ACN blank sample at first, then samples. Also place an ACN blank sample after each ten samples.

7.4.6 Inject 20 µL of the sample into the HPLC. If the sample response is above that of the highest calibration standard, either dilute the sample until it is in the measurement range of the calibration line or prepare additional calibration standards. If the sample response is below that of the lowest calibration standard, prepare additional calibration standards. If additional calibration standards are prepared, there will be at least two standards, which bracket the response of the sample. These standards should produce approximately 80% and 120% of the response of the sample.

8. Calculation

8.1 Precision. Calculate individual response factor (RF) for each compound in the calibration standard using Equation 1:

$$RF = A_s / C_s \qquad \text{(Equation 1)}$$

where:

RF= response factor

A_s = area counts of the standard, and

C_s = concentration of compound in the standard, µg/mL.

For each compound, determine the average RF and standard deviation of the RF values for all the standards. If the percent relative standard deviation (%RSD) is greater than 10%, take corrective action to improve method precision. When RSD% is less than 10%, then the mean RF is acceptable for use in calculating the concentration of the samples

8.2 Construction of Calibration Curves.

Construct the calibration curve for each target compound using the area counts against the concentrations, and the concentration in the sample are calculated using Equation 2:

$C_{ex} = (A_{ex} - A_F - A_B - b)/m$ (Equation 2)

where:

C_{ex} = concentration of compound in the sample extract, µg/mL
A_{ex} = area counts of the sample,
A_F = area counts of the field blank sample,
A_B = area counts of solvent blank (coming from the carrier over)
m = slope of the calibration curve, and
b = intercept of the calibration curve.

8.3 Calculate the Concentration in the Sample Air.

The concentration (C_{air}, in µg/m³) of an airborne carbonyl was calculated from the following equation,

$$C_{air} = \frac{C_{ex} \cdot V_{ex}}{R \cdot T} \times 10^6 \qquad \text{(Equation 3)}$$

where: V_{ex} = extraction volume, in mL
R = the sampling rate, in mL/min
T = sampling time or exposure duration, in min.

PAKS sampling rates (R) for the 8 tested carbonyl compounds to calculate airborne concentrations of the 8 tested carbonyl compounds using Equation (3) are shown in Table 2.

Table 2. PAKS sampling rates (R) for the carbonyl compounds *

Compound	**R (mL/min)**
Formaldehyde	7.21
Acetaldehyde	5.46
Acetone	4.61
Acrolein	4.77
Propionaldehyde	4.55
Crotonaldehyde	4.13
Benzaldehyde	3.50
Hexaldehyde	3.28

* The test temperature ranged from 20 to 40°C; relative humidity ranged from 10 to 90%, face velocity ranged from 0.01~0.10m/s, exposure duration ranged from 24~48hr, concentrations of the test carbonyls ranged from 1~200ppb

Part 5

Standard Operating Procedures for the Quality Control and Quality Assurance for the Analyses of Aldehydes and Ketones

(Draft 10/29/99)

1. Standard Operating Procedures (SOPs)

The SOPs should provide specific stepwise instructions, should be readily available, and understood.

2. HPLC Analytic System Performance

Variation of response for replicate HPLC injections should be 10% or less, day to day, for analyte calibration standards at 0.05 μg/mL or greater level.

3. Monitoring for Interferences

3.1 Reagent Blank. A reagent blank is a sample extract of a fresh DNSH-coated LC-C18 cartridge. Before processing any samples, the analyst must demonstrate, through analysis of the reagent blank, that there are no interference from the analytical system, glassware, and reagents that would bias the sample analysis results.

3.2 Field Blanks. Field blanks will be prepared by taking the DNSH-coated LC-C18 cartridges to a home and returning the cartridges back to the lab at the end of the 48-hour sampling period. Field blanks will be analyzed with each group of samples.

4. Method Precision and Accuracy

4.1 Duplicate. Ten percent of carbonyl samples will be collected in duplicate. Not more than one duplicate will be taken from each home. Precision for duplicate samples must be 20% or better.

4.2 Matrix Spike. Five percent of control samples spiking with the target compounds will be analyzed. Spiked sample recoveries of 80±10% should be achieved.

LBNL/CEC Field Study-- Laboratory Procedures
Extraction and analysis of Waters (part number WAT047205) DNPH-coated cartridges for formaldehyde and acetaldehyde (and Acetone)

Based on "5.0 Extraction of DNPH-coated (Supleco) C18 Sample Cartridges," RIOPA Study, written by J. Zhang et. al with final editing by D. Shendell and N. Yamamoto

v. 04/02/01 by D.Shendell, revised as final version 03/22/02 by D. Shendell

1.1 Prepare 2-ml test tube/vials for sample extraction

1.1.1 Get a number of 2-ml glass test tubes needed for Waters cartridge extraction. Label test tubes 1-n to match number of samples to analyze; 0 is internal standard.

1.1.2 Pipet 2-ml of acetonitrile (ACN) into each test tube, cap with glass stopper, lightly shake ACN. The bottom of the meniscus should be at white mark.

1.1.3 Rinse the test tube and dump the ACN into the (non-halogenated) waste. Place the test tube back in the rack.

1.2 Extraction of the carbonyl-DNPH samples from the Waters cartridges

1.2.1 Get sample cartridges from the freezer, each of which are in foil-lined white envelopes sealed with white tape.

1.2.2 Label with the lab pencil each test tube and vial with a number, the vial number in the day's sequence for HPLC analysis staring with n=1. A data sheet is created in MS Excel to match this number with the sample ID number and hence the date and location of the sampler. Numbers are entered on the data sheet in the appropriate column next to the appropriate sample ID number. Replace the test tube in the rack, and vials placed in order adjacent to an empty HPLC cartridge.

1.2.3 Get 2-ml glass syringe, one for all Waters cartridge/samples. The 2ml syringe, if not already, should be rinsed with ACN by filling and emptying them using the plunger and gravity.

1.2.4 Match the first test tube with the appropriate Waters cartridge sample, and remove from envelope. Attach piece used to connect syringe to cartridge during extraction; this piece has a silver colored metal ring on it.

1.2.5 Fill the syringe with 2-ml of ACN.

1.2.6 2-ml of ACN from the syringe drains through the cartridges by gravity. Give a little push on the plunger of the syringe as necessary. This process should be relatively slow, i.e, do not force ACN through the cartridge, avoiding spills of sample extract as well.

1.2.7 After all ACN has passed through, displace any ACN left in the cartridge using the plunger by raising and suppressing the plunger. Repeat this 2-4 times, and remove syringe from cartridge while raising plunger each time.

1.2.8 Remove the syringe from the extraction set-up, remove the Waters cartridge from the test tube and place the used cartridge in the appropriate beaker to air dry and later be discarded.

1.2.9 Add enough ACN to each extraction to fill to the 2-ml mark. Cap test tube, mix by gravity by turning it upside down two times.

1.2.10 The same syringe can be reused for all extractions, i.e., sample sequences, performed in one day.

1.2.11 Clean up equipment, seal test tubes and beakers with caps and Parafilm to preserve extract until HPLC/UV analysis initiated and completed, and properly discard of non-halogenated solvent waste. Discard used cartridges, wrapped in aluminum foil, in the garbage.

REPEAT STEPS 1.2.3 to 1.2.9 FOR EACH WATERS CARTRIDGE SAMPLE

1.3. Analysis of the carbonyl-DNPH sample extracts by HPLC with UV detection

1.3.1 Analyze the sample extracts as soon as possible or store the sample extract in the freezer until analysis

1.3.2 Preparing the sample extracts for placement in the Hewlett Packard HPLC 1090/ChemStation

1.3.2.1 Pour out about 1ml of sample extract into vials used for the HPLC. The vials are numbered with the same number appearing on the glass test tube/vials (see 1.2.2).

1.3.2.2 Cap the vial with the blue cap containing red septa with Teflon-lined backside. Tightness should be a little beyond "finger tight." Make sure red septa not pinched.

1.3.2.3 Confirm the vials are placed in the black cartridge in the right order, i.e., samples 1-10 should be in vial holder slots 0-9, respectively.

1.3.2.4 Place the black cartridge in the correct position in the HPLC after opening the top door/hood of the instrument. The order, if running multiple "0-9" sequences at once during a day, is 1-10, 11-20, etc. up to n=50 or 60. N=1-50 or 60 corresponds to the row number in the ChemStation "sample sequence file."

1.3.3 <u>HPLC with UV detection analysis: information entry, and method, sequence, and data files</u>

HPLC autoinjection, HP 1090-1 software, method file "ALD 8B" by AT Hodgson

1.3.1.1 Make new and/or filter mobile phase solvent "A" (65% H_2O, 35% ACN) and "B" (100% ACN).

1.3.1.2 Install appropriate column (Waters C_{18} 50 mm micropore column, part number WAT056975), connect only to sample injection system at first. Run pump 5-10 minutes to flush column. Connect column on other side to detector, then run pump and detector ~30 minutes; observe flat line—no spikes, no bubbles in column or system-- on computer monitor graph before proceeding with sequence.

1.3.1.3 Check to see compressed air pressure ~ 80 psi, and compressed He (g) ~ 2psi; for mobile phases and autoinjector.

1.3.1.4 Prepare and then save sequence table and data file, named using nomenclature YMMDDA.s and YMMDDA.d The bold type letter (A) can be changed to B, C, etc. for future table on same day.

1.3.1.5 Prepare one dilution of internal standard stock solution containing target compounds and acetone in known quantity; glass beaker, sealed, was removed from freezer > 30 minutes prior to use.

"vpets 2-7," made by Brett C. Singer (LBNL, IED/EETD) 9/2/99
1/40 dilution = 25 microliters to 1 milliliter with ACN
"vpets 2-7) prepared with, in nanograms per microliter,
38.37 H_2CO, 39.68 CH_3CHO, and 63.63 acetone.

Thus, with 1/40 dilution and 10 microliters injected per sample run into the HPLC/UV, the analysis results are expected to be, within 5-10%, 9.6 nanograms H_2CO and 9.9 nanograms CH_3CHO. The graph must show no contaminants or bubbles interfering with retention times (~ 7.6 +/- 0.2 minutes and ~ 9.6 +/- 0.2 minutes, respectively) or peak magnitudes. If there are, then second injection.

1.3.1.6 Extract samples while 1/40 dilution of internal standard solution in HPLC/UV

1.3.1.7 For each set of sample injections, inject one sample twice for analytic precision analysis. If sample size exceeds 10-12, inject one sample twice for every 10.

(NOTE: we chose for 9/01-3/01 to inject 1/40 dilution of internal standard solution twice, and disregarded first injection's data due to delayed retention times, likely due to infrequent use of column or HPLC/UV maintenance issues.)

1.3.1.8 Review data analysis for each sample completed. Confirm autointegration of peaks was correct, i.e., correct baselines drawn and no interference; redraw baselines as necessary. Confirm proper retention times for each target compound. Confirm data make sense, e.g., for CEC RC study RC A < or ~ RC B and both RCs are < outdoors. Raw data presented in nanograms per microliter.

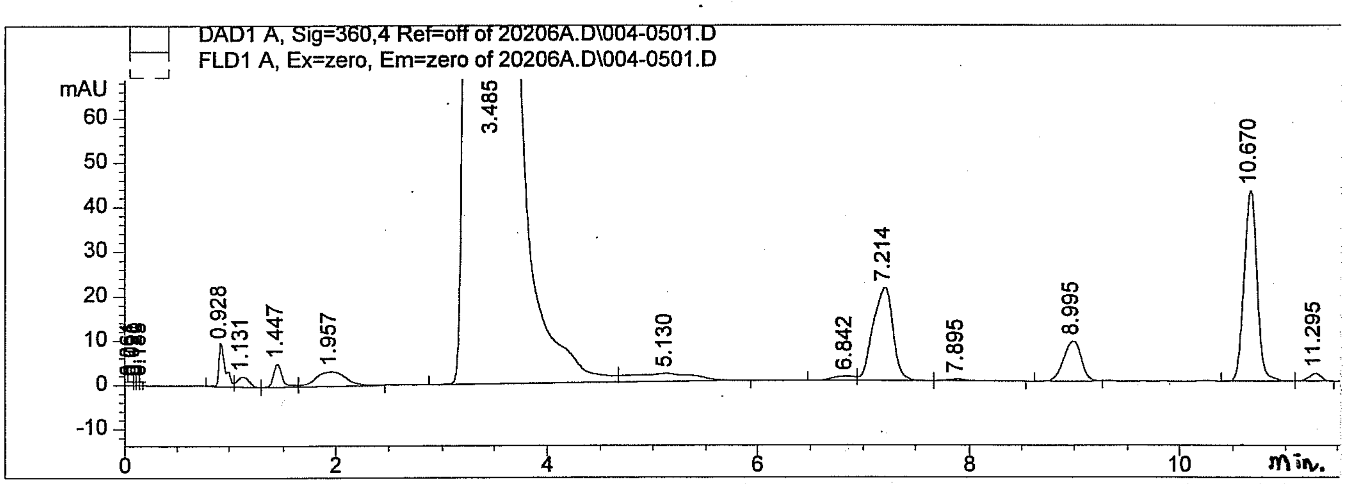
1.3.1.9 Print analysis reports, save data files to floppy disk in folder with data file's name.

1.3.1.10 Raw data and field-based calculations entered into appropriate MS Excel files.

```
Injection Date  : 2/6/02 12:00:04 PM              Seq. Line :   5
Sample Name     : M-29-7-013102                        Vial :   4
Acq. Operator   : DGS                                   Inj :   1
                                                 Inj Volume : 10 µl

Acq. Method     : C:\HPCHEM\1\METHODS\ALD8B.M
```

RT [min]	Sig	Type	Area	Amt/Area	Amount [ng/ul]	Grp	Name
7.214	1	VV	285.76407	1.63943e-3	4.68489e-1		Formaldehyde
8.995	1	PV	105.68547	2.22264e-3	2.34900e-1		Acetaldehyde
10.670	1	PV	365.92383	3.05297e-3	1.11715		Acetone



APPENDIX A.2

Study Design and Field Studies

A.2.7. Study Design: matrices showing the <u>expected</u> sample sizes, i.e., the estimated number of quantitative samples and qualitative survey responses and observations, Los Angeles County and Northern California studies

Appendix 2.7:
Study design: matrices showing the expected sample sizes, i.e., the estimated number of quantitative samples and qualitative survey responses and observations, for the Los Angeles County and Northern California studies

SOUTHERN CALIFORNIA (LOS ANGELES COUNTY)
(2 school districts, 1 (BPUSD) or 2 (LAUSD) seasons, 3(BPUSD) or 4 (LAUSD) schools with 2 and 3 as K-3rd, 2 portable and 1 main building classroom per school

	PORTABLES (note: # in parens = weekly integrated avg, school day avg)				**MAIN BLDG** (note: # in parens = weekly integrated avg, school day avg)			
	Total BPUSD	K-3rd BPUSD	Total LAUSD	K-3rd LAUSD	Total BPUSD	K-3rd BPUSD	Total LAUSD	K-3rd LAUSD
Acetaldehyde	(10, 5)	(8, 4)	(14, 18)	(12, 18)	(6, 3)	(4, 2)	(7, 3)	(6, 3)
Formaldehyde	(10, 5)	(8, 4)	(14, 18)	(12, 18)	(6, 3)	(4, 2)	(7, 3)	(6, 3)
VOCs (each of n=19 analyzed)	(10, 5)	(8, 4)	(14, 6)	(12, 6)	(6, 3)	(4, 2)	(7, 3)	(6, 3)
Air Exchange Rate	(10, 5)	(8, 4)	(14, 6)	(12, 6)	(6, 3)	(4, 2)	(7, 3)	(6, 3)

Appendix 2.7 (continued):
Study design: matrices showing the expected sample sizes, i.e., the estimated number of quantitative samples and qualitative survey responses and observations, for the Los Angeles County and Northern California studies

NORTHERN CALIFORNIA (LBNL/CEC FIELD STUDY)
2 school districts, 2 seasons, 4 weeks of each of 2 HVAC modes per season, 1 school per school district, 2 portables per school (1 with standard materials, 1 with advanced materials)

NEW PROTOTYPE" RELOCATABLE" PORTABLES

Advanced HVAC/ Std.Materials	Std. HVAC/ Std.Materials	Advanced HVAC/ Advanced Materials	Std. HVAC/ Advanced Materials	
(16, 16, 16) *(note: # in parens =*	(16, 16, 16) *weekly integrated avg,*	(16, 16, 16) *school day avg every day M-F,*	(16, 16, 16) *overnight avg every day M-F)*	**Acetaldehyde**
(16, 16, 16) *(note: # in parens =*	(16, 16, 16) *weekly integrated avg,*	(16, 16, 16) *school day avg every day M-F,*	(16, 16, 16) *overnight avg every day M-F)*	**Formaldehyde**
N/A FOR MY DISSERTATION		N/A FOR MY DISSERTATION		**VOCs (each of n=19 analyzed)**
?	?	?	?	**Air Exchange Rate**

(AT PRESENT, LBNL DOING NO QUANTITATIVE DIRECT MEASURE OF AER SINCE BOTH HVAC SYSTEMS WILL PROVIDE CONTINUOUS VENTILATION-- ADVANCED TECH. WITH 100% OUTDOOR AIR, BASELINE TECH. WITH 30% or more OUTSIDE AIR & up to 70% RECIRCULATED, FILTERED AIR. CO2 and occupany information for estimation not included in this dissertation)

Appendix 2.7 (continued):
Study design: matrices showing the expected sample sizes, i.e., the estimated number of quantitative samples and qualitative survey responses and observations, for the Los Angeles County and Northern California studies

NO STRATIFICATION BY SEASON APPEARS BELOW
COULD NOT STRATIFY BY SCHOOL DISTRICT IN LA COUNTY, THEN LOOK PORTABLES VS. M.B.

SOUTHERN CALIFORNIA (LOS ANGELES COUNTY)
(2 school districts, 1 (BPUSD) or 2 (LAUSD) seasons, 3(BPUSD) or 4 (LAUSD) schools with 2 and 3 as K-3rd, 2 portable and 1 main building classroom per school

	PORTABLES				MAIN BLDG			
	Total BPUSD (*note: # in parens =*	K-3rd BPUSD *weekly integrated avg,*	Total LAUSD *school day avg every day M-F,*	K-3rd LAUSD *overnight avg every day M-F)*	Total BPUSD (*note: # in parens =*	K-3rd BPUSD *weekly integrated avg,*	Total LAUSD *school day avg every day M-F,*	K-3rd LAUSD *overnight avg every day M-F)*
Temperature (in F and C)	(5, 5, 5)	(4, 4, 4)	(14, 14, 14)	(12, 12, 12)	(3, 3, 3)	(2, 2, 2)	(7, 7, 7)	(6, 6, 6)
%Relative Humidity	(5, 5, 5)	(4, 4, 4)	(14, 14, 14)	(12, 12, 12)	(3, 3, 3)	(2, 2, 2)	(7, 7, 7)	(6, 6, 6)
Carbon Monoxide* *(Heating Season, LAUSD ONLY)*	(1 or 2, 1 or 2, 1 or 2)	(1 or 2, 1 or 2, 1 or 2)	(1 or 2, 1 or 2, 1 or 2)	(1 or 2, 1 or 2, 1 or 2)	(1 or 2, 1 or 2, 1 or 2)	(1 or 2, 1 or 2, 1 or 2)	(1 or 0, 1 or 0, 1 or 0)	(1 or 0, 1 or 0, 1 or 0)

*ISSUE TO RESOLVE: Carbon Monoxide: 1 newer portable and one main building classroom, as currently in prospectus, OR two newer portables, since they have the compressor-based heat pumps in their HVAC?
(In school district B (BPUSD), since cooling season choose elementary school near freeway.)

Appendix 2.7 (continued):
Study design: matrices showing the expected sample sizes, i.e., the estimated number of quantitative samples and qualitative survey responses and observations, for the Los Angeles County and Northern California studies

NORTHERN CALIFORNIA (LBNL/CEC FIELD STUDY)
2 school districts, 2 seasons, 4 weeks of each of 2 HVAC modes per season, 1 school per school district, 2 portables per school (1 with standard materials, 1 with advanced materials)

NEW PROTOTYPE" RELOCATABLE" PORTABLES

Advanced HVAC/ Std.Materials	Std. HVAC/ Std.Materials	Advanced HVAC/ Advanced Materials	Std. HVAC/ Advanced Materials	
(16, 16, 16)	(16, 16, 16)	(16, 16, 16)	(16, 16, 16)	**Temperature** (in F and C)
(16, 16, 16)	(16, 16, 16)	(16, 16, 16)	(16, 16, 16)	**%Relative Humidity**
?	PROBABLY NOT TO BE MEASURED		?	**Carbon Monoxide*** *(Heating Season, LAUSD ONLY)*
(note: # in parens =	*weekly integrated avg,*	*school day avg every day M-F,*	*overnight avg every day M-F)*	

Appendix 2.7 (continued):
Study design: matrices showing the expected sample sizes, i.e., the estimated number of quantitative samples and qualitative survey responses and observations, for the Los Angeles County and Northern California studies

NO STRATIFICATION BY SEASON APPEARS BELOW
COULD NOT STRATIFY BY SCHOOL DISTRICT IN LA COUNTY, THEN LOOK PORTABLES VS. M.B.

SOUTHERN CALIFORNIA (LOS ANGELES COUNTY)
(2 school districts, 1 (BPUSD) or 2 (LAUSD) seasons, 3(BPUSD) or 4 (LAUSD) schools with 2 and 3 as K-3rd, 2 portable and 1 main building classroom per school

	PORTABLES				MAIN BLDG			
	Total BPUSD	K-3rd BPUSD	Total LAUSD	K-3rd LAUSD	Total BPUSD	K-3rd BPUSD	Total LAUSD	K-3rd LAUSD
Technician Walk-Through Survey	5	4	8	6	3	2	4	3

Plan is for descriptive statistics, no correlations with pollutant concentrations; see notes below as well.
Number of student desks/tables (I.e., occupancy, max.) = #2G
Number of hours in typical school day for students AND teachers, I.e., classroom is occupied? = #8
Length of time in typical activities outside the portable during school day, I.e., occupany, hours (re: #8) on average? = #9A-9D

Was portable raised above ground level? = #3
Kind of surface, I.e., foundation, classroom was sited upon = #4
Is floor carpeted, tile, etc.? = #7d
FOR summary observations about potential biological contamination, with "smell?" observations?
Stationary soures within 50 yards or 0.5 km = #5A-5H
Approximate horizontal distance to nearest major thoroughfare (highway or primary arterial?), etc? = #6A-6E
Approximate horzontal distance to school parking lots, loading/unloading area for trucks, boarding area for school buses? = #7eD-7eF

Location and general type of vegetation inside and outside the classroom: Y/N for inside? Immediately outside? = #7f
RE: Potential sources of biogenic hydrocarbons, including alpha-pinene, beta-pinene, and d-limonene
Approximate volume, based on technician measures of W, L, ceiling H = #7a NEED FOR AER CALCULATION FORMULAS

Appendix 2.7 (continued):
Study design: matrices showing the expected sample sizes, i.e., the estimated number of quantitative samples and qualitative survey responses and observations, for the Los Angeles County and Northern California studies

SOUTHERN CALIFORNIA (LOS ANGELES COUNTY)

Operations and Maintenance Questionnaire FOR THREE SCHOOLS BPUSD AND FOUR SCHOOLS LAUSD = 7

Questions below for descriptive statistics, grouped by topic

Age of portable classroom, I.e., when sited at school? = # 3C
Age of main building, I.e., school? = # 3D
Date of last major renovation to school (related to available money for renovation and modernization)? = # 3E

Time of day HVAC system turned on and off (auto setting)? = # 4B-4C
Is the current filter changed? = # 5A
When was the filter last changed? = # 5B
Frequency of changing filters, and by whom? = # 5C
Size of school maintenance staff; full-time and part-time? = # 2B

Indoor temperature when heat turned on, and turned off? = # 7A, #8A
Month when school teachers begin using heat, and stop using heat? = # 7B, #8B
Indoor temperature when AC turned on, and turned off, if classroom has one? = # 9A, # 10A
Month when school teachers begin using AC, and stop using AC? = # 9B, #10B

The average (outdoor) air intake rate? = # 6

NOTE: no school custodians knew answer, found out from district officials later on.

Appears question, along with 3 below, may be indicators of need for better communication and training.

Occurrence, timing, and frequency of staff training? = # 12
Existence of standardized written protocol or manual…? = # 13A-B
Existence of maintenance log…? = # 13C and/or #13D

Appendix 2.7 (continued):

Study design: matrices showing the expected sample sizes, i.e., the estimated number of quantitative samples and qualitative survey responses and observations, for the Los Angeles County and Northern California studies

	SOUTHERN CALIFORNIA (LOS ANGELES COUNTY)							
	Total BPUSD	K-3rd BPUSD	Total LAUSD	K-3rd LAUSD	Total BPUSD	K-3rd BPUSD	Total LAUSD	K-3rd LAUSD
Classroom Spotcheck Checklist	25 or 30	20 or 24	60	54	15 or 18	10 or 12	30	27

Main door open or closed?

Doors to adjacent room(s) open or closed?

HVAC system, by sound, on or off?

Windows open or closed? NOTE: number of windows counted, so if open, % open known as well

For only descriptive statistics, factors affecting classroom ventilation; questions on natural and mechanical influences.

Recorded relatively strong chemical or musty odor

RE: SEE ABOVE, summary observation about potential biological contamination?

Thermostat reading, if available

RE: SEE ABOVE, plan to compare with actual measured data, see above.

Appendix 2.7 (continued):
Study design: matrices showing the expected sample sizes, i.e., the estimated number of quantitative samples and qualitative survey responses and observations, for the Los Angeles County and Northern California studies

NORTHERN CALIFORNIA (LBNL/CEC FIELD STUDY)			
2 school districts, 2 seasons, 4 weeks of each of 2 HVAC modes per season, 1 school per school district, 2 portables per school (1 with standard materials, 1 with advanced materials)			
NEW PROTOTYPE" RELOCATABLE" PORTABLES			
Advanced HVAC/ Std.Materials	Std. HVAC/ Std.Materials	Advanced HVAC/ Advanced Materials	Std. HVAC/ Advanced Materials
2?	2?	2?	2?

Technician Walk-Through Survey

Plan is for descriptive statistics, no correlations with pollutant concentrations; see notes below as well.
Number of student desks/tables (I.e., occupancy, max.) = #2G
Number of hours in typical school day for students AND teachers, I.e., classroom is occupied? = #8
Length of time in typical activities outside the portable during school day, I.e., occupany, hours (re: #8) on average? = #9A-9D

Was portable raised above ground level? = #3
Kind of surface, I.e., foundation, classroom was sited upon = #4
Is floor carpeted, tile, etc.? = #7d
FOR summary observations about potential biological contamination, with "smell?" observations?
Stationary soures within 50 yards or 0.5 km = #5A-5H
Approximate horizontal distance to nearest major thoroughfare (highway or primary arterial?), etc? = #6A-6E
Approximate horzontal distance to school parking lots, loading/unloading area for trucks, boarding area for school buses? = #7eD-7eF
Location and general type of vegetation inside and outside the classroom: Y/N for inside? Immediately outside? = #7f
RE: Potential sources of biogenic hydrocarbons, including alpha-pinene, beta-pinene, and d-limonene

Appendix 2.7 (continued):
Study design: matrices showing the expected sample sizes, i.e., the estimated number of quantitative samples and qualitative survey responses and observations, for the Los Angeles County and Northern California studies

NORTHERN CALIFORNIA (LBNL/CEC FIELD STUDY)

FOR TWO SCHOOLS LBNL/CEC PROJECT, 10 SCHOOLS LBNL/OEHHA PROJECT= 12	**Operations and Maintenance Questionnaire**

Questions below for descriptive statistics, grouped by topic

Age of portable classroom, I.e., when sited at school? = # 3C
Age of main building, I.e., school? = # 3D
Date of last major renovation to school (related to available money for renovation and modernization)? = # 3E

Time of day HVAC system turned on and off (auto setting)? = # 4B-4C
Is the current filter changed? = # 5A
When was the filter last changed? = # 5B
Frequency of changing filters, and by whom? = # 5C
Size of school maintenance staff; full-time and part-time? = # 2B

Indoor temperature when heat turned on, and turned off? = # 7A, #8A
Month when school teachers begin using heat, and stop using heat? = # 7B, #8B
Indoor temperature when AC turned on, and turned off, if classroom has one? = # 9A, # 10A
Month when school teachers begin using AC, and stop using AC? = # 9B, #10B

The average (outdoor) air intake rate? = # 6

NOTE: no school custodians knew answer, found out from district officials later on.
Appears question, along with 3 below, may be indicators of need for better communication and training.

Occurrence, timing, and frequency of staff training? = # 12
Existence of standardized written protocol or manual...? = # 13A-B
Existence of maintenance log...? = # 13C and/or #13D

Appendix 2.7 (continued):

Study design: matrices showing the expected sample sizes, i.e., the estimated number of quantitative samples and qualitative survey responses and observations, for the Los Angeles County and Northern California studies

NORTHERN CALIFORNIA (LBNL/CEC FIELD STUDY)

Advanced HVAC/ Std.Materials	Std. HVAC/ Std.Materials	Advanced HVAC/ Advanced Materials	Std. HVAC/ Advanced Materials	
32	32	32	32	**Classroom Spotcheck Checklist**

OBSERVATION EACH VISIT, ESTIMATE MINIMUM TWO VISITS PER WEEK PER PORTABLE

Main door open or closed?

Doors to adjacent room(s) open or closed?

HVAC system, by sound, on or off?

Windows open or closed? NOTE: number of windows counted, so if open, % open known as well

For only descriptive statistics, factors affecting classroom ventilation; questions on natural and mechanical influences.

Recorded relatively strong chemical or musty odor

RE: SEE ABOVE, summary observation about potential biological contamination?

Thermostat reading, if available

RE: SEE ABOVE, plan to compare with actual measured data, see above.

APPENDIX A.2

Study Design and Field Studies

A.2.8. Field Study Schedules

A.2.8.1 UCLA PCS

A.2.8.1a: Study design for weekly integrated and school day integrated or grab samples, second seasonal sampling (winter 2001), SD 2

A.2.8.1b: Study design for weekly integrated and school day samples, second cooling season sampling (late May or early June 2001), SD 1

A.2.8.2 LBNL RCS, SD 3, cooling season, fall 2001
A.2.8.3 LBNL RCS, SD 4, cooling season, fall 2001
A.2.8.4 LBNL RCS, SD 3, heating season, winter 2002
A.2.8.5 LBNL RCS, SD 4, heating season, winter 2002
A.2.8.6 LBNL RCS, approximate daily schedule, SD 3
A.2.8.7 LBNL RCS, approximate daily schedule, SD 4

A.2.8.1a Revised Study Design for Weekly Integrated and School Day Samples, Second Cooling Season Sampling (early June 2001), SD B, UCLA PCS

Classroom Type (n= number of schools*number of classrooms per school participating)	Monday	Tuesday	Wednesday	Thursday	Friday	Dates in Spring 2001 (NOTE:June dates match 2000 sampling dates exactly)
Portable Classrooms (n= 3 + 1 library = 4; with one JrHS = 5)					First Visit, all schools, all portables	**WEEK 1, 5/28-6/1/01**
	Start Weekly Integrated Sample, AM before school	(aldehydes, VOC, PFTs & CAT)			Stop/Cap Weekly Integrated Sample, PM after school	**WEEK 2, 6/4-8/01**
	Start of School Day Integrated Sample, Day 1, AM->PM	School Day Integrated Sample, Day 2, AM->PM	School Day Integrated Sample, Day 3, AM->PM	School Day Integrated Sample, Day 4, AM->PM	End of School Day Integrated Sample, Day 5, AM->PM	
		(aldehydes, VOC, PFTs & CAT)				
	One-day aldehyde sample AM->PM				One-day aldehyde sample AM->PM	
Main Building Classrooms (n = 2*1 = 2; with one JrHS = 3)					First Visit, all schools, all portables	**WEEK 1, 5/28-6/1/01**
	Start Weekly Integrated Sample, AM before school	(aldehydes, VOC, PFTs & CAT)			Stop/Cap Weekly Integrated Sample, PM after school	**WEEK 2, 6/4-8/01**
	Start of School Day Integrated Sample, Day 1, AM->PM	School Day Integrated Sample, Day 2, AM->PM	School Day Integrated Sample, Day 3, AM->PM	School Day Integrated Sample, Day 4, AM->PM	End of School Day Integrated Sample, Day 5, AM->PM	
		(aldehydes, VOC, PFTs & CAT)				

NOTE: In week 2, AM visits are "second visits," while PM visits are "third visits."

A.2.8.1b Revised Study Design for Weekly Integrated and School Day Integrated or Grab Samples, Second Seasonal Sampling (Winter 2001), SD A, UCLA PCS

Classroom Type (n= number of schools*number of classrooms per school participating)	Monday	Tuesday	Wednesday	Thursday	Friday	Dates in February 2001
Portable Classrooms (n= 3*2 = 6)					First Visit, all schools, all portables	**WEEK 1, 2/19-23/01**
	Start Weekly Integrated Sample, AM before school	(aldehydes, VOC, PFTs & CAT)			Stop/Cap Weekly Integrated Sample, PM after school	**WEEK 2, 2/26-3/2/01**
	Start of School Day Integrated Sample, Day 1, AM->PM	School Day Integrated Sample, Day 2, AM->PM	School Day Integrated Sample, Day 3, AM->PM	School Day Integrated Sample, Day 4, AM->PM	End of School Day Integrated Sample, Day 5, AM->PM	
		(aldehydes, VOC, PFTs & CAT)				
	One-day aldehyde sample AM->PM				One-day aldehyde sample AM->PM	
Main Building Classrooms (n = 3*1 = 3)					First Visit, all schools, all portables	**WEEK 1, 2/19-23/01**
	Start Weekly Integrated Sample, AM before school	(aldehydes, VOC, PFTs & CAT)			Stop/Cap Weekly Integrated Sample, PM after school	**WEEK 2, 2/26-3/2/01**
	Start of School Day Integrated Sample, Day 1, AM->PM	School Day Integrated Sample, Day 2, AM->PM	School Day Integrated Sample, Day 3, AM->PM	School Day Integrated Sample, Day 4, AM->PM	End of School Day Integrated Sample, Day 5, AM->PM	
		(aldehydes, VOC, PFTs & CAT)				

NOTE: In week 2, AM visits are "second visits," while PM visits are "third visits."

LBNL/CEC Field Study: Estimated Time Schedule of Key Activities

FINAL VERSION

PART I = CUSD-Stevens Creek Elementary, 8/27/01 through 11/2/01, "cooling season"

El. 6 Project Year	Week of	LBNL Holidays	Staff Taking Holiday between M-F?	Known Meetings/ Conference	School Holidays (CUSD= Cupertino; MCS)	Tasks during LBNL visits to the schools (approximately 6:30/7 AM to 4:30 PM)
2	8/27-31/01, first week	NO	Dennis, Doug	NO	only teachers present week of 8/20 (CUSD)	**Meeting between CUSD and LBNL staff at Stevens Creek Elementary school 8/20/01 2-3:15 PM, and, if necessary, another for thermostat training and further Q&A** CUSD: initial CO2 decay, VOC and aldehyde sampling 8/20 PM; systems check and IDEC "seal off" Thursday 8/30 PM; Bard mode for "air out"
2	9/3-7/01	9/3 (M, Labor Day)	NO	NO	9/3 (M, Labor Day, MCS) 9/3 (M, Labor Day, CUSD)	CUSD: sampling on opposite day from other school district = Thursday, Bard mode
2	9/10-14/01	NO	NO	9/10-11 (M-Tu, DGS in D.C.)	NO	CUSD: sampling on opposite day from other school district = Wed., IDEC mode
2	9/17-21/01	NO	NO	NO	NO	CUSD: sampling on opposite day from other school district = Tuesday, Bard mode
2	9/24-28/01	NO	NO	NO	NO	CUSD: sampling on opposite day from other school district = Thursday, IDEC mode
2	10/1-5/01	NO	NO	NO	NO	CUSD: sampling on opposite day from other school district = Thursday, Bard mode
2	10/8-12/01	NO	NO	NO	NO	CUSD: sampling on opposite day from other school district = Thursday, IDEC mode
2	10/15-19/01	NO	NO	NO	NO	CUSD: sampling on opposite day from other school district = Tuesday, Bard mode
2	10/22-26/01	NO	NO	NO	NO	CUSD: sampling on opposite day from other school district = Tuesday, IDEC mode
2	10/29-11/2/01, optional 10th week	NO	NO	*11/3-8/01 ISEA in Charleston, SC (DGS, MGA, ...)*	NO, *but BOTH have 3-day weekend 11/10-12*	CO2 decay and short-term sampling (like late 8/01), IDEC
						ABOVE PLAN EQUALS 9 WEEKS WITH TEACHERS & STUDENTS (CUSD); 4-5 IDEC, 4-5 Bard.

First of two environmental education classes, on energy and the environment, Thursday 11/15/01 14:00-15:00 (30 min per class), with data download and equipment maintena

NOTE: "Sampling" includes thermal comfort cart monitoring. goal = in each operating mode, for each school/SD, 4 weeks Tu /W, 4 weeks Th

LBNL/CEC Field Study: Estimated Time Schedule of Key Activities

FINAL VERSION

PART II = MCS-Rose Avenue Elementary, 8/27/01 through 11/2/01, "cooling season"

El. 6 Project Year	Week of	LBNL Holidays	Staff Taking Holiday between M-F?	Known Meetings/ Conference	School Holidays (CUSD; MCS= Modesto)	Tasks during LBNL visits to the schools (approximately 6:30/7 AM to 4:30 PM)
2	8/27-31/01, first week	NO	Dennis, Doug	NO	only teachers present (MCS)	**Meeting between CUSD and LBNL staff at Rose Avenue Elementary school 8/27/01, 8:30-9:30 AM (+/- 15 minutes), and, if necessary, another for thermostat training and further Q&A at end of week.** MCS: initial CO2 decay, VOC and aldehyde sampling as well as IDEC "seal off" Wednesday 8/29; Bard on for "air out"
2	9/3-7/01	9/3 (M, Labor Day)	NO	NO	9/3 (M, Labor Day, MCS) 9/3 (M, Labor Day, MCS)	MCS: sampling on Wednesday, Bard mode
2	9/10-14/01	NO	NO	9/10-11 (M-Tu, DGS in D.C.)	NO	MCS: sampling on Thursday, IDEC mode
2	9/17-21/01	NO	NO	NO	NO	MCS: sampling on Thursday, Bard mode
2	9/24-28/01	NO	NO	NO	NO	MCS: sampling on Tuesday, IDEC mode
2	10/1-5/01	NO	NO	NO	NO	MCS: sampling on Tuesday, Bard mode
2	10/8-12/01	NO	NO	NO	NO	MCS: sampling on Tuesday, IDEC mode
2	10/15-19/01	NO	NO	NO	NO	MCS: sampling on Thursday, Bard mode
2	10/22-26/01	NO	NO	NO	NO	MCS: sampling on Thursday, IDEC mode
2	10/29-11/2/01, optional 10th week	NO	NO	*11/3-8/01 ISEA in Charleston, SC (DGS, MGA, ...)*	NO, *but BOTH have 3-day weekend 11/10-12*	CO2 decay and short-term sampling (like 8/30/01), IDEC
						ABOVE PLAN EQUALS 8 WEEKS WITH TEACHER AND STUDENTS (MCS), 4-5 with Bard, 4-5 with IDEC

First of two environmental education classes, on energy and the environment, Monday 12/3/01 12:30-13:20, with data download and equipment maintenance.

NOTE: "Sampling" includes thermal comfort cart monitoring.
goal = in each operating mode, for each school/SD, 4 weeks Tu /W, 4 weeks Th

LBNL/CEC Field Study: Estimated Time Schedule of Key Activities

FINAL VERSION

PART III = CUSD-Stevens Creek Elementary, 1/2/02 through 3/15/02, "heating season"

El. 6 Project Year	Week of	LBNL Holidays	Staff Taking Holiday	Known Meetings/ Conference	School Holidays (CUSD= Cupertino; MCS)	Tasks during LBNL visits to the schools (approximately 6:30/7 AM to 4:30 PM)
2	12/31/01-1/4/02	12/31/01 to 1/1/02	????	NO	12/31/01-1/6/01 (MCS) 12/31/01-1/6/01 (CUSD)	NONE NONE Preparations for wintertime "heating" season.
2	1/7-11/02	NO	NO	NO	NO	CUSD: sampling on opposite day from MCS = Thursday, Bard mode
2	1/14-18/02	NO	??1/18??	NO	NO	CUSD: sampling on opposite day from MCS = Thursday, IDEC mode
2	1/21-25/02	1/21 (M, MLK Day)	NO	NO	1/21 (M, MLK Day, MCS) 1/21 (M, MLK Day, CUSD	CUSD: sampling on opposite day from MCS = Wednesday, IDEC mode; aldehydes only (no VOCs)
2	1/28-2/1/02	NO	NO	NO	NO	CUSD: sampling on opposite day from MCS = Tuesday, Bard mode
2	2/4-8/02	NO	NO	NO	NO	CUSD: sampling on opposite day from MCS = Tuesday, Bard mode; aldehydes only (no VOCs)
2	2/11-15/02	NO	??2/15??	NO	2/11 (M, Lincoln's birthday, MCS)	CUSD: sampling on opposite day from MCS = Tuesday, IDEC mode
2	2/18-22/02	2/18 (M, Pres. Day)	NO	NO	2/18 (M, Washington's birthday, MCS) 2/16-2/24/02 Winter Break Week (CUSD)	NONE (keep in IDEC mode through 2/15/02 Friday, then have Bard starting 2/25/02 Monday)
2	2/25-29/02	NO	NO	NO	NO	CUSD: sampling on opposite day from MCS = Thursday, Bard mode
2	3/4-8/02	NO	NO	NO	NO	CUSD: sampling on opposite day from MCS = Tuesday, IDEC mode
2	3/11-15/02, optional 10th week	NO	NO	NO	STAR Stanford 9 testing & make-ups likely to begin weeks of 3/10, 3/17, 3/24, and/or 3/31	CO2 decay and short-term sampling, IDEC, and second of two environmental education classes, as a "show and tell" of sampling equipment in the study, given

ABOVE PLAN EQUALS
8 WEEKS WITH TEACHERS & STUDENTS (CUSD), 4-5 IDEC, 4-5 Bard.

NOTE: "Sampling" includes thermal comfort cart monitoring.
goal = in each operating mode, for each school/SD, 4 weeks Tu /W, 4 weeks Th

LBNL/CEC Field Study: Estimated Time Schedule of Key Activities

FINAL VERSION

PART IV = MCS-Rose Avenue Elementary, 1/2/02 through 3/15/02, "heating season"

El. 6 Project Year	Week of	LBNL Holidays	Staff Taking Holiday	Known Meetings/ Conference	School Holidays (CUSD; MCS= Modesto)	Tasks during LBNL visits to the schools (approximately 6:30/7 AM to 4:30 PM)
2	12/31/01-1/4/02	12/31/01 to 1/1/02	????	NO	12/31/01-1/6/01 (MCS) 12/31/01-1/6/01 (CUSD)	NONE NONE Preparations for wintertime "heating" season.
2	1/7-11/02	NO	NO	NO	NO	MCS: sampling on Tuesday, Bard mode
2	1/14-18/02	NO	??1/18??	NO	NO	MCS: sampling on Tuesday, IDEC mode
2	1/21-25/02	1/21 (M, MLK Day)	NO	NO	1/21 (M, MLK Day, MCS) 1/21 (M, MLK Day, CSD)	MCS: sampling on Thursday, IDEC mode; aldedhyes only (no VOCs)
2	1/28-2/1/02	NO	NO	NO	NO	MCS: sampling on Thursday, Bard mode
2	2/4-8/02	NO	NO	NO	NO	MCS: sampling on Thursday, Bard mode; aldedhyes only (no VOCs)
2	2/11-15/02	NO	??2/15??	NO	2/11 (M, Lincoln's birthday, MCS)	MCS: sampling on Thursday, IDEC mode
2	2/18-22/02	2/18 (M, Pres. Day)	NO	NO	2/18 (M, Washington's birthday, MCS) 2/16-2/24/02 Winter Break Week (CSD)	MCS: sampling on Wednesday, IDEC mode; aldehydes only (no VOCs)
2	2/25-29/02	NO	NO	NO	NO	MCS: sampling on Tuesday, Bard mode
2	3/4-8/02	NO	NO	NO	NO	MCS: sampling on Thursday, IDEC mode
2	3/11-15/02, optional 10th week	NO	NO	NO	STAR Stanford 9 testing & make-ups likely to begin weeks of 3/10, 3/17, 3/24, and/or 3/31	CO2 decay and short-term sampling, IDEC, and second of two environmental education classes, as a "show and tell" of sampling equipment in the study, given

ABOVE PLAN EQUALS
9 WEEKS WITH TEACHERS & STUDENTS (MCS), 4-5 IDEC, 4-5 Bard

NOTE: "Sampling" includes thermal comfort cart monitoring.
goal = in each operating mode, for each school/SD, 4 weeks Tu /W, 4 weeks Th

LBNL/CEC Relocatable (RC) Classrooms Study, Year Two—Field Study

v061801, then 071101-071901-082201 FINAL, then 060702 with additions/comments based on field experiences

Cupertino USD, Stevens Creek Elementary

Estimated "sampling day" schedule of activities-- Tuesday, Wednesday, or Thursday—at the participating school in a participating school district (n=2) (2 RCs, side-by-side, at each school).

NOTE: Please refer to MS Excel workbook containing detailed draft schedule for sampling during the cooling and heating seasons, including thermal comfort cart measurements.

Assumption:

The head custodian at both Cupertino's Stevens Creek Elementary School arrives by 7:00 AM (maybe as early as 6:00 AM), and school begins about 9:05 AM and ends 3:05 PM.

*Since two 4th grade classes, 30-32 students each on <34'L by 24'W carpeted floor area.

Monday (for Tuesday), Tuesday (for Wednesday, if Monday is LBNL and/or school holiday), and/or Wednesday (for Thursday):

Preparations for the field visit the following day include picking up LBNL van by 3 PM Monday; loading thermal comfort carts into the van; VOC multisorbent tubes and DNPH cartridges into cooler with ice and then into the van; preparing pre-printed field data sheets and checklists in binders; bringing laptop computer and RS232 cables for HOBO.

Tuesday/Wednesday or Thursday (one day at each school) = **Daily Sampling Schedule**

OVERVIEW:

Duration of travel time from Walnut Creek (safety margin included for traffic scenarios):

Stevens Creek Elementary, Cupertino = 1.5 hours

Duration of school day for LBNL SRA/RA= 9 hours, with short breaks

Duration of travel time back to LBNL, Berkeley (safety margin included for traffic scenarios):

Stevens Creek Elementary, Cupertino = 1.5-2 hours, per freeways and bridge

Duration of time needed to unload car, store samples in fridge, return car, etc. = 0.5 hour

TOTAL TIME REQUIRED OF STAFF, 2 DAYS/WEEK =
about 13-14 hrs/day, 26-28 hrs/week

TOTAL TIME REQUIRED OF STAFF A WEEK, INCLUDING LBNL PREP =
about 30 hrs

NOTE: SRA/RA (DGS) will have laptop to do work when not inside/outside test RCs

TIME/TIME PERIOD	LOCATION	ACTIVITY
5:15 AM – 6:30 AM	Walnut Creek to Cupertino	outbound commute
6:30 AM- 8:15 AM (+/- 5 minutes at end)	Participating School in Cupertino (Stevens Creek Elementary)	unload, sampler set-ups, pump calibrations
6:30/6:40 AM – 7:05AM	Participating school available parking nearest the two RCs	Unload cooler with samples, thermal comfort(TC)carts, tool box, monitor, zip drive, etc and bring to RCs

NOTE: move van off-campus by 8:30 AM

NOTE: by between 7:00 AM – 7:10 AM — Gain access to RCs with custodian.

7:00 AM – 7:20 AM (10 minutes outdoors, 5 minutes in each RC)	In RCs	Set up LBNL shelf once cabinets opened, set up monitor, keyboard and mouse. Conduct classroom conditions checklist, check teacher's T setting.

TIME/TIME PERIOD	LOCATION	ACTIVITY
7:20-7:35 AM (5 minutes per RC or outdors)		Measure PM counter flow rates, and calibrate as necessary to adjust to PSI nominal flow. Inspect and fix as needed. Confirm proper operation settings. Record important observations.

NOTE: from end of cooling season through remainder of field study

7:35 AM – 8:00 AM (10 minutes each RC, inc. outdoors)	In RCs, sampler pump box	Remove samples from cooler. Open cabinet, start and inspect pumps for VOC and DNPH aldehydes samples. Record sample ID number, date, pump number, school, and classroom number on field sheet. (Pre-programmed pump, start time.) Include any duplicates. Handle field blanks.
during 7:20 AM – 8:00 AM (7-8 minutes in each RC)	In RCs	Calibrate noise sound level meter (SLM, Extech). Visual inspection of CO2, CDAQS noise, and T/RH/door/window samplers and sensors for physical integrity. Pack cooler and equipment finished with.

** Complete tasks in one RC, then move to the other.

8:00 AM-8:10 AM - (5 minutes in each RC)	In RCs, first location, TC cart	Start TC cart measurements at 1st location.
8:10 AM – 8:30 AM - (<10 minutes in each RC)	In RCs	Download previous "week" (5-9 days) data from HOBOs to laptop, "relaunch" HOBOs.

NOTE: can be done in AM or duirng morning recess or during lunch period as well.

8:15 AM – 8:25 AM	Around/in the RCs	Pack equipment and tools finished with.

NOW, OTHER ACTIVITIES OCCUR OUTSIDE

8:30 AM- 8:55 AM (At each RC, 3-5 min. each sampling system/set of pumps)	LBNL locker outside behind RC (unlock/lock with padlock & key)	Record flow rates of peristaltic pumps** used for the VOC and DNPH sampling.

*****Start with indoor pumps, then the outdoor pumps.***

8:55 AM – 9:05 AM	Outside back side RC,	Visual inspection of components "weather station" and samplers and connection to central DAQS by conduit. Check gas/H20 lines to IDEC & heater.

TIME/TIME PERIOD	LOCATION	ACTIVITY
9:05-9:25	LBNL locker outside behind RC (unlock/lock with padlock & key)	Confirm proper operation of continuous samplers for indoor T and RH% sensors, indoor /outdoor CO2, door and window sensors, particle counts, outdoor T and RH%, and outdoor wind speed and direction via CDAQS operation, i.e., data collection. Check for any leaks/moisture.
By 9:30-10:00 AM	*Project Cell Phone*	Call LBNL (MGA, DPS, Dennis), report "all checks made, all O.K." and/or issues. Also, confirm check in w/ office, prinicipal.
end of phone call until 10:30 am	**In town, and/or in van**	Breakfast break; read, do paperwork = sources checklist (outdoor,start indoor with AM observations). Start review of previous week data in MS Excel templates.
10:40 AM – 10:55 AM (2-6 minutes per classroom per task)	In RCs	move TC cart to 2nd location if no rain, conduct classroom conditions checklist
until school's lunch break	**In van**	work with laptop work with previous week data cont.
12:30 PM- 1:10 PM (during lunch break) (20 minutes per classroom)	In RCs	move TC cart to 3rd location (2nd if rain), conduct classroom conditions checklist, finish sources checklist (indoor with cleaning compounds, etc.), TC clo checklist (based on AM observations)
from end of school's lunch until near end (3:15PM) of student's day (3:35 PM)	**In van/in town**	work on laptop, break

TIME/TIME PERIOD	LOCATION	ACTIVITY
3:20 PM—3:30 PM	** Save work tasks on personal computer and prepare for final field work!	
3:30 PM – 5:30/6:00 PM	In/Outside RCs	

Calibrate peristaltic pumps; stop, cap, and store integrated school day VOC and DNPH samples in cooler for transport; view and inspect continuous sensors and sampler data; complete TC cart measures; HOBO and noise data.

TIME/TIME PERIOD	LOCATION	ACTIVITY
3:35 PM – 4:00 PM (10 minutes in each RC, including outdoor pumps)	In RCs, sampler pump boxes	Record final flow rates for peristaltic pumps for VOC&DNPH samples and duplicates, and note any unusual physical conditions of pump and cartridge or noise made by pump. Confirm sample ID number, pump number, and classroom number on field sheet. Turn off pump and record pump time. <u>Collect field blanks (if not done in AM)..</u> Store samples in cooler.
4:00 PM – 4:30 PM - (up to 10 minutes in each RC)	In RCs, first location, TC cart	Stop TC cart measurements at last location; end data collection, review data, save file.
Also 4:00 PM – 4:30 PM (3-5 minutes in each RC)	In RCs	Check teacher's HVAC T setting; conduct classroom conditions checklist
4:30-PM – 5:00 PM (12-15 minutes per RC)	In RCs	Record flow rate of indoor and outdoor MetOne 237B particle counters with BIOS DryCal or Gilibrator bubble flow meter. Calibrate CO2 monitors using protocol.
by 4:00, 6:00 PM		Check out with main office and principal. Remind them (night custodians) LBNL on campus until about 6:00 PM.
5:00 PM – 5:10 PM	LBNL locker outside behind RC (unlock/lock with padlock & key)	Confirm proper operation of continuous samplers for indoor T and RH% sensors, indoor/outdoor CO2, door and window sensors, particle counts, outdoor T and RH%, and outdoor wind speed and direction by viewing parts of day's data. Download this week's data to a zip disk. Remove monitor and zip drive.
5:10 PM – 5:40 PM	In RCs	TC carts stored in van. Load cooler with samples, calibration equipment tool box, laptop PC, etc. into van. Bring monitor, zip drive and disk to van. Get HVAC system "seal off" panels.

5:40 PM – 5:55 PM

AT SCHOOL: at the end of the sampling day, before leaving the school for LBNL

After school day is over, shut down the HVAC system operating the previous week. This includes sealing off, with method to be determined, the supply side at the air filters and relief vents (IDEC only). Then, open and start the other HVAC system for the present week.

PROTOCOL:

Bard HVAC system: seal off 28" by 9.5" air intake opening/relief opening outdoors on the Bard unit with LBNL designed Al panel and 3M velcro. Turn Bard "off" at indoor thermostat, and timer to zero, then lock its plastic box.

IDEC HVAC system and relief vents: seal off three parts of the LBNL designed inlet filter racks with appropriately sized Lexan panels and 3M velcro. Switch master electrical disconnect outdoors at circuit breaker box to off. Turn IDEC "off" at indoor thermostat, then lock its plastic box.

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by 6:00-6:15 PM	*Project Cell Phone*	Call LBNL (MGA, DPS, Dennis), report "all checks made, all O.K." and/or issues. Organization and final review of field data sheets and checklists from the day.
~6:15-7:30/7:45	Cupertino to LBNL Inbound commute, after a drink/snack Park LBNL van at Bldg. 90 or W.C.	Unload cooler with samples**, and tools (as necessary), laptop PC, checklists, data sheet binder, disks.

**Samples go into home refrigerator overnight (cooling season) or kept in van cargo area overnight (heating season) and then to Al Hodgson, building 70-221, the following morning

LBNL/CEC Relocatable (RC) Classrooms Study, Year Two—Field Study

v061801, then 071101-071901-082201 FINAL, then 060702 with additions/comments based on field experiences

Modesto City Schools, Rose Avenue Elementary

Estimated "sampling day" schedule of activities-- Tuesday, Wednesday, or Thursday—at the participating school in a participating school district (n=2) (2 RCs, side-by-side, at each school).

NOTE: Please refer to MS Excel workbook containing detailed draft schedule for sampling during the cooling and heating seasons, including thermal comfort cart measurements.

Assumption:

The head custodian at Modesto's Rose Avenue Elementary School arrives by 7:00 AM, and school begins about 8:30 AM +/- five min. and ends about 2:35 PM +/- five min.

AT LBNL: Monday (for Tuesday), Tuesday (for Wednesday, if Monday is LBNL and/or school holiday), and/or Wednesday (for Thursday):

Preparations for the field visit the following day include picking up LBNL van between 1-3 PM Monday; loading thermal comfort carts into the van; VOC multisorbent tubes and DNPH cartridges into cooler with ice and then into the van; preparing pre-printed field data sheets and checklists in binders; CO2 "cal bags;" bringing laptop computer and RS232 cables for HOBO.

Tuesday/Wednesday or Thursday (one day at each school)

Daily Sampling Schedule

OVERVIEW:

Duration of travel time from Walnut Creek (safety margin included for traffic scenarios):
Rose Avenue Elementary, Modesto = 1.5 hours

Duration of school day for LBNL staff = 9.5-10 hours, with short snack breaks

Duration of travel time back to LBNL, Berkeley (safety margin included for traffic scenarios):
Rose Avenue Elementary, Modesto = 1.5-2 hours, per I-580 situation and town

Duration of time needed to unload car, store samples in fridge, return car, etc. = 0.5 hour

TOTAL TIME REQUIRED OF SRA/RA, 2 DAYS/WEEK =
about 13-14 hrs/day, 26 hrs/week

TOTAL TIME REQUIRED OF SRA/RA A WEEK, INCLUDING LBNL PREP =
about 30 hrs

NOTE: SRA/RA (DGS) will have laptop to do work when not inside/outside test RCs

TIME/TIME PERIOD	LOCATION	ACTIVITY
5:20 AM – 6:50 AM or earlier	Walnut Creek to Modesto	outbound commute

TIME/TIME PERIOD	LOCATION	ACTIVITY
6:50 AM- 8:15 AM (+/- 5 minutes at end)	Participating School in Modesto (Rose Avenue Elementary)	unload, sampler set-ups, pump calibrations
6:50 AM – 7:10 AM	Participating school available parking nearest the two RCs	Unload and carry cooler with samples, thermal comfort(TC) carts, tools, monitor, zip drive. Assumes access to RCs gained.
7:10 AM – 7:20 AM (5 minutes in each RC)	In RCs	Conduct classroom conditions checklist, check teacher's T setting.
7:20 AM – 7:45 AM (10 minutes each RC, inc. outdoors)	In RCs, sampler pump box	Remove samples from cooler. Open cabinet, start and inspect pumps for VOC and DNPH aldehydes samples. Record sample ID number, date, pump number, school, and classroom number on field sheet. (Pre-programmed pump, start time.) Include any duplicates and field blanks.
during 7:45 AM – 7:55 AM (5 minutes in each RC)	In RCs	Calibrate noise sound level meter (SLM, Extech). Visual inspection of CO2, particle count, CDAQS, noise, and T/RH/door/window samplers and sensors for physical integrity.

** Complete tasks in one RC, then move to the other.

7:55 AM-8:05 AM - (5 minutes in each RC)	In RCs, first location, TC cart	Start TC cart measurements at 1st location.
8:05 AM – 8:10 AM	In RCs	Pack up cooler and equipment finished with.

NOW, OTHER ACTIVITIES OCCUR OUTSIDE

8:10 AM- 8:30 AM (At each RC, 3-5 min. each sampling system/set of pumps)	LBNL locker outside behind RC (unlock/lock with padlock & key)	Record flow rates of peristaltic pumps** used for the VOC and DNPH aldehyde sampling pumps.

***Start with indoor pumps, then the outdoor pumps.*

8:30 AM – 8:40 AM	Around the RCs	Pack equipment and tools finished with.
8:40 AM – 8:45 AM	Outside back side RC, "weather station" and samplers	Visual inspection of components and connection to central DAQS by conduit. Check gas/H20 lines to IDEC & heater.
8:45 AM – 9:15 AM (NOTE: set-up of monitor can be <6:45 as well)	LBNL locker outside behind RC	Set-up monitor and zip drive in locker. Confirm proper operation of continuous samplers for indoor T and RH% sensors,

TIME/TIME PERIOD	LOCATION	ACTIVITY
		indoor /outdoor CO2, door and window sensors, particle counts, outdoor T and RH%, and outdoor wind speed and direction via CDAQS operation, i.e., data collection. Check for any leaks/moisture in and around LBNL locker..
after AM work	*Project Cell Phone*	Call LBNL (MGA, DPS, Dennis), report "all checks made, all O.K." and/or issues. Also, confirm check in w/ office, prinicipal.
end of phone call until 10:15 am	**In van**	Breakfast break; read, do paperwork = sources checklist (outdoor,start indoor with AM observations) and start review of previous week data in MS Excel templates.
10:15 AM – 10:30 AM (during recess break, if no rain) (5 minutes per classroom)	In RCs	move TC cart to 2nd location; classroom conditions checklist
until school's lunch break	**In van**	work with previous week data cont.
11:45 AM- 12:25 PM (during lunch break) (20 minutes per classroom)	In RCs	move TC cart to 3rd location (2nd if rain); classroom conditions checklist, finish sources checklist (indoor with cleaning compounds, etc.) and TC clo checklist (based on AM observations)
from end of school's lunch until near end (2:20 PM) of student's day (2:35 PM)	**In van/in town**	work on laptop, read, class attendance checklist (for today and since previous week's field visit) through school secretary, break with drink/snack

TIME/TIME PERIOD	LOCATION	ACTIVITY
2:25 PM—2:40 PM		** Save work tasks on laptop and prepare for final field work!
2:40 PM – 4:15-4:30 PM	In/Outside RCs	

Calibrate peristaltic pumps; stop, cap, and store integrated school day VOC and DNPH samples in cooler for transport; view and inspect continuous sensors and sampler data; complete TC cart measures; HOBO and noise data.

2:40 PM – 3:10 PM (10 minutes in each RC, including outdoor pumps)	In RCs, sampler pump boxes	Record final flow rates for peristaltic pumps for VOC&DNPH samples and duplicates, and note any unusual physical conditions of pump and cartridge or noise made by pump. Confirm sample ID number, pump number, and classroom number on field sheet. Turn off pump and record pump time. <u>Collect field blanks (if not done in AM).</u>. Store samples in cooler.
3:10 PM – 3:35 PM - (up to 10 minutes in each RC)	In RCs, first location, TC cart	Stop TC cart measurements at last location; end data collection, save and review files.
Also 3:10 PM – 3:35 PM	In RCs	Check teacher's HVAC T setting; conduct classroom conditions checklist
3:35 PM – 4:30 PM (20 minutes per RC)	In RCs	Record flow rate of indoor and outdoor MetOne 237B particle counters with BIOS DryCal or Gilibrator bubble flow meter. Calibrate CO2 monitors using protocol.

NOTE: during heating season weekly visits winter 2002 and spring 2002 bi-/tri-weekly visits, measured flow rate of particle counters once in both AM and PM, performing necessary calibration to nominal flow.

4:30 PM – 4:40 PM	In RCs	TC carts stored in van. Check out with main office and principal, but remind them (PM custodian) LBNL on campus to ~5-6PM.
4:40 PM – 4:50 PM -	In RCs	Download previous "week" (5-9 days) data from HOBOs to laptop, "relaunch" HOBOs, put back in RCs.

NOTE: during heating season weekly visits winter 2002, HOBOs during lunch period or after school.

4:50 PM – 5:00 PM	LBNL locker outside behind RC (unlock/lock with padlock & key)	Confirm proper operation of CDAQS and continuous samplers for indoor T and RH%, indoor/outdoor CO2, door and window sensors, particle counts, outdoor T and RH%, and outdoor wind speed and direction by viewing parts of day's data. Download this week's data to a zip disk. Remove monitor and zip drive.

5:00 PM – 5:10 PM	Participating school, available	Load cooler with samples, calibration equipment tool box, laptop PC, etc. into van. Get HVAC system "seal off" Lexan or Al panels.

5:10– 5:20 PM

AT SCHOOL: at the end of the sampling day, before leaving the school for LBNL

After school day is over, shut down the HVAC system operating the previous week. This includes sealing off, with method to be determined, the supply side at the air filters and relief vents (IDEC only). Then, open and start the other HVAC system for the present week.

PROTOCOL:

Bard HVAC system: seal off 28" by 9.5" air intake opening/relief opening outdoors on the Bard unit with LBNL designed Al panel and 3M velcro. Turn Bard "off" at indoor thermostat, and timer to zero, then lock its plastic box.

IDEC HVAC system and relief vents: seal off three parts of the LBNL designed inlet filter racks with appropriately sized Lexan panels and 3M velcro. Switch master electrical disconnect outdoors at circuit breaker box to off. Turn IDEC "off" at indoor thermostat, then lock its plastic box.

by 6:00 PM	*Project Cell Phone*	Call LBNL (MGA, DPS, Dennis), report "all checks made, all O.K." and/or issues. Organization and final review of field data sheets and checklists from the day.
~6:00 – 7:30/8:00 PM	Modesto to LBNL or W.C. Inbound commute, after a drink/snack Park LBNL van at Bldg. 90 or W.C.	Unload cooler with samples**, and tools (as necessary), laptop PC, checklists, data sheet binder, disks.

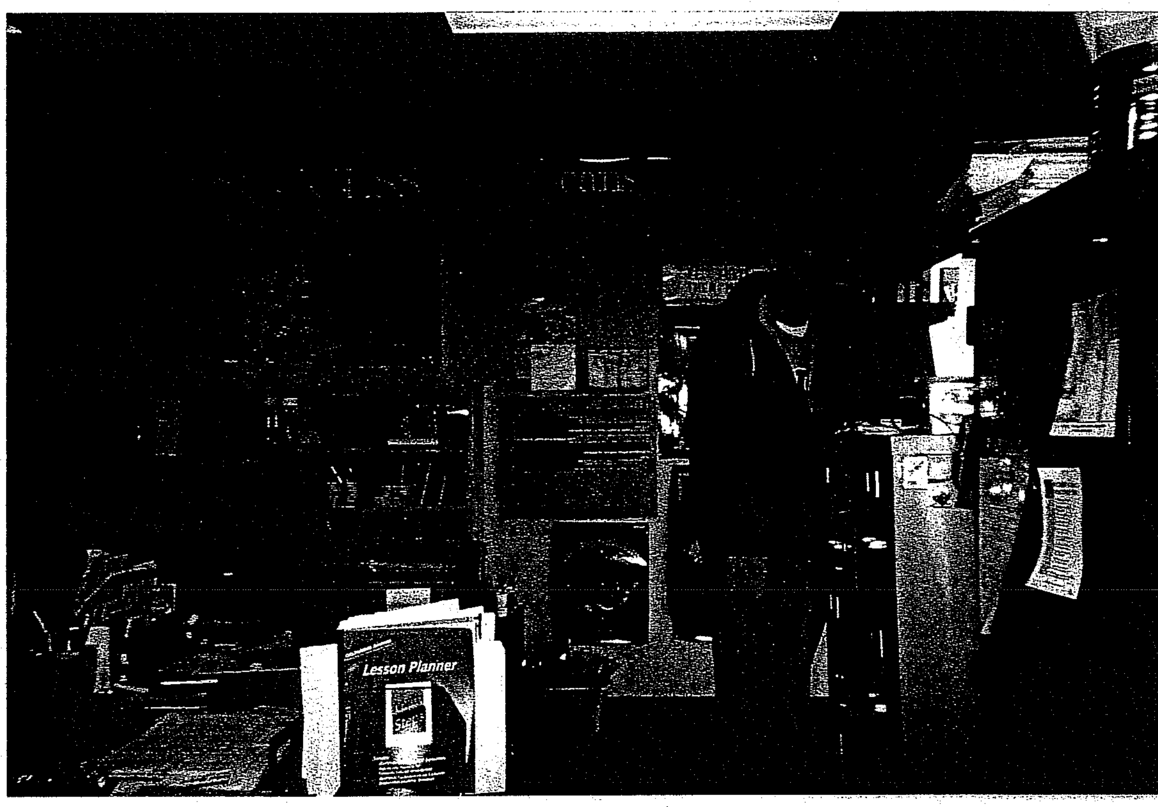
**Samples go into home refrigerator overnight (cooling season) or kept in van cargo area overnight (heating season) and then to Al Hodgson, building 70-221, the following morning.

APPENDIX A.2

Study Design and Field Studies

A.2.9. Field Study Standard Operating Procedures and Protocols

A.2.9.1 UCLA PCS, SD 1 and 2
A.2.9.2 LBNL RCS, aldehyde and VOC sampling



A.2.9. Technician downloading temperature and relative humidity data from HOBO H8 family Pro logger, typically located near the teacher desk or workstation but out of sight and/or reach, during the field studies.

C:\My Documents\SchoolsStudy\FieldDataCollectionInstruments\UCLA PCS_field study SOP.doc

UCLA PUBLIC SCHOOL PORTABLE CLASSROOMS STUDY

STANDARD OPERATING PROCEDURES, FIELD WORK

USED 5/31/00-6/8/01

V. 6/7-8/01 final, D.G.SHENDELL, UCLA School of Public Health, ESE Program (D.Env. candidate)

Pre-field work preparations

Prior to the start of field work, field data sheets are prepared and organized first by school, within each participating school district, and second by measured compounds, parameter, or checklist. Any information which can be entered prior to the first field visit is transcribed.

Samples are received about one week in advance from collaborating institutions and stored properly. Dansylhydrazine aldehyde samplers (DNSH PAKS) are stored in a freezer compartment or cold refrigerator at equal to or less than 40 degrees Fahrenheit. Capillary absorption tubes and perfluorocarbon tracers, comprising the air exchange rate measurement system, are stored in separate plastic Ziploc bags containing activated carbon/charcoal paper and maintained a significant distance apart from each other, e.g., opposite sides of a room.

****For all visits to participating schools, the technician must report to the main office and follow any sign-in/sign-out procedures and wear a "visitor" and/or name badge as directed by the school administrative staff. If a key to the classrooms is lent out to the technician, the technician must sign-in/sign-out the borrowed key as well. ****

The school principal will have received a reminder letter, mailed or FAX, and the secretary a phone call, a few weeks before and the week of, respectively, the field work. The communications contain the approximate schedule for the visits. The need for coordination with the school secretary and custodians for self or escorted access to the classrooms is emphasized.

The day before fieldwork begins, separate soft cooler packs are used to separate samples for each school (VOC OVMs, CATs; PFTs are transported separately). DNSH PAKS are put into separate Ziploc plastic bags and kept in cold storage; they are brought to the field in a cooler with one or two ice packs. Furthermore, single "school day only" DNSH PAKS are further separated into smaller Ziploc bags. Samplers for all schools surveyed in the week are combined and placed into one smaller Ziploc bag for each day samplers are deployed, i.e., Monday and Friday, and Wednesday (if applicable). These smaller bags are also transported in the cooler containing one or two ice packs. Again, all

DNSH PAKS remain wrapped in aluminum foil unless used in the classrooms until analysis at EOHSI/Rutgers University.

First Visit:

Thursday or Friday before sampling week, AM before school hours or PM after school hours, office open

During the first sampling period for each school district, the goals of the first visit of three total visits to each participating school and classrooms were:

• Conduct the "Technician Walk-through Questionnaire," with a sketch of the classroom and potential sources as well as the classroom dimensions determined using a measuring tape.

• Determine appropriate locations for the two perfluorocarbon (perfluoromethyl cyclohexane, C_7F_{14}) tracer source blocks (PFTS), which would be set out today, and the passive samplers and HOBO Pro to be deployed the following Monday. Record locations on classroom sketch.

> Criteria included: at least 0.5-1.0 feet or more away from walls, high enough above the floor level to be out of sight and reach of children, level wooden or metal surface, and an area not in front of windows. Also, PFTs had to be at least 4-6 feet away from the capillary absorption tube (CAT) in the horizontal direction.
>
> PFTs, with an ID number label taped to one side (YY-###), were removed from a Ziploc bag, which contained activate charcoal paper; PFTs were placed back in bag when a sampling period is completed. PFTs are always kept separated physically and by distance from the CATs.

• Conduct the "Classroom Checklist" to inventory physical environmental attributes, indicators of electricity use, e.g., lights, computers, and ventilation influences like open doors and windows.

• Conduct, if he or she was available, or schedule of 15-minute afternoon period the following week during Monday-Thursday, for the "Operations and Maintenance" survey with the custodian.

During the second sampling period for each school district, the goals of the first visit of eleven total visits to each participating school and classrooms were:

• Using the same appropriate locations, set out the two PFTs as well as the HOBO Pro data logger for continuous measurements of temperature and humidity. The sampling interval for the HOBO Pro was set to five minutes, and the internal clock was programmed to begin sampling at 6:30 AM (if AM visit) or 2:30 PM (if PM visit). If the classroom furniture layout had been altered by the teacher or school district, the technician modified and documented changes in locations of monitoring equipment on the field data sheets, i.e., the bottom of the page covering "air exchange rate measurement system" data.

> Again, the criteria included: at least 0.5-1.0 feet or more away from walls, high enough above the floor level to be out of sight and reach of children, level wooden or metal surface, and an area not in front of windows. Also, PFTs had to be at least 4-6 feet away from the capillary absorption tube (CAT) in the horizontal direction.

• Conduct the "Classroom Checklist" to inventory physical environmental attributes, indicators of electricity use, e.g., lights, computers, and ventilation influences like open doors and windows.

Second Visits:

I. *(first and second sampling periods)*

Monday AM before school hours when office open and/or custodian present.

The goals of the second "set up" visit of three total visits (first sampling period), or of eleven total visits (second sampling period), to each participating school and classrooms were:

• Unpack from coolers, open/uncap and place the samplers for passive measurement of volatile organic compounds (VOCs OVM), formaldehyde and acetaldehyde (DNSH PAKS), and air exchange rate measurement (CAT) in the predetermined appropriate locations. The date, sample ID numbers, and start times were recorded on the field data sheets.

For DNSH PAKS, whose study sample ID number label was already affixed, aluminum foil wrapping was removed prior to deployment for sampling; aluminum foil wrapping is replaced when the sampling period is completed.

For CAT, as for PFTs, the sampler with a study ID number etched on it was removed from a small Ziploc bag transported in a larger Ziploc bag which also contained activate charcoal paper. CATs are placed back in the Ziploc bags when the sampling period is completed.

For VOCs OVM, open can, remove sampler, affix rectangular 3M badge label on back of sampler and recap the can which now contains only the plastic analysis cap and a small piece of tubing for solvent extraction. Deploy the sampler in the predetermined appropriate location.
NOTE: matching circle 3M badge label already on can, along with study sample ID number label.

For the wintertime heating season sampling, the carbon monoxide data logger/sampler (Langan T15 DataBear) was collocated with these samplers. A Langan T15 DataBear was placed in each portable classroom in the study for one of the following three periods:

1st Friday AM through Monday PM;
Monday PM through Wednesday PM;
Wednesday PM through Friday PM.

The sampling interval was set for five minutes to be consistent with the HOBO Pros. The date, instrument ID number and start time were recorded on the field data sheet containing HOBO Pro information.

• In the first sampling period, the HOBO Pro data logger for continuous temperature and relative humidity measurements was placed in the same location as the passive monitoring samplers on the Monday. This instrument's internal clock was programmed to begin measurements at 6:30 AM. The sampling interval was set for five minutes to be consistent with the Langan T15 DataBear.

• Conduct the "Classroom Checklist" to inventory physical environmental attributes, indicators of electricity use, e.g., lights, computers, and ventilation influences like open doors and windows.

Second Visits (CONTINUED)

II. *(second sampling period)* **FOR: Monday PM through Friday AM**
AM before school hours or PM after school hours when office open and/or custodians present.

During the second sampling period for each school district, the goals of the third through tenth of eleven total visits to each participating school and classrooms were:

• Re-cap during PM visits and then uncap during AM visits the VOCs OVM, DNSH PAKS, and CAT passive samplers in each participating school's portable and main building control classrooms. Daily "stop" and "start" times, respectively, were recorded on field data sheets.

> NOTE: sampler caps are kept loose (DNSH PAKS), in the cans (plastic analytical cap, VOCs OVM), or in Ziploc bags (CATs) in the cooler packs.
>
> For the CAT, the **red** cap is placed on the end with the etched "H" and the **black** cap is placed on the end with the etched sample ID number.

• Conduct the "Classroom Checklist" to inventory physical environmental attributes, indicators of electricity use, e.g., lights, computers, and ventilation influences like doors and windows.

Third/Final Visit

Friday PM after school hours when office is open and/or custodians are present.

The goals of the final "take-down" visit of three total visits (first sampling period), or of eleven total visits (second sampling period), to each participating school and classrooms were:

• Conduct the "Classroom Checklist" to inventory physical environmental attributes, indicators of electricity use, e.g., lights, computers, and ventilation influences like doors and windows.

• Re-cap all passive samplers and measurement systems. The end date and time are recorded on field data sheets; study sample ID numbers are confirmed as well.

Place DNSH PAKS in a plastic bag, which is kept wrapped in aluminum foil, and then in the cooler, which contains one or two ice packs.

Place VOCs OVM in its can and then the can in the same aforementioned cooler.

Place the CAT in the small Ziploc bag containing activated carbon/charcoal paper and then in the same aforementioned cooler. NOTE: at the end of the afternoon's field work, the small Ziploc bag from each school will be placed into the larger Ziploc bag containing activated carbon/charcoal paper in preparation for shipment to Harvard School of Public Health/Dr. Robert Weker.

• Remove the two PFTs from their locations. They are placed in Ziploc bag containing activated carbon/charcoal paper and then in the technician's tool kit or another cooler pack WITHOUT ice to provide physical separation from the CATs during transport.

NOTE: at the end of the afternoon's field work, this Ziploc bag containing PFTs from all participating schools and classrooms studied during the week will be placed into bubble wrap in preparation for shipment to Harvard School of Public Health/Dr. Robert Weker.

• Remove HOBO Pro, and Langan T15 DataBear in the heating season, from sampling locations. The stop date and time are recorded on the field data sheet, and instrument ID numbers are confirmed. These monitoring devices are placed in cooler packs WITHOUT ice, and cardboard boxes bordered in bubble wrap, respectively, in preparation for transport.

C:\My Documents\SchoolsStudy\FieldDataCollectionInstruments\UCLA PCS field study SOP.doc

Post fieldwork activities

For the HOBO Pro and Langan T15 DataBear data loggers, raw data files, to view data graphically, and text files, to be used to import into Microsoft Excel for data management, reduction, and analysis, are downloaded from the instruments and saved to a laptop computer and diskettes within two days.

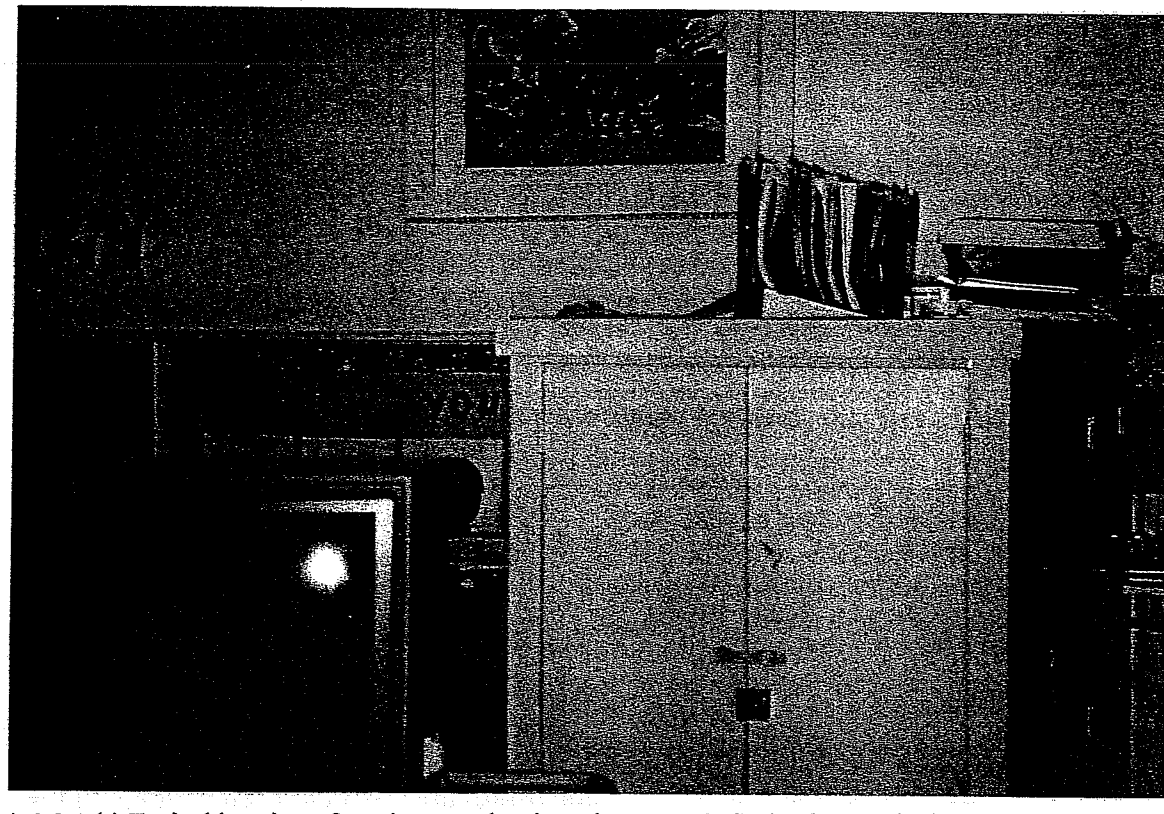
Field data sheets and the "Classroom Checklist" are entered as a group into corresponding Microsoft Excel files and saved to a laptop computer and diskettes within one week, and if possible within two days. The "Technician Walk-Through" Survey and the "Operations and Maintenance" questionnaire are entered as a group in one session within a week of completed data collection. These items are entered as a group, verbatim, to minimize information bias and maintain consistency in data entry technique, vocabulary, and word order.

Completed paper work is stored in separate hanging folders corresponding to each participating school and then grouped by participating school districts in a filing cabinet. Within each folder are three subfolders: 1.) completed questionnaires and surveys; 2.) field data sheets and "Classroom Checklist;" 3.) school campus maps, driving directions, copies of letters sent to principals with fieldwork schedules, etc.

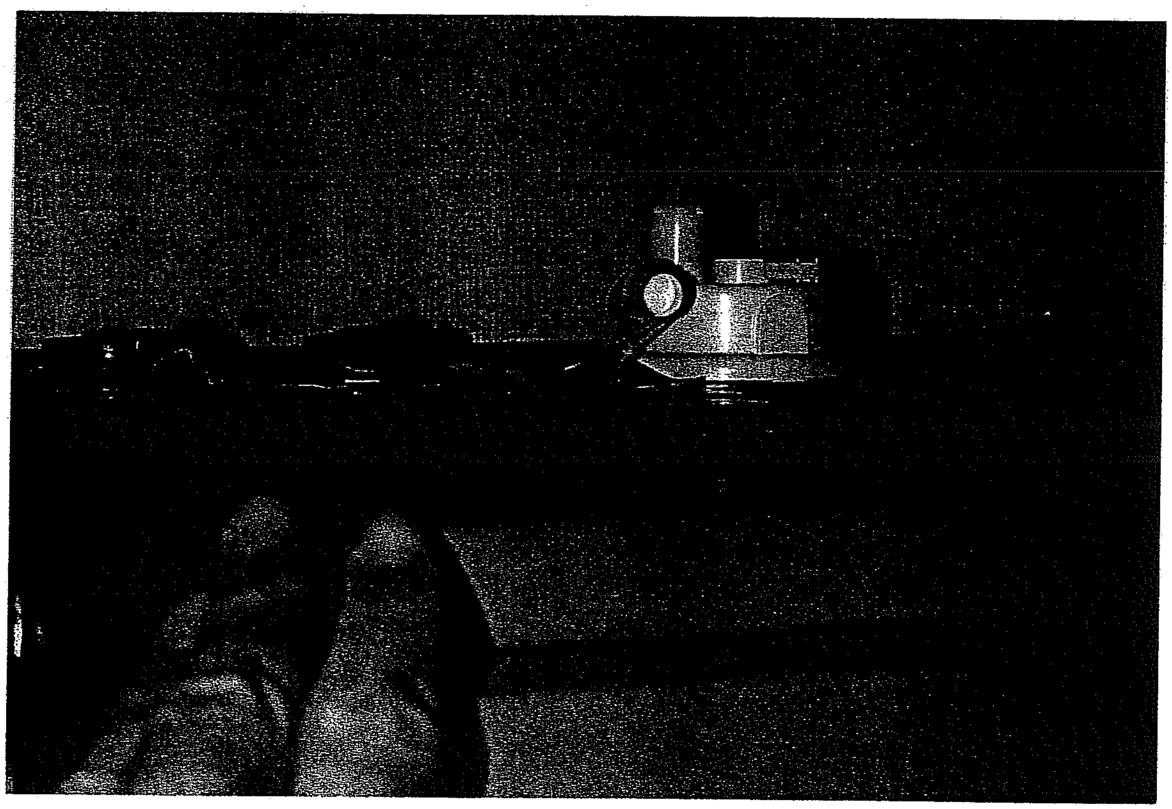
Passive samplers are shipped FedEx priority overnight on the final Friday evening and/or the following Monday and Tuesday to the following collaborating institutions for final sample processing and analyses:

EOHSI/Rutgers University, Dr. Jim Zhang and Dr. Lin Zhang—DNSH PAKS
University of Texas-Houston School of Public Health, Environmental Sciences,
Dr. Thomas Stock and Ms. Silvia Maberti—VOCs OVMs
Harvard University School of Public Health, Environmental Sciences,
Dr. Robert Weker and Mr. Antonio Chemor—CATs (first day), PFTs (second day, or same day but in completely separate packages)

Analyses are conducted within two weeks of receipt (DNSH PAKS, VOCs OVMs) or as soon as possible (CATs). Samples are properly handled, stored, extracted, and analyzed by documented, experimentally validated procedures with known precision and sensitivity.



A.2.9.1 (a) Typical location of passive samplers in a classroom, UCLA PCS standard operating procedures



A.2.9.1 (b) Passive sampling systems employed in the UCLA PCS, pictured as group at sampling location.

FINAL REALIZED procedures (v060902, replacing v082801),
VOC and DNPH aldehydes (ALD) sampling, LBNL relocatable classroom (RC) study

Introduction

VOC and ALD sampling systems, located on shelves in steel, Hoffman weatherproof lockers outside each RC at the back wall corner directly behind the large storage closet indoors, consist of **peristaltic pumps controlled by programmable timers.** Systems **are for aldehydes and VOCs indoors (and outdoors for one of two RCs at each school)**; they consist of a double head pump controlled by the timers for collecting single or duplicate VOC samples, and a single head pump controlled by the timers for collecting an aldehyde sample. Duplicate aldehyde samples, 10% overall and collected only inside the RCs, will be collected with a separate peristaltic pump located with the other pumps. Inlet and outlet lines are numbered as follows:

RC “A” samples are 3 = ALD, 4 = ALD2 (duplicate), 1 = VOC1, 2 = VOC2.
Outdoor samples (at RC “A” enclosure) are 9 = VOC1, 10 = VOC2, 11 = ALD.
RC “B” samples are 7 = ALD, 8 = ALD2 (duplicate), 5 = VOC1, 6 = VOC2.

The inlet and outlet tubes for each pump head are collected in a lower corner of the shelf area. Here the inlet tubes transition to 1/8-inch copper/metal tubes. The copper tubes EITHER:

- exit the back panel of the shelf/outdoor locker and travel in a conduit through the wall of the RC and the back panel of the LBNL indoor cabinet to reach the RC air space. The copper tubes end at the sampling location, approximately 2 m above the floor and 0.7 m (26 in.) from the back wall. These outlet tubes, exiting holes (n=4) in our cabinet’s 4” lower panel lip, end in leur fittings. This is where flow rate measurements are made.
- OR, through holes (n=3) out the side of the outdoor locker away from the Bard HVAC unit. Tubing extends about three feet from RC back wall. This is where flow rate measurements are made.

The ALD sampling locations each have a leur fitting on the end. VOC sampling locations end in ¼-inch Swagelock fittings, and sampling tubes are capped with nylon caps and Teflon ferrules.

Standard Operating Procedures

The sampling system is fully automated. The timers on all samplers are programmed to start on Tuesday, Wednesday, or Thursday as established in the study design; programming is confirmed for the following week at the end of the present week's sampling. The samplers run from 7:00-7:20 AM and 8:15 AM-15:35 PM (CUSD) or 7:50 AM UNTIL 15:00 PM (MCS). The earlier run period is to "warm up" the pump. The technician must install all VOC tubes and aldehyde cartridges between 7:30-8:00 (CUSD) or 7:20-7:50 (MCS). VOC tubes and aldehyde cartridges will be transported to and from the lab in a small cooler with an ice pack. The VOC tube holders and the aldehyde foil pouches are labeled ahead of time to speed handling in the field; aldehyde cartridges are also labeled, in the lab or at the school. The aldehyde cartridges and the foil pouches for transporting completed samples will be labeled SCCL-MMDDYY (S = SCHOOL DISTRICT/SCHOOL, CC = CLASSROOM NUMBER, L= Location #, MM =Month, DD =Day, YY = YEAR. The aldehyde field blank will be labeled with SCCL = 0000. The VOC tubes are permanently numbered; the tube holder will be labeled SCCL-MMDDYY-NNN (S = SCHOOL DISTRICT/SCHOOL, CC = CLASSROOM NUMBER, L =location (inlet #), MM =Month, DD =Day, YY = YEAR, NNN= sorbent tube number). The VOC field blank will be labeled with SCCL = 0000. Outdoor samples will be labeled with CC = "OA."

Field procedures

1.) ARRIVE AT THE SCHOOL ON TUESDAY, WEDNESDAY, OR THURSDAY ~6:30-6:45 AM. UNLOAD CAR, CARRY SAMPLERS TO STUDY RCs.

2.) Proceed to the SAMPLING EQUIPMENT FOR LOCATION INDOOR RC "A."

Open the cabinet and record the values on the left and right elapsed time indicators. Verify the time and day of week are correct on both timers by pressing the clock button on the timer. Time and day can be corrected by holding down the clock button while hitting the day, hour and minute buttons. Verify the control indicator in the lower right corner of the screen is set to "AUTO," which is ensured by pressing the "ON/AUTO/OFF" button, and that the programming is correct. Pressing the "PROG" button will scroll through the six programs. 1ON should be set for Tuesday/WEDNESDAY/THURSDAY at 7:00 AM. 1OFF should be set for Tuesday/WEDNESDAY/THURSDAY at 7:20 AM. 2ON should be set for Tuesday/WEDNESDAY/THURSDAY at 8:15 AM (CUSD) or 7:50 AM (MCS). 2OFF should be set for Tuesday/WEDNESDAY/THURSDAY at 15:35 (CUSD) or 15:00 (MCS). The four other programs should not have times in them. Any of these other programs with time settings should be erased; press the "RST/RCL" button. Press the "CLOCK" button to return the timer to clock mode.

Entering the classroom, you will see the four numbered copper tubes ending in appropriate fittings out the front lower panel lip of the LBNL closest located at a corner of the back wall. Tubes #3 (and #4) have a male leur fitting. This is for the ALD sample (and duplicate ALD sample). Remove an aldehyde cartridge from its sealed pouch. Remove the leur plugs from both ends, and securely install the cartridge on location #3 or 7. Save the leur plugs with the pre-labeled foil pouch for this location. (Repeat if a duplicate ALD sample at location #4 or 8 will be taken.) Next, locate the two VOC sorbent tubes. Remove the tube for location #1 from its holder and remove the nylon caps from the sorbent tube. Store the caps in the holder. Install the sorbent tube in VOC sample location #1. <u>The end with the black carbon sorbent goes into the sample fitting</u>. Repeat this procedure for VOC sample location #2.

3-4.) Repeat the entire procedure for RC "B" indoors and outdoors sample sites, before 8:00 AM (CUSD) or 7:50 AM (MCS).

5.) Wait at least 15 minutes after 7:50 AM and proceed to each location—RC "A" indoors followed by outdoors and then RC "B" indoors-- to measure the sample flow rates. Open the cabinet/locker. The outlet lines from each pump are bundled with the inlet. Flow rates are measured with a BIOS DryCal with a low-flow cell for aldehydes and a manually operated bubble tube and timer for VOCs. Connect the inlet of the BIOS DryCal to the outlet of each aldehyde sample pump so air continues to flow out of this in-line system through the BIOS outlet. Measure and record the average of ten flow measurements at each location; Loc#3, 7 and 11 (and #4 and 8) should be ~150 ml/min.

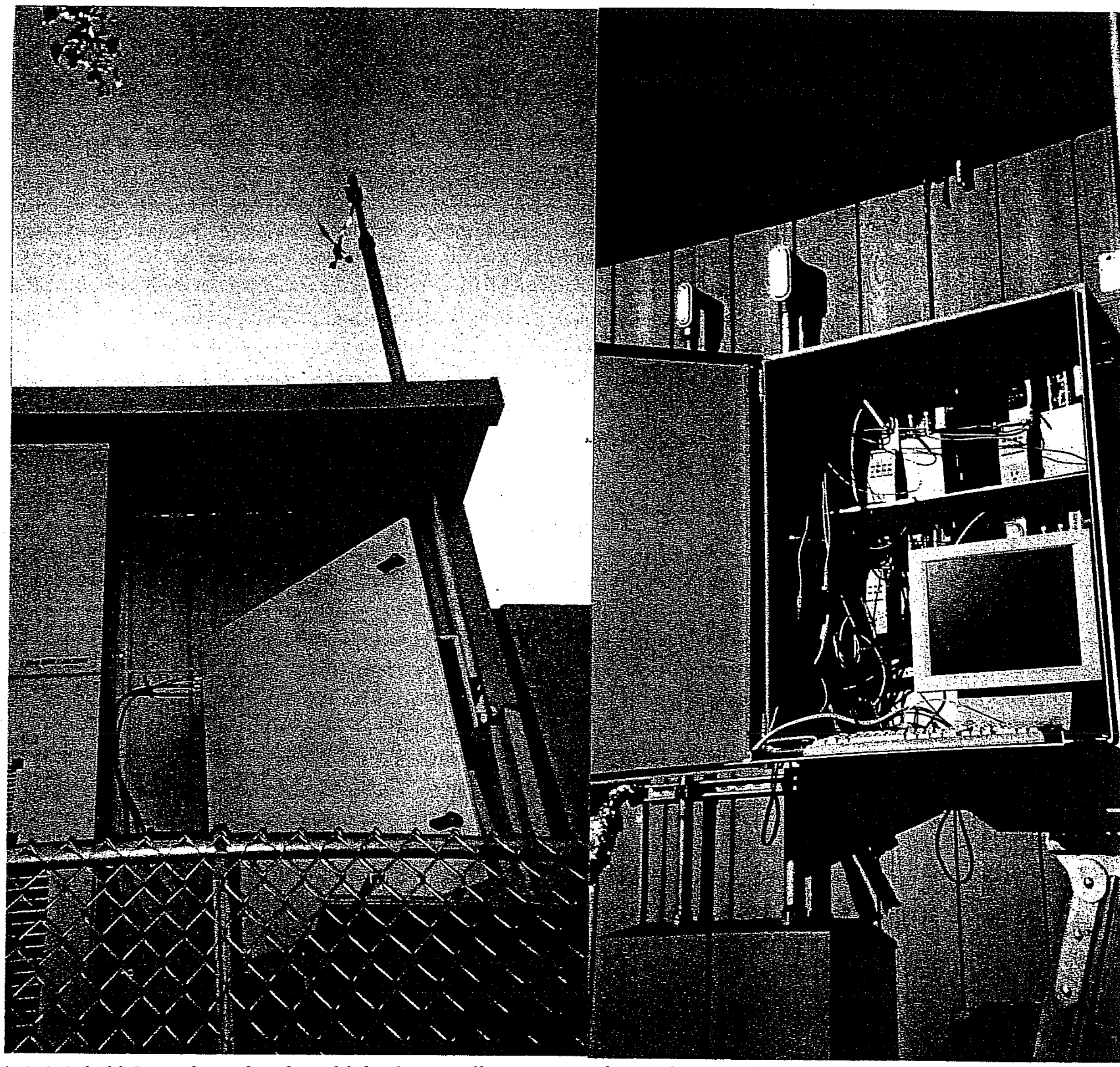
Repeat the process for VOCs using the bubble tube and timer. Record three or four sets of measurements, which are the time required for a bubble to travel up the bubble tube a distance equivalent to 0.5 cc (ml). After a series of field calculations, Loc#1-2, #5-6, and #9-10 should be ~5 ml\min, definitely < 6 ml/min. Record the air temperature from the temperature sensor installed in the BIOS carrying case.

6.) Collect one aldehyde sample and one VOC sorbent tube as field blanks. These blanks should be removed from their sealed pouch or holder. The plugs and nylon caps should be removed and then replaced. Place the ALD blank in its pre-labeled foil pouch; and return the VOC blank to its pre-labeled holder.

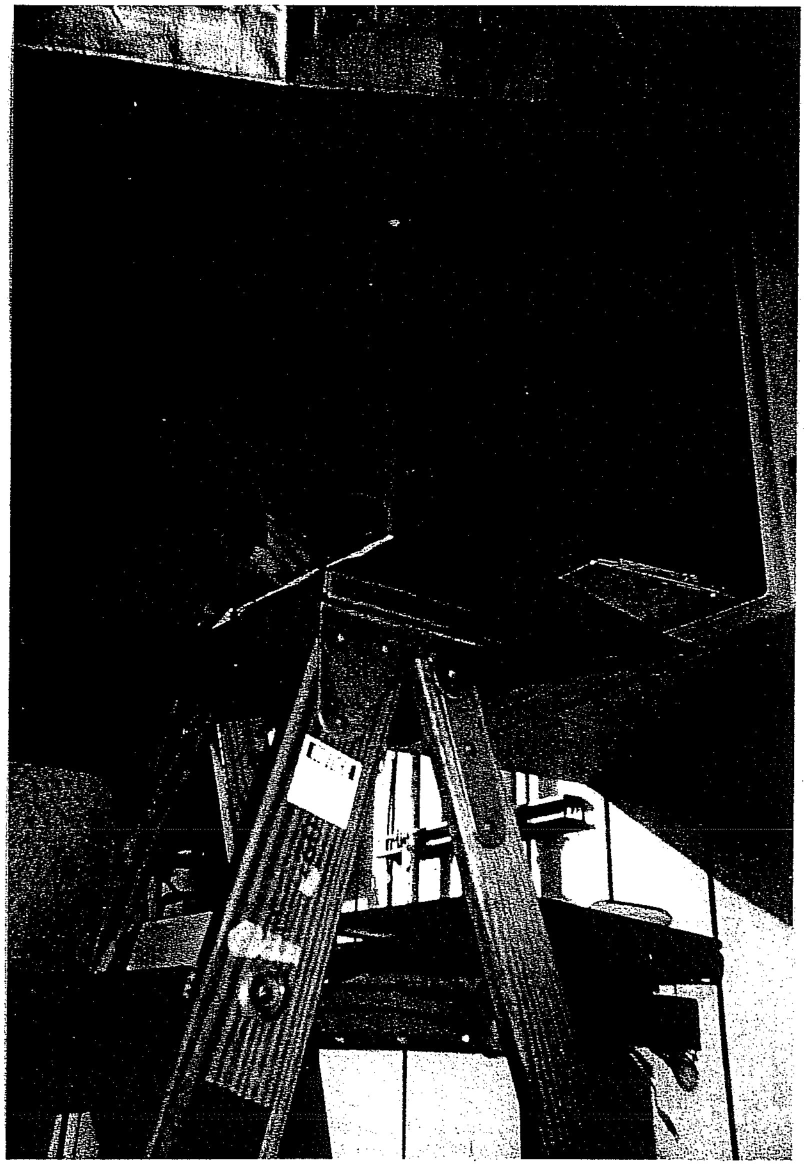
7.) At around 15:10 (CUSD) or 14:35 (MCS), repeat the flow measurement at all locations. This must completed before sampling stops at 15:35 (CUSD) or 15:00 (MCS).

8.) After sampling stops collect samplers. Record the elapsed time of both timers. Remove the aldehyde cartridge. Take correct foil-lined pouch by verifying the sample ID number, replace the leur plugs, and put the ALD cartridge(s) in the pouch. Fold the pouch and seal the end with white tape. Remove the VOC tubes. Verifying the sample ID numbers, take correct tube holders, install the nylon caps finger tight onto the sorbent tubes, and return each tube to its respective holder.

9.) Store/transport the samplers and field blanks in the hand held cooler with ice pack. Samples should be returned to Al's lab (building 70-221) the same evening if possible or, most likely, the next morning Storage until extraction and analysis must be in an LBNL or otherwise approved refrigerator.



A.2.9.2 (a-b) Location of active aldehyde sampling systems in outdoor enclosures mounted on back wall of RCs, LBNL RCS. Note how in the left corner of the left-hand photo aluminum foil protected the DNPH cartridges from sunlight. Copper sampling lines led out from the outdoor enclosure and bent away from the wall and HVAC.

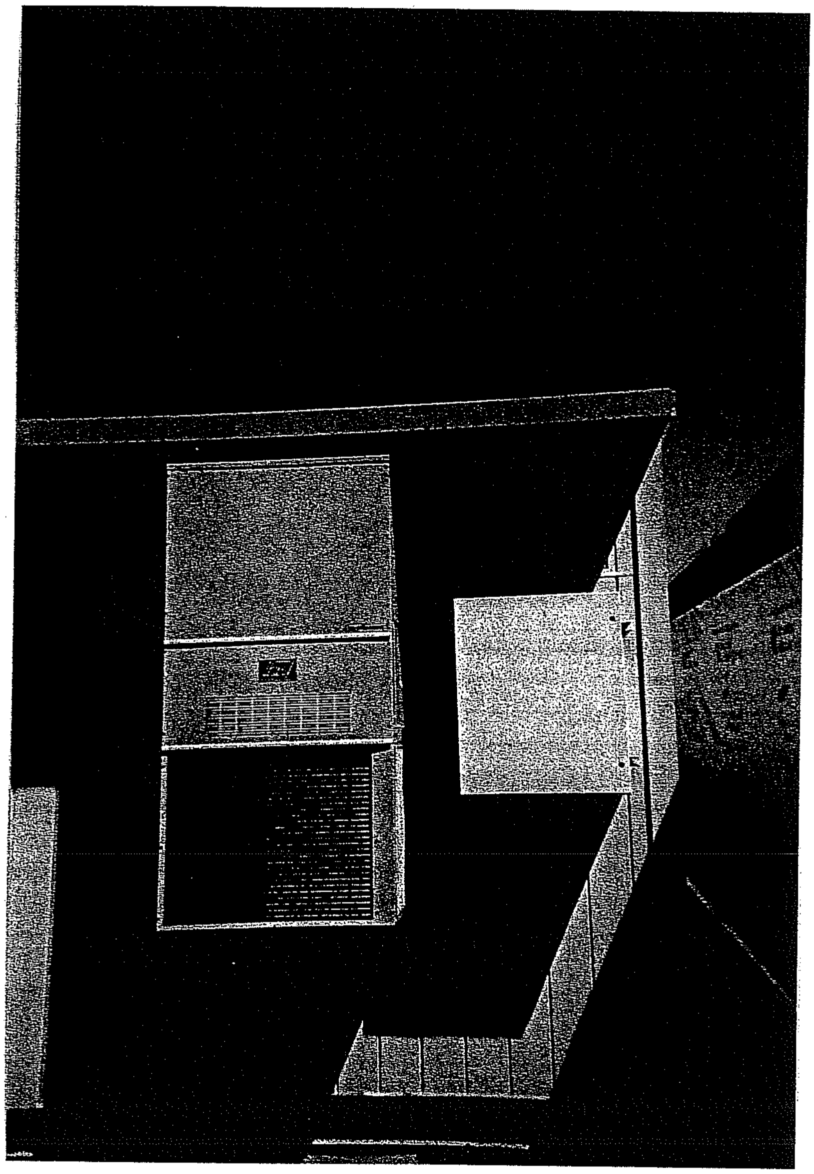


A.2.9.2 (c) Measurement of flow rates using a BIOS DryCal with low flow cell, aldehyde active sampling system, LBNL RCS. Note how during the winter heating season the procedure was conducted under a waterproof tarp which also shielded the sun's UV rays.

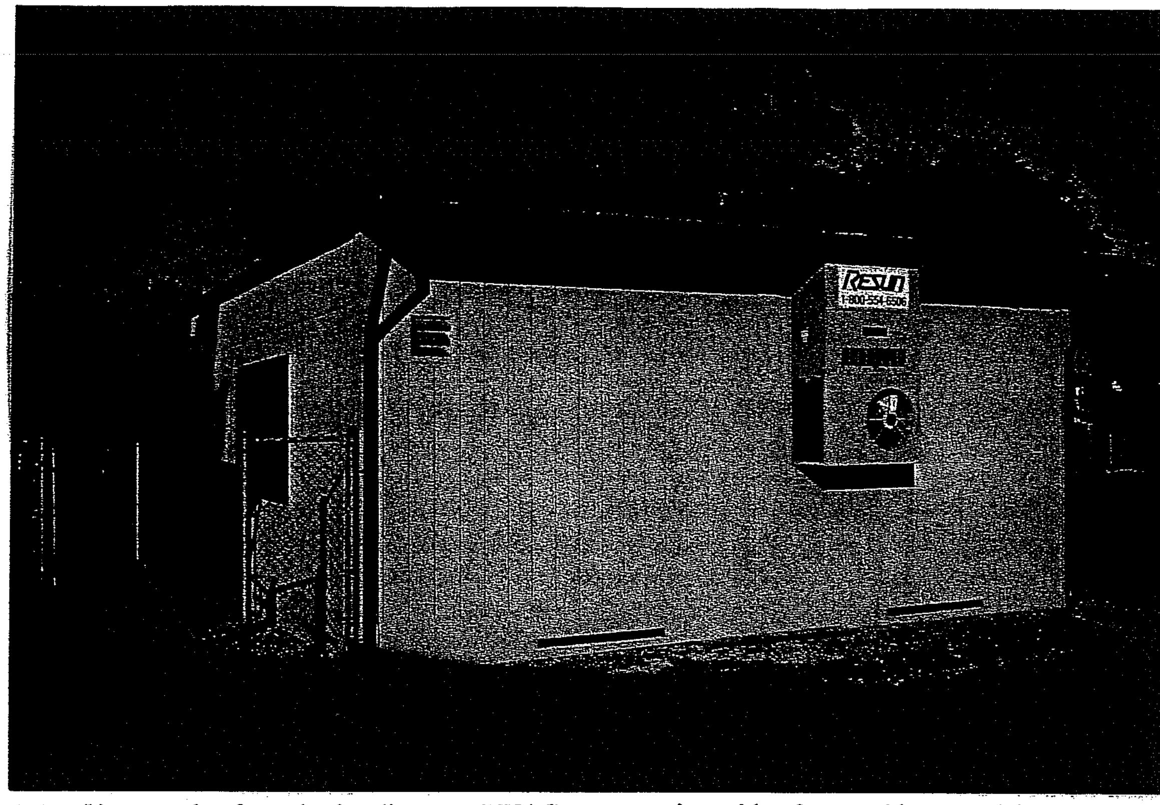
APPENDIX A.3

Pictures and Specifications, Portable/Relocatable Classrooms and HVAC Systems

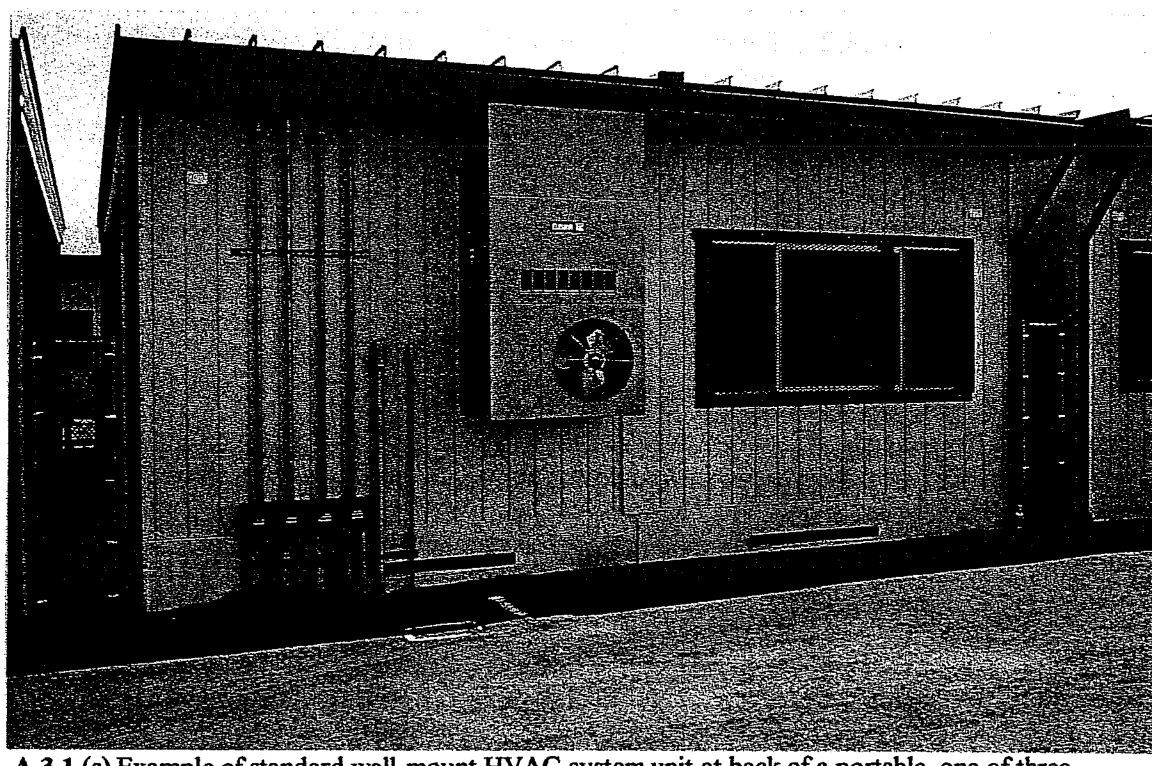
A.3.1 Typical conventional HVAC system



A.3.1 (a) Example of standard wall-mount HVAC system unit at back of a portable, second and most popular of three manufacturers observed, UCLA PCS and LBNL studies.



A.3.1 (b) Example of standard wall-mount HVAC system unit at side of a portable, one of three manufacturers observed, UCLA PCS. This portable was sited on pressure-treated wood on grass and soil.



A.3.1 (c) Example of standard wall-mount HVAC system unit at back of a portable, one of three manufacturers observed, UCLA PCS. This portable was sited on pressure-treated wood on asphalt.

APPENDIX A.3

Pictures and Specifications, Portable/Relocatable Classrooms and HVAC Systems

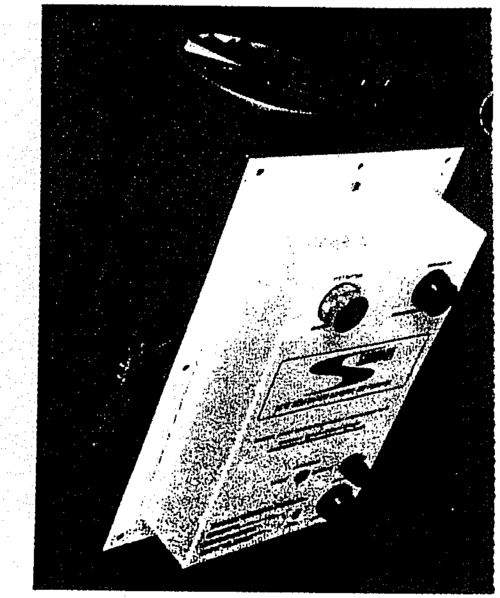
A.3.2 Advanced HVAC Systems

A.3.2.1 Diagram of the novel Sanuvox™ HVAC and air filtration system used for a newer portable classroom in SD 1, UCLA PCS

A.3.2.2 Diagram of the Indirect-Direct Evaporative Cooling/Air Conditioning (IDEC) unit, the advanced HVAC technology tested in the LBNL RCS

The Patented Sanuvox Next Generatio

R100C Residential-Light Commercial In-Duct Next Generation Natural Air Purifier™



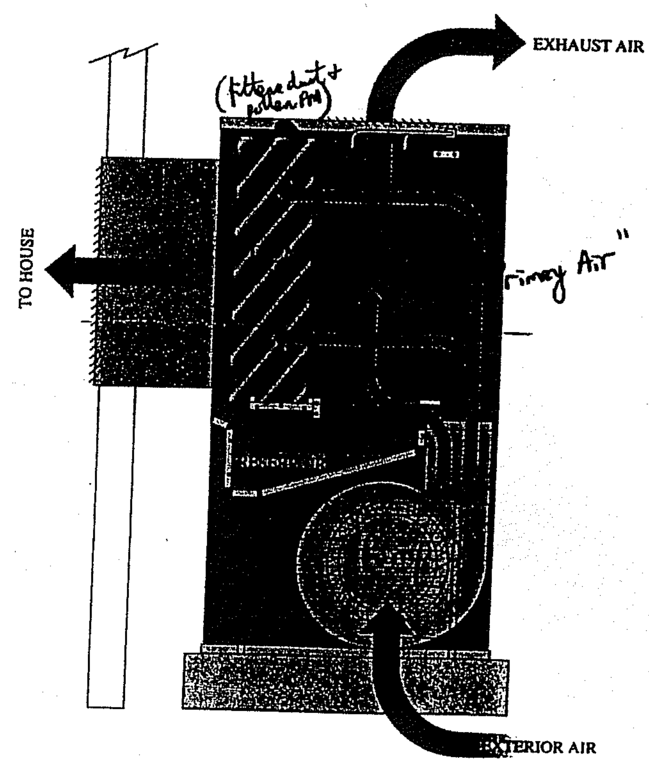
Outside Dimensions:	12" high x 8" wide (305 x 203 mm)
Plenum Opening Requirements:	11" high x 6" wide (269 x 152 mm)
Weight:	12 lbs (5.5 Kg)
Power Requirements:	120V. 25 Watts
Starting:	Vacuum Sensing Switch for Automatic Operation, or Bypass vacuum switch and Hardwire directly to Air Handler
Vacuum Switch Setting:	-0.06 in. W.C.
UV Lamp Dimensions:	J type (Proprietary) Ultraviolet Split Lamp 10.5 in. (267 mm)
Lamp Arc Length:	17.7 in. (450 mm)
UVV Output (Photo Oxidation):	330 milliwatts at 180 nm
UVC Output (Germicidal dose):	2425 milliwatts at 254 nm
Average Ultraviolet Intensity:	28,092 microwatt/cm²
Air Exposure Time to UV Lamp - per pass:	53 milliseconds
Germicidal Ultraviolet Dose:	1684 microwatt.sec/cm²
Average Bacteria Kill (per pass):	80.2 %
UV Reflector:	5" Dia. x 12" Long Aluminium Reflective Tube (127 x 305 mm)
Certifications:	NRTL/C, C.S.A.
Options:	Remote Installation Kit; UVC (Germicidal) J Lamp

KEY BENEFITS HVAC MODELS

- *NO MAINTENANCE OR CLEANING REQUIRED*
- ONLY WORKS WHEN THE HVAC BLOWER IS FUNCTIONING
- ONE MODEL CAN BE USED FOR UPDRAFT, DOWNDRAFT, OR HORIZONTAL APPLICATIONS
- STERILIZES HVAC SYSTEM FILTER
- NEGLIGIBLE POWER CONSUMPTION
- RESIDUAL OZONE LESS THAN .01 PPM.
- STERILIZES HUMIDIFIER
- *TREATS BIOLOGICAL AND CHEMICAL CONTAMINANTS AT THE SAME TIME*

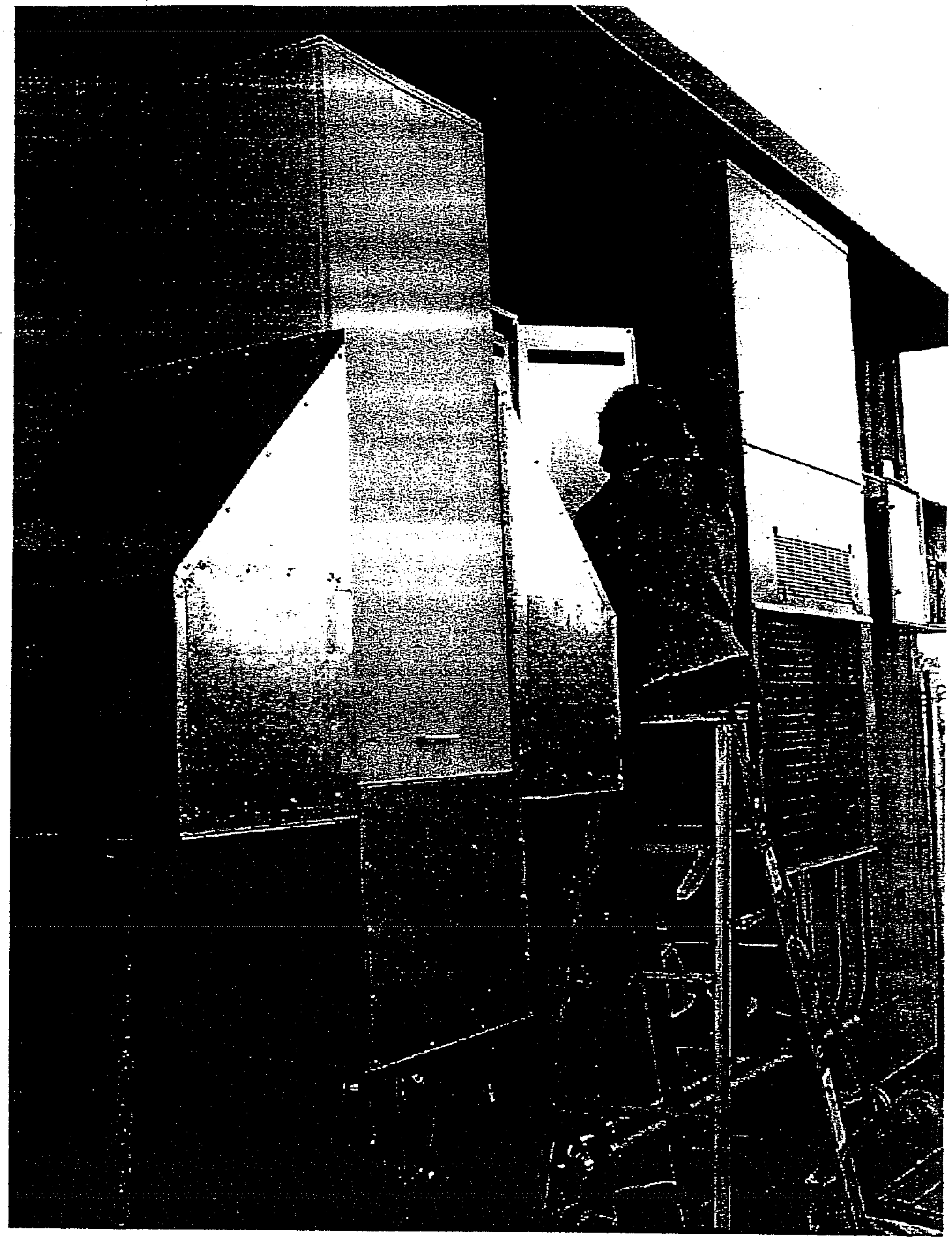
- Dramatic Energy Savings (EER 26 to 56)
- Significantly Lower Installed Cost
- Built-In Quality Air Filtration
- Optimum Humidity Levels
- CFC-Free
- 100% Air Turnover
- Replaces Attic Fans
- Aesthetic Installation
- Predicted Lower Maintenance

How does IDAC work?



The heart of IDAC is the Indirect Cooling Module (ICM) which first cools incoming fresh air without adding moisture. The air then passes through the Direct Cooling Module (DCM), is cleansed and the humidity is optimized. The cooled air enters the home via a central inlet, moving through the house to distant barometric dampers in the ceiling then cooling the attic before exiting by the roof vents.

The small amount of water used in this process is renewed reservoir. This water can be used to irrigate landscaping or system cools, cleans and circulates air using no more power

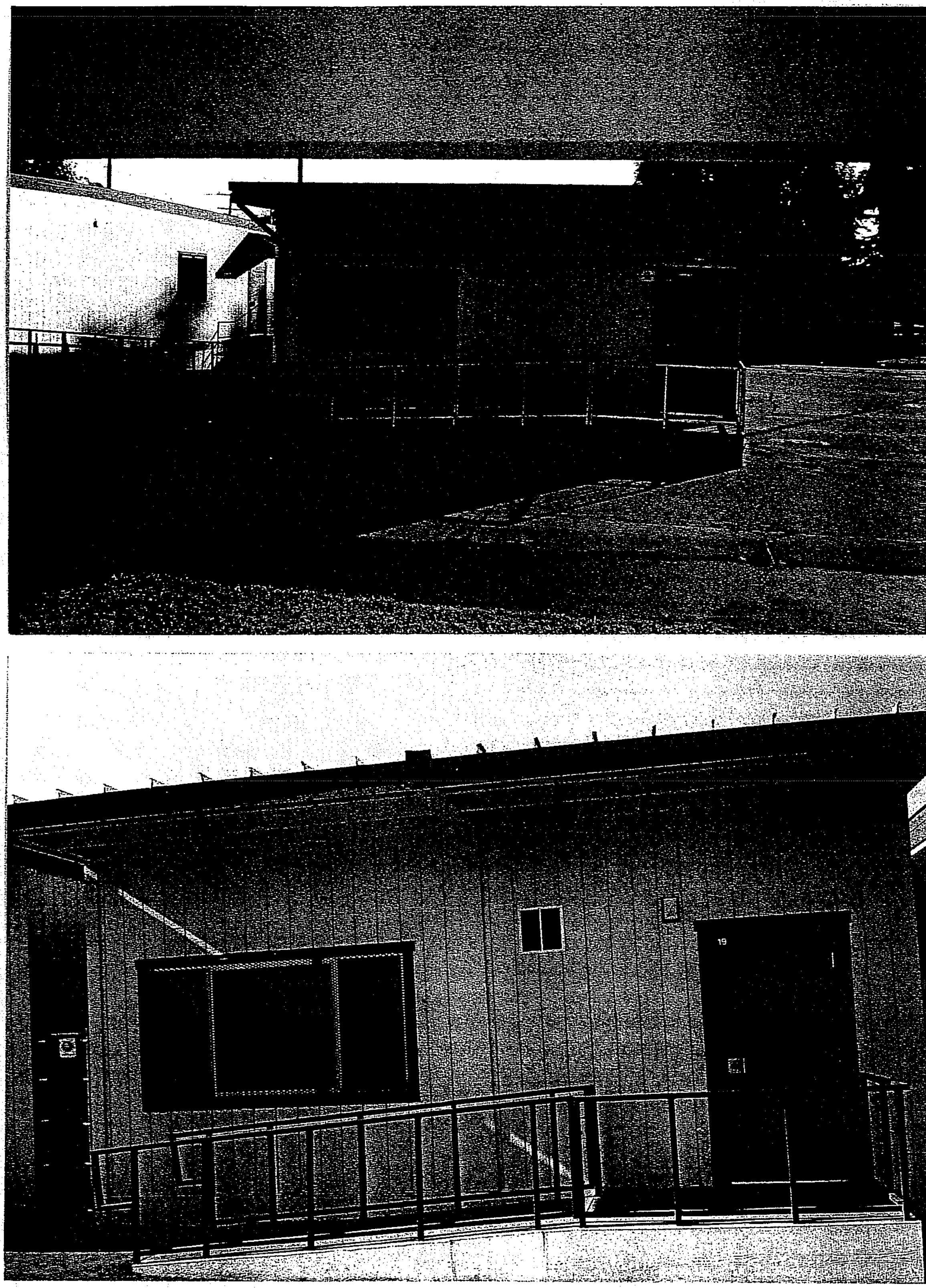


A.3.2.2 Photo of back wall-mounted advanced HVAC system employed in the LBNL RCS. T his was an indirect-direct evaporative cooler (IDEC0 coupled with a natural gas-fired hydronic loop and 65% efficient dust spot particle filtration comprised of three inlet filters in customized holder racks.

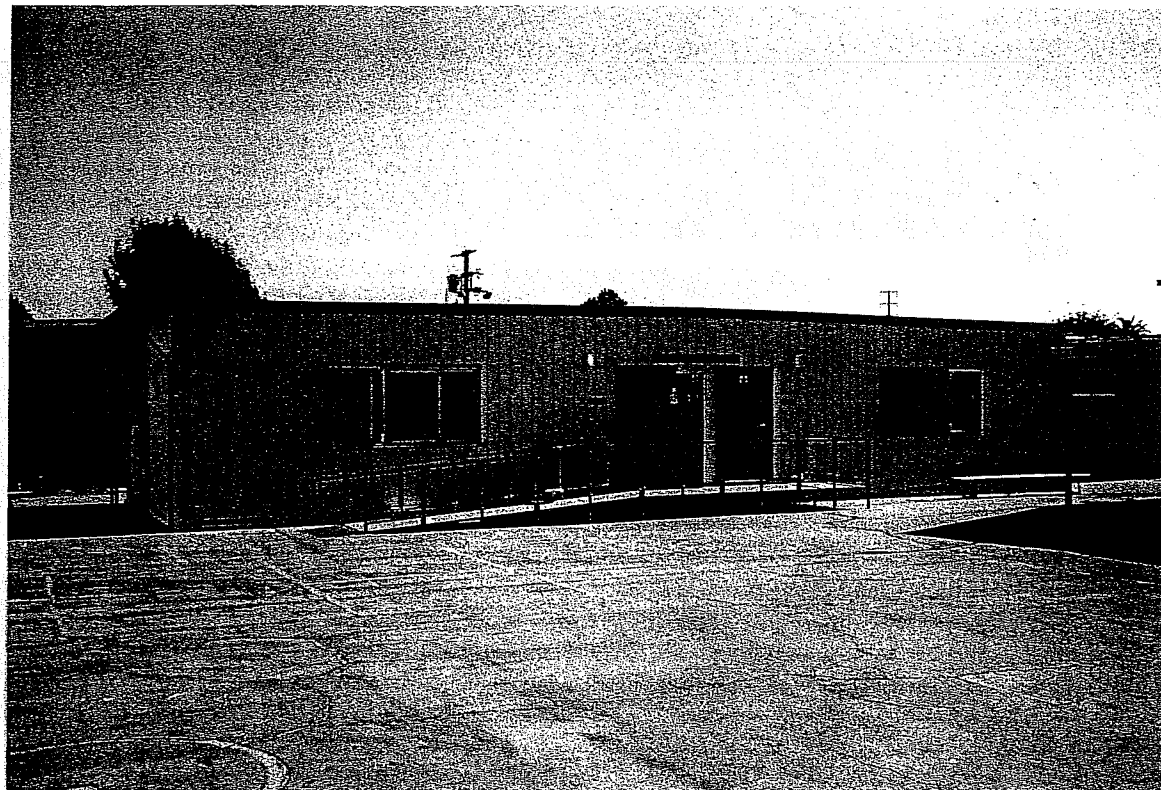
APPENDIX A.3

Pictures and Specifications, Portable/Relocatable Classrooms and HVAC Systems

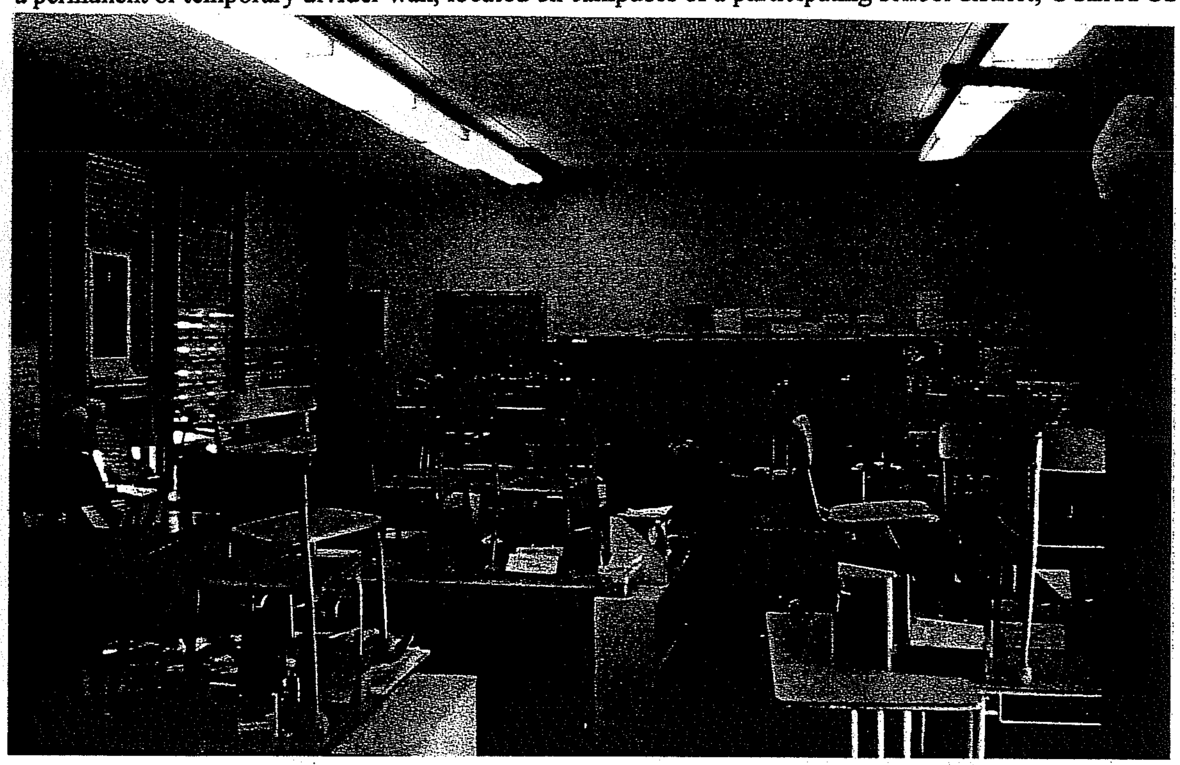
A.3.3. Typical portable classrooms, SD 1 and 2, UCLA PCS



A.3.3 (a-b) Typical newer portables located on campuses of participating school districts, UCLA PCS.



A.3.3 (C) Typical older, larger portable which had a wall-mount HVAC unit, split into two classrooms with a permanent or temporary divider wall, located on campuses of a participating school district, UCLA PCS.

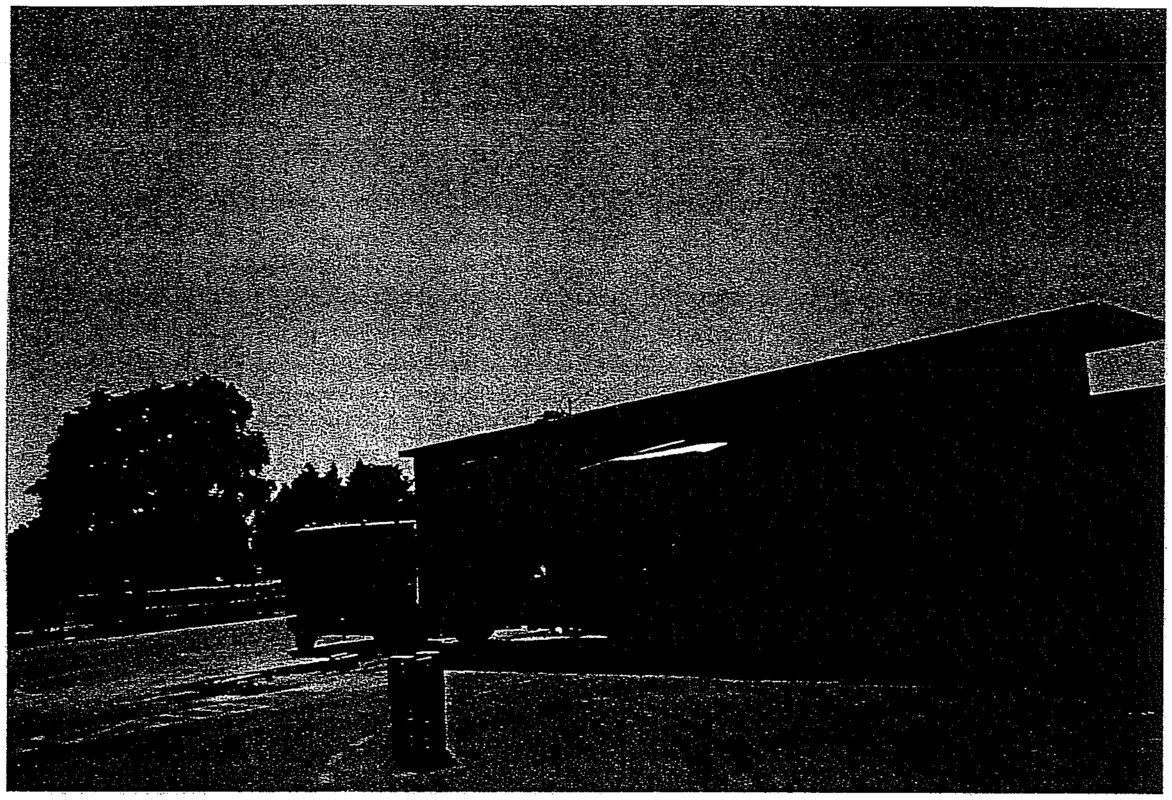


A.3.3 (d) Interior set-up of a typical very old portable located at participating school districts, UCLA PCS. Note how there was a wall-mount heater, powered by electricity or natural gas, but no air conditioning.

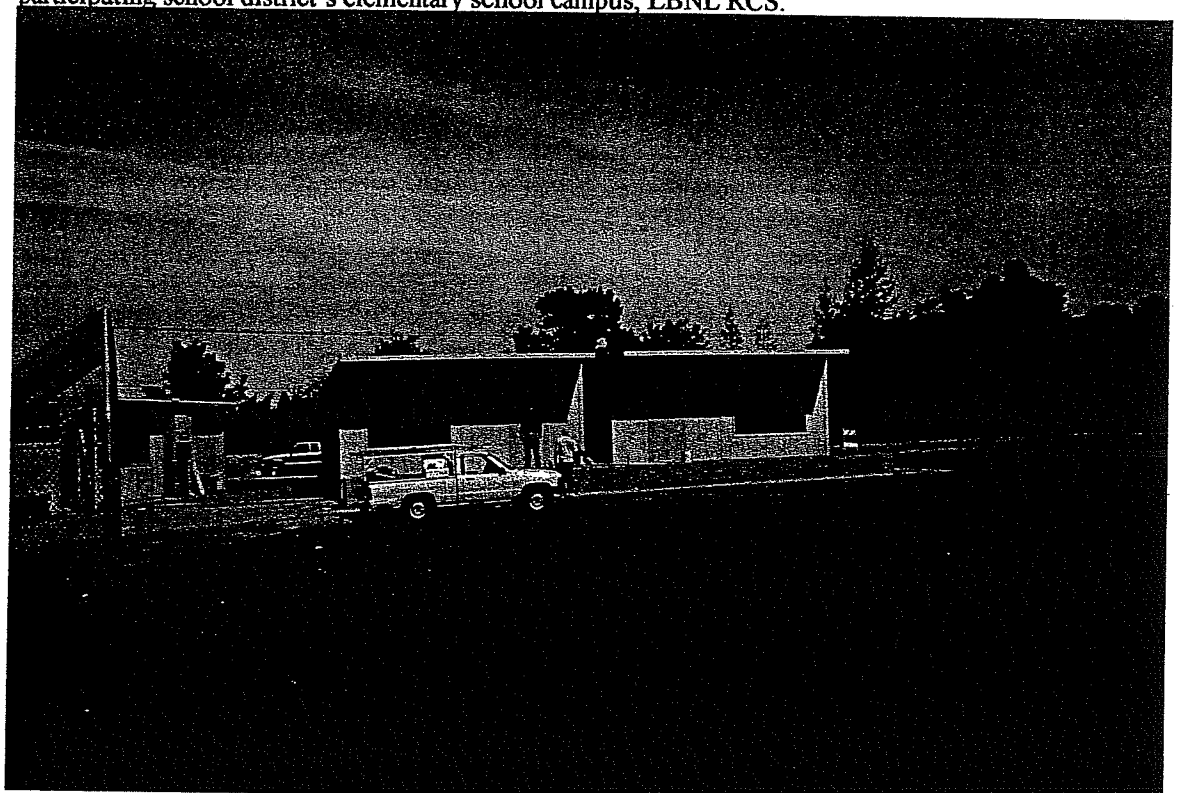
APPENDIX A.3

Pictures and Specifications, Portable/Relocatable Classrooms and HVAC Systems

A.3.4 Prototype relocatable classrooms, SD 3 and 4, LBNL RCS



A.3.4 (a) Delivery of a module, one of two comprising a new portable or RC, to a prepared site on a participating school district's elementary school campus, LBNL RCS.



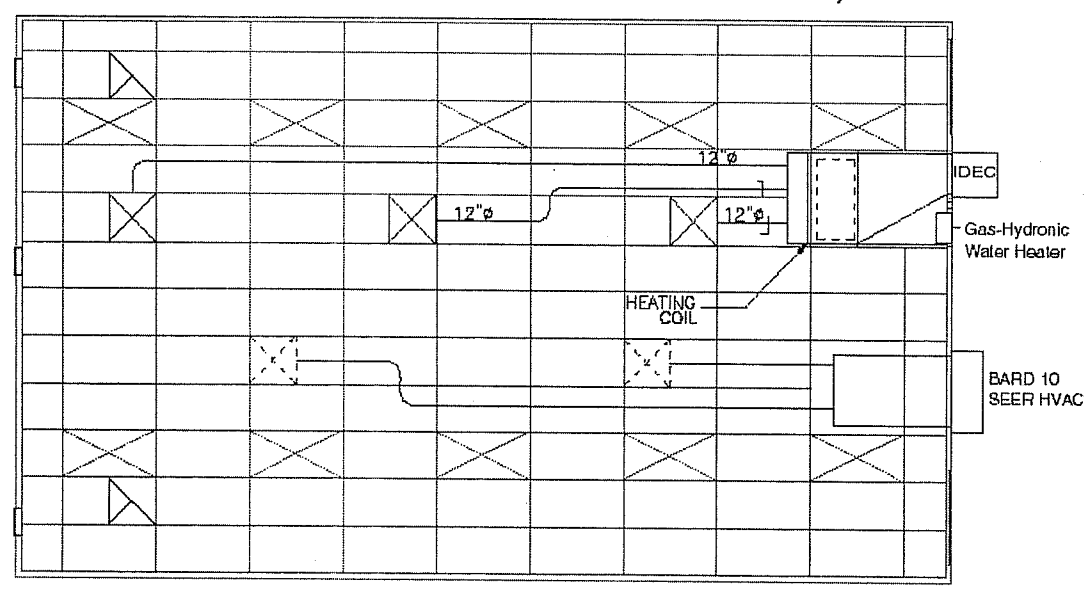
A.3.4 (b) Pair of new RCs, located side-by-side, LBNL RCS. They differed among SD by exterior colors.

APPENDIX A.3

Pictures and Specifications, Portable/Relocatable Classrooms and HVAC Systems

A.3.5 Architectural engineering drawing of HVAC systems and conditioned air delivery and relief, LBNL RCS

24'x40' Modular Relocatable Classroom with Conventional and Test HVAC Systems



APPENDIX A.4

Field Data and Related Calculations

A.4.1 VOC coding for raw data and SAS v.6.12 Microsoft Excel files

A.4.1 Coding used for target VOCs in raw data tables from collaborating laboratory at UT-Houston and in data files for SAS v.6.12 analyses, UCLA PCS measured concentrations, June 2000-June 2001.

Data Table Code	UT-H Code	Coding for SAS Analyses	Name of Compound
1	BUTDIE	BUTDIE	1,3-butadiene
2	METCHL	MetChl	methylene chloride
3	MTBE	MTBE	MTBE
4	CHLPRE	CHLPRE	chloroprene
5	CHLFRM	CHLFRM	chloroform
6	CARTET	CarTetCl	carbon tetrachloride
7	BENZEN	BENZENE	benzene
8	TRICHE	TRICHE	trichloroethylene
9	TOLUEN	TOLUENE	toluene
10	TETCHE	TetChlEt	tetrachloroethylene
11	ETHBEN	ETHBENZ	ethylbenzene
12	MP_XYLE	MP_XYLE	m-/p-xylene
13	NAPTHA	NAPTHA	naphthalene
14	O_XYLE	O_XYLE	o-xylene
15	STYREN	STYRENE	styrene
16	a-PINEN	a-PINENE	a-pinene
17	b-PINEN	b-PINENE	b-pinene
18	d-LIMON	d-LIMON	d-limonene
19	DCHBEN	DiChlBen	p-dichlorobenzene

APPENDIX A.4

Field Data and Related Calculations

A.4.2 AER measurements, SD 1 and 2, UCLA PCS

A.4.2.1 Calculation of average permeation rates (Rperm)
A.4.2.2 Calculation of AER by classroom by sampling event

A.4.2.1 Air Exchange Rate calculations, finding Rperm
UCLA PCS, BPUSD

A SUM OF 4 USED PFTs' AT 24 DEGREES C — for entire period of CAT exposure — AT X DEGREES C

School	Class-room #	Main Building (M.B.) or Portable (P)	Sampling /Visit#	# of PFTs used = N	ID #s of the PFTs used	Rperm, first PFT used	Rperm, second PFT used	Permeation Rate, Rperm	corrected Rperm	mean indoor T, degrees F	mean indoor T, degrees C	Rperm up 3% per degree C	Corrected Rperm, for mean indoor T
1	1	P	1	2	99-122, 99-149	-370	-397	-767	767	73.2	22.9	-25.567	741.4
1	0	M.B.	1	2	99-188, 99-150	-380	-399	-779	779	71.9	22.2	-42.845	736.2
2	1	P	1	2	99-123, 99-114	-450	-375	-825	825	68.5	20.3	-92.125	732.9
2	0	M.B.	1	2	99-121, 99-199	-371	-375	-746	746	71.3	21.8	-48.490	697.5
3	1	P	1	2	99-107, 99-109	-378	-373	-751	751	73.0	22.8	-27.537	723.5
3	2	P	1	2	99-108, 99-110	-391	-390	-781	781	78.3	25.7	40.352	821.4
3	3/Library	P	1	2	99-111, 99-113	-371	-382	-753	753	75.3	24.1	1.255	754.3
3	0	M.B.	1	2	99-049, 99-041	-420	-411	-831	831	72.9	22.7	-31.855	799.1
1--STUDY BLANK	n/a	Put in P. 22	1	2	99-122, 99-149	-370	-397	-767	767	73.2	22.9	-25.567	741.4
3--duplicate	3/Library	P	1	2	99-111, 99-113	-371	-382	-753	753	75.3	23.7	-6.275	746.7
1	1	P	2	2	00-071, 00-072	-450	-412	-862	862	74.7	23.7	-7.183	854.8
1	0	M.B.	2	2	00-073, 00-074	-400	-415	-815	815	70.5	21.4	-63.842	751.2
1--STUDY BLANK	n/a	Put in P. 22	2	2	00-071, 00-072	-450	-412	-862	862	74.7	23.7	-7.183	854.8
1--duplicate	1	P	2	2	00-071, 00-072	-450	-412	-862	862	74.7	23.7	-7.183	854.8
1	1	P	2	2	00-071, 00-072	-450	-412	-862	862	74.7	23.7	-7.183	854.8
1	0	M.B.	2	2	00-073, 00-074	-400	-415	-815	815	70.5	21.4	-63.842	751.2
1--duplicate	0	M.B.	2	2	00-073, 00-074	-400	-415	-815	815	70.5	21.4	-63.842	751.2
2	1	P	2	2	00-075, 00-076	-397	-388	-785	785	71.2	21.8	-52.333	732.7
2	0	M.B.	2	2	00-077, 00-078	-413	-379	-792	792	70.7	21.5	-59.400	732.6
2-- STUDY BLANK	n/a	Put in P. 30	2	2	00-075, 00-076	-397	-388	-785	785	71.2	21.8	-52.333	732.7
2	1	P	2	2	00-075, 00-076	-397	-388	-785	785	71.2	21.8	-52.333	732.7
2	0	M.B.	2	2	00-077, 00-078	-413	-379	-792	792	70.7	21.5	-59.400	732.6
3	1	P	2	2	00-081, 00-082	-402	-413	-815	815	72	22.2	-43.467	771.5
3	1	P	2	2	00-081, 00-082	-402	-413	-815	815	72	22.2	-43.467	771.5
3	2	P	2	2	00-083, 00-084	-401	-406	-807	807	75	23.9	-2.690	804.3
3	2	P	2	2	00-083, 00-084	-401	-406	-807	807	75	23.9	-2.690	804.3
3	3/Library	P	2	2	00-085, 00-086	-387	-427	-814	814	76.2	24.6	13.567	827.6
3	3/Library	P	2	2	00-085, 00-086	-387	-427	-814	814	76.2	24.6	13.567	827.6
3	0	M.B.	2	2	00-079, 00-080	-389	-404	-793	793	73.7	23.2	-19.825	773.2
3	0	M.B.	2	2	00-079, 00-080	-389	-404	-793	793	73.7	23.2	-19.825	773.2

A.4.2.1 Air Exchange Rate calculations, finding Rperm

UCLA PCS, LAUSD Region C

A SUM OF 4 USED PFTs' Rperm! AT 24 DEGREES C

for entire period of CAT exposure

AT X DEGREES C

School	Class-room #	Main Building (M.B.) or Portable (P)	Sampling Visit#	# of PFTs used = N	ID #s of the PFTs used	Rperm, first PFT used	Rperm, second PFT used	Permeation Rate, Rperm	corrected Rperm	mean indoor T, degrees F	mean indoor T, degrees C	Rperm up 3% per degree C	Corrected Rperm, for mean Indoor T
3	0	M.B.	1	2	00-007, 00-008	-436	-419	-855	855	79.1	26.2	55.575	910.6
3	2	P	1	2	00-011, 00-012	-386	-414	-800	800	73.1	22.8	-28.000	772.0
3	1	P	1	2	00-009, 00-010	-423	-397	-820	820	76.7	24.8	20.500	840.5
4	2	P	1	2	00-007, 00-008	-436	-419	-855	855	76.3	24.6	15.675	870.7
4	1	P	1	2	00-011, 00-012	-386	-414	-800	800	76.6	24.8	18.667	818.7
4	0	M.B.	1	2	00-009, 00-010	-423	-397	-820	820	75.1	23.9	-1.367	818.6
2	2	P	1	2	00-017, 00-018	-392	-410	-802	802	71.8	22.1	-45.447	756.6
2	1	P	1	2	00-013, 00-014	-421	-403	-824	824	72.2	22.3	-41.200	782.8
2	0	M.B.	1	2	00-015, 00-016	-408	-416	-824	824	76.3	24.6	15.107	839.1
2	2	P	1	2	00-017, 00-018	-392	-410	-802	802	71.8	24.6	14.703	816.7
2	0	M.B.	1	2	00-015, 00-016	-408	-416	-824	824	76.3	24.6	15.107	839.1
1	1	P	1	2	00-005, 00-006	-402	-420	-822	822	74.5	23.6	-9.590	812.4
1	2	P	1	2	00-003, 00-004	-390	-366	-756	756	73.0	22.8	-27.720	728.3
1	0	M.B.	1	2	00-001, 00-002	-398	-387	-785	785	75.7	24.3	6.542	791.5
3	0	M.B.	2	2	00-015, 00-016	-409	-416	-825	825	65.8	18.8	-129.250	695.8
3	0	M.B.	2	2	00-015, 00-016	-409	-416	-825	825	65.8	18.8	-129.250	695.8
3	2	P	2	2	00-019, 00-020	-424	-411	-835	835	66.8	19.3	-116.900	718.1
3	2	P	2	2	00-019, 00-020	-424	-411	-835	835	66.8	19.3	-116.900	718.1
3	1	P	2	2	00-017, 00-018	-393	-413	-806	806	62.0	16.7	-177.320	628.7
3	1	P	2	2	00-017, 00-018	-393	-413	-806	806	62.0	16.7	-177.320	628.7
2	2	P	2	2	00-005, 00-006	-405	-422	-827	827	67.5	19.7	-106.132	720.9
2	2	P	2	2	00-005, 00-006	-405	-422	-827	827	67.5	19.7	-106.132	720.9
2	2	P	2	2	00-005, 00-006	-405	-422	-827	827	67.5	19.7	-106.132	720.9
2	1	P	2	2	00-003, 00-004	-391	-364	-755	755	65.7	18.7	-119.542	635.5
2	1	P	2	2	00-003, 00-004	-391	-364	-755	755	65.7	18.7	-119.542	635.5
2	1	P	2	2	00-003, 00-004	-391	-364	-755	755	65.7	18.7	-119.542	635.5
2	0	M.B.	2	2	00-002, 00-001	-390	-399	-789	789	68.6	20.3	-86.790	702.2
2	0	M.B.	2	2	00-002, 00-001	-390	-399	-789	789	68.6	20.3	-86.790	702.2
2	0	M.B.	2	2	00-002, 00-001	-390	-399	-789	789	68.6	20.3	-86.790	702.2
1	1	P	2	2	00-013, 00-014	-421	-404	-825	825	70.5	21.4	-64.625	760.4
1	1	P	2	2	00-013, 00-014	-421	-404	-825	825	70.5	21.4	-64.625	760.4
1	1	P	2	2	00-013, 00-014	-421	-404	-825	825	70.5	21.4	-64.625	760.4
1	2	P	2	2	00-009, 00-010	-424	-398	-822	822	67.8	19.9	-101.380	720.6
1	2	P	2	2	00-009, 00-010	-424	-398	-822	822	67.8	19.9	-101.380	720.6
1	0	M.B.	2	2	00-011, 00-012	-389	-412	-801	801	66.9	19.4	-110.805	690.2
1	0	M.B.	2	2	00-011, 00-012	-389	-412	-801	801	66.9	19.4	-110.805	690.2

A.4.2.2 Air Exchange Rate calculations (corrected)

UCLA PCS-- BPUSD

School	Class-room #	Main Building (M.B.) or Portable (P)	Sampling/ Visit#	Number of PFTs used = N	ID #s of PFTs used	Permeation Rate, Rperm (FINAL, i.e., T corrected, in ng./min.)	ID# of CAT used	CAT collection rate, Rcat (0.008308*2, since two ends in L/hr.) <- NUMERATOR	CAT exposure time, Tcat (in minutes)	Classroom Volume, ft.3 (main living area) DENOMINATOR ->	Classroom Volume, L	Volume of PMCH (PFT) on CAT, pL	Volume PMCH, ng	**AER, 1/hr**
1	1	P	1	2	99-122, 99-149	741.4	13623	0.016616	6267	7554.4	213789.5	154.68	2.21	**0.2**
1	0	M.B.	1	2	99-168, 99-150	736.2	15180	0.016616	6269	8231.8	232959.9	17.58	0.25	**1.3**
2	1	P	1	2	99-123, 99-114	732.9	12729	0.016616	6188	11805.4	334092.8	177.86	2.55	**0.1**
2	0	M.B.	1	2	99-121, 99-199	697.5	336	0.016616	6193	9695.8	274391.1	38.55	0.55	**0.5**
3	1	P	1	2	99-107, 99-109	723.5	10074	0.016616	6130	7826.8	221498.4	202	2.89	**0.1**
3	2	P	1	2	99-108, 99-110	821.4	16752	0.016616	6135	11067	313196.1	45.9	0.66	**0.4**
3	3/Library	P	1	2	99-111, 99-113	754.3	3736	0.016616	6226	13650.3	386303.5	36.5	0.52	**0.4**
3	0	M.B.	1	2	99-049, 99-041	799.1	347	0.016616	6123	8224.2	232744.9	64.59	0.92	**0.4**
1-- STUDY BLANK	1	P	1	2	99-122, 99-149	741.4	15354	0.016616	0	7554.4	213789.5	0.32	0.00	**0.0**
Lab and field blanks were good.														
3-- duplicate	3/Library	P	1	2	99-111, 99-113	746.7	10109	0.016616	6226	13650.3	386303.5	36.4	0.52	**0.4**

Duplicates in perfect agreement.

A.4.2.2 Air Exchange Rate calculations (corrected)

UCLA PCS-- BPUSD

<- NUMERATOR DENOMINATOR ->

Permeation Rate: FINAL, i.e., T corrected, in ng./min.

CAT collection rate: 0.008308*2, since two ends in L/hr.

CAT exposure time: in minutes

Classroom Volume: (main living area)

School	Class-room #	Main Building (M.B.) or Portable (P)	Sampling/ Visit# a = SWIA, b = SDIA	Number of PFTs used = N	ID #s of PFTs used	Permeation Rate, Rperm	ID# of CAT used	CAT collection rate, Rcat	CAT exposure time, Tcat	Classroom Volume, ft.3	Classroom Volume, L	Volume of PMCH (PFT) on CAT, pL	Volume PMCH, ng	AER, 1/hr
1	1	P	b2	2	00-071, 00-072	854.8	3018	0.016616	2505	7554.4	213789.5	15.20	0.22	**0.8**
1	0	M.B.	b2	2	00-073, 00-074	751.2	10276	0.016616	2551	8231.8	232959.9	10.60	0.15	**0.9**
1	n/a	Put in P. 22	2	2	n/a	854.8	772	0.016616	0	7554.4	213789.5	0.30	0.00	**0.0**
1	1	P	b2	2	00-071, 00-072	854.8	7061	0.016616	2506	7554.4	213789.5	15.80	0.23	**0.7**
1	1	P	a2	2	00-071, 00-072	854.8	18266	0.016616	6262	7554.4	213789.5	120.40	1.72	**0.2**
1	0	M.B.	a2	2	00-073, 00-074	751.2	551	0.016616	6285	8231.8	232959.9	38.50	0.55	**0.6**
1	0	M.B.	a2	2	00-073, 00-074	751.2	296	0.016616	6285	8231.8	232959.9	38.80	0.56	**0.6**
2	1	P	b2	2	00-075, 00-076	732.7	10295	0.016616	2215	11805.4	334092.8	37.50	0.54	**0.2**
2	0	M.B.	b2	2	00-077, 00-078	732.6	7954	0.016616	2240	9695.8	274391.1	11.50	0.16	**0.6**
2	1	Put in P. 30	2	2	n/a	732.7	6150	0.016616	0	11805.4	334092.8	0.00	0.00	**0.0**
2	1	P	a2	2	00-075, 00-076	732.7	6179	0.016616	6180	11805.4	334092.8	96.40	1.38	**0.2**
2	0	M.B.	a2	2	00-077, 00-078	732.6	9826	0.016616	6210	9695.8	274391.1	45.20	0.65	**0.4**
3	1	P	a2	2	00-081, 00-082	771.5	17687	0.016616	6218	7826.8	221498.4	282.50	4.04	**0.1**
3	1	P	b2	2	00-081, 00-082	771.5	15085	0.016616	2361	7826.8	221498.4	101.10	1.45	**0.1**
3	2	P	a2	2	00-083, 00-084	804.3	8074	0.016616	6240	11067	313196.1	57.60	0.82	**0.3**
3	2	P	b2	2	00-083, 00-084	804.3	18164	0.016616	2372	11067	313196.1	16.20	0.23	**0.4**
3	3/Library	P	a2	2	00-085, 00-086	827.6	8198	0.016616	6227	13650.3	386303.5	26.50	0.38	**0.6**
3	3/Library	P	b2	2	00-085, 00-086	827.6	16853	0.016616	2350	13650.3	386303.5	4.50	0.06	**1.3**
3	0	M.B.	a2	2	00-079, 00-080	773.2	7865	0.016616	6228	8224.2	232744.9	69.00	0.99	**0.3**
3	0	M.B.	b2	2	00-079, 00-080	773.2	10472	0.016616	2393	8224.2	232744.9	5.00	0.07	**1.8**

First duplicate pair in good agreement,
second duplicate pair in perfect agreement.
Lab and field blanks were good.

A.4.2.2 Air Exchange Rate calculations (corrected)

UCLA PCS-- LAUSD Region C

FINAL, i.e., T corrected, in ng./min. — 0.008308*2, since two ends in L/hr. — <- NUMERATOR — in minutes — (main living area) — DENOMINATOR ->

School	Class-room #	Main Building (M.B.) or Portable (P)	Sampling/ Visit#	Number of PFTs used = N	ID #s of PFTs used	Permeation Rate, Rperm	ID# of CAT used	CAT collection rate, Rcat	CAT exposure time, Tcat	Classroom Volume, ft.3	Classroom Volume, L	Volume of PMCH (PFT) on CAT, pL	Volume PMCH, ng	AER, 1/hr
3	0	M.B.	1	2	00-007, 00-008	910.6	7276	0.016616	6229	9245.8	261656.1	78.76	1.13	**0.3**
3	2	P	1	2	00-011, 00-012	772.0	8888	0.016616	6226	12042.2	340794.3	76.5	1.10	**0.2**
3	1	P	1	2	00-009, 00-010	840.5	16295	0.016616	6226	6958.3	196919.9	5.73	0.08	**5.4**
4	2	P	1	2	00-007, 00-008	870.7	9149	0.016616	6253	9160.2	259233.7	27.06	0.39	**0.9**
4	1	P	1	2	00-011, 00-012	818.7	7200	0.016616	6261	8834.4	250013.5	17.66	0.25	**1.3**
4	0	M.B.	1	2	00-009, 00-010	818.6	9180	0.016616	6252	12559	355419.7	4.4	0.06	**3.8**
2	2	P	1	2	00-017, 00-018	756.6	9160	0.016616	6257	12707.6	359625.1	45.97	0.66	**0.3**
2	1	P	1	2	00-013, 00-014	782.8	11078	0.016616	6257	11339	320893.7	76	1.09	**0.2**
2	0	M.B.	1	2	00-015, 00-016	839.1	9230	0.016616	6261	9614.8	272098.8	73.39	1.05	**0.3**
2--duplicate	2	P	1	2	00-017, 00-018	816.7	11017	0.016616	6257	12707.6	359625.1	50.16	0.72	**0.3**
2--BLANK	0	M.B.	1	2	00-015, 00-016	839.1	15738	0.016616	0	9614.8	272098.8	0	0.00	**0.0**
1	1	P	1	2	00-005, 00-006	812.4	18284	0.016616	6149	20860	590338.0	45.4	0.65	**0.2**
1	2	P	1	2	00-003, 00-004	728.3	9212	0.016616	6169	13938.4	394456.7	72.74	1.04	**0.2**
1	0	M.B.	1	2	00-001, 00-002	791.5	18532	0.016616	6193	7273.8	205848.5	49.7	0.71	**0.6**

Duplicates in perfect agreement.
Lab and field blanks were good.

A.4.2.2 Air Exchange Rate calculations (corrected)

UCLA PCS-- LAUSD Region C

<- NUMERATOR DENOMINATOR ->

Permeation Rate: FINAL, i.e., T corrected, in ng./min.
CAT collection rate: 0.008308*2, since two ends in L/hr.
CAT exposure time: in minutes
Classroom Volume, ft.3: (main living area)

School	Class-room #	Main Building (M.B.) or Portable (P)	Sampling/ Visit#	Number of PFTs used = N	ID #s of PFTs used	Permeation Rate, Rperm	ID# of CAT used	CAT collection rate, Rcat	CAT exposure time, Tcat	Classroom Volume, ft.3	Classroom Volume, L	Volume of PMCH (PFT) on CAT, pL	Volume PMCH, ng	AER, 1/hr
			a = SWIA, b = SDIA											
3	0	M.B.	a2	2	00-015, 00-016	695.8	8975	0.016616	6213	9245.8	261656.1	52.00	0.74	**0.4**
3	0	M.B.	b2	2	00-015, 00-016	695.8	6387	0.016616	2349	9245.8	261656.1	13.00	0.19	**0.6**
3	2	P	a2	2	00-019, 00-020	718.1	13378	0.016616	6218	12042.2	340794.3	106.00	1.52	**0.1**
3	2	P	b2	2	00-019, 00-020	718.1	9245	0.016616	2389	12042.2	340794.3	35.00	0.50	**0.2**
3	1	P	a2	2	00-017, 00-018	628.7	15743	0.016616	6210	6958.3	196919.9	17.00	0.24	**1.4**
3	1	P	b2	2	00-017, 00-018	628.7	9020	0.016616	2345	6958.3	196919.9	3.00	0.04	**2.9**
2	2	P	a2	2	00-005, 00-006	720.9	15879	0.016616	6219	12707.6	359625.1	63.00	0.90	**0.2**
2--duplicate	2	P	a2	2	00-005, 00-006	720.9	9273	0.016616	6219	12707.6	359625.1	60.00	0.86	**0.2**
2	2	P	b2	2	00-005, 00-006	720.9	9211	0.016616	2380	12707.6	359625.1	16.00	0.23	**0.3**
2	1	P	a2	2	00-003, 00-004	635.5	15948	0.016616	6225	11339	320893.7	83.00	1.19	**0.2**
2	1	P	b2	2	00-003, 00-004	635.5	6678	0.016616	2381	11339	320893.7	19.00	0.27	**0.3**
2--duplicate	1	P	b2	2	00-003, 00-004	635.5	19014	0.016616	2381	11339	320893.7	15.00	0.21	**0.4**
2	0	M.B.	q2	2	00-002, 00-001	702.2	7056	0.016616	6262	9614.8	272098.8	66.00	0.94	**0.3**
2	0	M.B.	b2	2	00-002, 00-001	702.2	8461	0.016616	2434	9614.8	272098.8	14.00	0.20	**0.5**
2--BLANK	0	M.B.	2	2	00-002, 00-001	702.2	15700	0.016616	0	9614.8	272098.8	0.00	0.00	**0.0**
1	1	P	a2	2	00-013, 00-014	760.4	9081	0.016616	6225	20860	590338.0	45.00	0.64	**0.2**
1	1	P	b2	2	00-013, 00-014	760.4	5283	0.016616	2364	20860	590338.0	14.00	0.20	**0.3**
1--BLANK	1	P	2	2	00-013, 00-014	760.4	7494	0.016616	0	20860	590338.0	0.00	0.00	**0.0**
1	2	P	a2	2	00-009, 00-010	720.6	11035	0.016616	6212	13938.4	394456.7	59.00	0.84	**0.2**
1	2	P	b2	2	00-009, 00-010	720.6	18669	0.016616	2356	13938.4	394456.7	10.00	0.14	**0.5**
1	0	M.B.	a2	2	00-011, 00-012	690.2	15956	0.016616	6228	7273.8	205848.5	38.00	0.54	**0.6**
1	0	M.B.	b2	2	00-011, 00-012	690.2	11045	0.016616	2421	7273.8	205848.5	8.00	0.11	**1.2**

First duplicate pair in good agreement,
second duplicate pair in perfect agreement.
Lab and field blanks were good.

APPENDIX A.4

Field Data and Related Calculations

A.4.3 Using final measured concentrations (SWIA, SDIA) to interpolate concentrations during overnight, unoccupied hours (OUPIA), UCLA PCS

A.4.3.1 SD 1, main building control classrooms
A.4.3.2 SD 1, portable classrooms
A.4.3.3 SD 2, main building control classrooms
A.4.3.4 SD 2, portable classrooms

A.4.3.1 Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD A Main Building Control Classrooms, UCLA PCS.

NOTE: for DNSH aldehyde samples with duplicates, used average concentration of pair

Compound or Measure	School #, Classroom Type & #	Sampling # or Season	SWIA	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR)	INTERPOLATED OUPIA, 2nd sampling	INTERPOLATED OUPIA 1st sampling	INTERPOLATED SDIA, 1st sampling
	(#, M,B, or F, #)	(1 or 2)	(conc. in ug/m3, AER in hr-1)				SDIA sampling duration/SWIA sampling duration	(SWIA - (SDR*SDIA)) / (1-SDR)	L(x-1)*D(x)	(SWIA -(OUPIA 1st sampling)*(1-SDR))/SDR
H2CO	1, MB, 1	2	15.42	6291	12.02	2556	0.41	17.75	n/a	n/a
		1	12.98	6273	n/a	n/a	0.41	n/a	14.94	10.12
H2CO	2, MB, 1	2	17.43	6211	17.01	2242	0.36	17.67	n/a	n/a
		1	14.04	6193	n/a	n/a	0.36	n/a	14.23	13.70
H2CO	3, MB, 1	2	14.59	6231	15.76	2397	0.38	13.86	n/a	n/a
		1	19.6	6123	n/a	n/a	0.38	n/a	18.62	21.17
CH3CHO	1, MB, 1	2	5.91	6291	8.62	2556	0.41	4.06	n/a	n/a
		1	0.08	6273	n/a	n/a	0.41	n/a	0.05	0.12
CH3CHO	2, MB, 1	2	8.53	6211	13.48	2242	0.36	5.73	n/a	n/a
		1	1.71	6193	n/a	n/a	0.36	n/a	1.15	2.70
CH3CHO	3, MB, 1	2	6.06	6231	8.12	2397	0.38	4.77	n/a	n/a
		1	0.82	6123	n/a	n/a	0.38	n/a	0.65	1.10
AER	1, MB, 1	2	0.6	6285	0.9	2551	0.41	0.4	n/a	n/a
		1	1.3	6269	n/a	n/a	0.41	n/a	0.9	1.9
AER	2, MB, 1	2	0.4	6210	0.6	2240	0.36	0.3	n/a	n/a
		1	0.5	6193	n/a	n/a	0.36	n/a	0.4	0.7
AER	3, MB, 1	2	0.4	6228	1.9	2393	0.38	-0.6	n/a	n/a
		1	0.4	6123	n/a	n/a	0.38	n/a	-0.6	2.0
VOC 2	1, MB, 1	2	0.51	6288	0.83	2552	0.41	0.29	n/a	n/a
		1	0.062	6274	n/a	n/a	0.41	n/a	0.04	0.10
VOC 2	2, MB, 1	2	0.51	6213	1.13	2243	0.36	0.16	n/a	n/a
		1	0.693	6195	n/a	n/a	0.36	n/a	0.22	1.54
VOC 2	3, MB, 1	2	0.55	6231	1.14	2395	0.38	0.18	n/a	n/a
		1	0.749	6119	n/a	n/a	0.38	n/a	0.25	1.55
VOC 3	1, MB, 1	2	4.44	6288	4.73	2552	0.41	4.24	n/a	n/a
		1	0.316	6274	n/a	n/a	0.41	n/a	0.30	0.34
VOC 3	2, MB, 1	2	4.68	6213	5.26	2243	0.36	4.35	n/a	n/a
		1	5.246	6195	n/a	n/a	0.36	n/a	4.88	5.90
VOC 3	3, MB, 1	2	4.68	6231	5.29	2395	0.38	4.30	n/a	n/a
		1	4.363	6119	n/a	n/a	0.38	n/a	4.01	4.93
VOC 6	1, MB, 1	2	0.44	6288	0.53	2552	0.41	0.38	n/a	n/a
		1	0	6274	n/a	n/a	0.41	n/a	0.00	0.00
VOC 6	2, MB, 1	2	0.45	6213	0.51	2243	0.36	0.42	n/a	n/a
		1	0.417	6195	n/a	n/a	0.36	n/a	0.39	0.47
VOC 6	3, MB, 1	2	0.41	6231	0.59	2395	0.38	0.30	n/a	n/a
		1	0.419	6119	n/a	n/a	0.38	n/a	0.30	0.60

A.4.3.1 (CONTINUED): Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD A Main Building Control Classrooms, UCLA PCS.

VOC 9 (toluene) not included because < MDL-SWIA 1st sampling	(#, M.B. or P. #)	(1 or 2)	(conc. in ug/m3; AER in hr-1)			VOC 15 and 17 not included < MDL @ 2nd and 1st sampling respectively	SDIA sampling duration/SWIA sampling duration	INTERPOLATED (SWIA-(SDR*SDIA)) /(1-SDR)	INTERPOLATED L(x-1)*D(x)	INTERPOLATED (SWIA-(OUPIA 1st sampling)*(1-SDR))/SDR
Compound or Measure	School #, Classroom Type & #	Sampling # or Season	SWIA	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR)	OUPIA 2nd sampling	OUPIA 1st sampling	SDIA 1st sampling
VOC 7	1, MB, 1	2	1.48	6288	1.34	2552	0.41	1.58	n/a	n/a
		1	0.001	6274	n/a	n/a	0.41	n/a	0.00	0.00
VOC 7	2, MB, 1	2	1.39	6213	1.49	2243	0.36	1.33	n/a	n/a
		1	1.427	6195	n/a	n/a	0.36	n/a	1.37	1.53
VOC 7	3, MB, 1	2	2.37	6231	2.17	2395	0.38	2.49	n/a	n/a
		1	2.194	6119	n/a	n/a	0.38	n/a	2.31	2.01
VOC 10	1, MB, 1	2	0.79	6288	0.94	2552	0.41	0.69	n/a	n/a
		1	0.033	6274	n/a	n/a	0.41	n/a	0.03	0.04
VOC 10	2, MB, 1	2	0.81	6213	1.12	2243	0.36	0.63	n/a	n/a
		1	0.887	6195	n/a	n/a	0.36	n/a	0.70	1.23
VOC 10	3, MB, 1	2	1.09	6231	1.24	2395	0.38	1.00	n/a	n/a
		1	0.63	6119	n/a	n/a	0.38	n/a	0.58	0.72
VOC 11	1, MB, 1	2	0.86	6288	0.97	2552	0.41	0.78	n/a	n/a
		1	0.067	6274	n/a	n/a	0.41	n/a	0.06	0.08
VOC 11	2, MB, 1	2	0.91	6213	1.08	2243	0.36	0.81	n/a	n/a
		1	1.136	6195	n/a	n/a	0.36	n/a	1.02	1.35
VOC 11	3, MB, 1	2	0.96	6231	1.07	2395	0.38	0.89	n/a	n/a
		1	0.724	6119	n/a	n/a	0.38	n/a	0.67	0.81
VOC 12	1, MB, 1	2	2.73	6288	2.94	2552	0.41	2.59	n/a	n/a
		1	0.258	6274	n/a	n/a	0.41	n/a	0.24	0.28
VOC 12	2, MB, 1	2	2.96	6213	3.23	2243	0.36	2.81	n/a	n/a
		1	3.582	6195	n/a	n/a	0.36	n/a	3.40	3.91
VOC 12	3, MB, 1	2	2.51	6231	2.96	2395	0.38	2.23	n/a	n/a
		1	2.461	6119	n/a	n/a	0.38	n/a	2.19	2.90
VOC 14	1, MB, 1	2	0.98	6288	1.03	2552	0.41	0.95	n/a	n/a
		1	0.079	6274	n/a	n/a	0.41	n/a	0.08	0.08
VOC 14	2, MB, 1	2	1.09	6213	1.23	2243	0.36	1.01	n/a	n/a
		1	1.392	6195	n/a	n/a	0.36	n/a	1.29	1.57
VOC 14	3, MB, 1	2	0.88	6231	1.09	2395	0.38	0.75	n/a	n/a
		1	1.237	6119	n/a	n/a	0.38	n/a	1.05	1.53
VOC 16	1, MB, 1	2	0.3	6288	0.36	2552	0.41	0.26	n/a	n/a
		1	0.034	6274	n/a	n/a	0.41	n/a	0.03	0.04
VOC 16	2, MB, 1	2	0.57	6213	0.68	2243	0.36	0.51	n/a	n/a
		1	0.481	6195	n/a	n/a	0.36	n/a	0.43	0.57
VOC 16	3, MB, 1	2	0.5	6231	0.43	2395	0.38	0.54	n/a	n/a
		1	0.597	6119	n/a	n/a	0.38	n/a	0.65	0.51
VOC 19	1, MB, 1	2	0.44	6288	0.66	2552	0.41	0.29	n/a	n/a
		1	0.15	6274	n/a	n/a	0.41	n/a	0.10	0.23
VOC 19	2, MB, 1	2	0.29	6213	0.28	2243	0.36	0.30	n/a	n/a
		1	0.777	6195	n/a	n/a	0.36	n/a	0.79	0.75
VOC 19	3, MB, 1	2	2.2	6231	3.18	2395	0.38	1.59	n/a	n/a
		1	1.218	6119	n/a	n/a	0.38	n/a	0.88	1.76

A.4.3.2 Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD A Portable Classrooms, UCLA PCS.
NOTE: for VOC and DNSH aldehyde samples with duplicates, used average concentration of pair

	(#, M,B, or P, #)	(1 or 2)	(conc. in ug/m3, AER in hr-1)				SDIA sampling duration/SWIA sampling duration	INTERPOLATED (SWIA - (SDR*SDIA)) / (1-SDR)	INTERPOLATED L(x-1)*D(x)	INTERPOLATED (SWIA -(OUPIA 1st sampling)*(1-SDR))/SDR
Compound or Measure	School #, Classroom Type & #	Sampling # or Season	SWIA	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR)	OUPIA, 2nd sampling	OUPIA 1st sampling	SDIA, 1st sampling
H2CO	1, P, 1	2	19.59	6259	18.20	2504	0.40	20.52	n/a	n/a
		1	55.19	6271	n/a	n/a	0.40	n/a	57.80	51.27
H2CO	2, P, 1	2	17.73	6175	21.05	2211	0.36	15.88	n/a	n/a
		1	19.36	6188	n/a	n/a	0.36	n/a	17.34	22.99
H2CO	3, P, 1	2	19.41	6217	16.70	2363	0.38	21.07	n/a	n/a
		1	27.31	6130	n/a	n/a	0.38	n/a	29.65	23.50
H2CO	3, P, 2	2	15.66	6244	17.39	2373	0.38	14.60	n/a	n/a
		1	23.14	6131	n/a	n/a	0.38	n/a	21.57	25.70
H2CO	3, P, 3/LIB	2	16.78	6225	14.90	2380	0.38	17.94	n/a	n/a
		1	18.98	6228	n/a	n/a	0.38	n/a	20.30	16.85
CH3CHO	1, P, 1	2	6.02	6259	8.19	2504	0.40	4.57	n/a	n/a
		1	11.57	6271	n/a	n/a	0.40	n/a	8.79	15.74
CH3CHO	2, P, 1	2	11.67	6175	14.55	2211	0.36	10.06	n/a	n/a
		1	20.06	6188	n/a	n/a	0.36	n/a	17.30	25.01
CH3CHO	3, P, 1	2	11.67	6217	12.94	2363	0.38	10.89	n/a	n/a
		1	25.29	6130	n/a	n/a	0.38	n/a	23.60	28.04
CH3CHO	3, P, 2	2	6.09	6244	8.77	2373	0.38	4.45	n/a	n/a
		1	0.75	6131	n/a	n/a	0.38	n/a	0.55	1.08
CH3CHO	3, P, 3/LIB	2	5.18	6225	6.85	2380	0.38	4.15	n/a	n/a
		1	3.3	6228	n/a	n/a	0.38	n/a	2.64	4.36
AER	1, P, 1	2	0.2	6262	0.8	2505	0.40	-0.1	n/a	n/a
		1	0.2	6267	n/a	n/a	0.40	n/a	-0.1	0.5
AER	2, P, 1	2	0.2	6180	0.2	2215	0.36	0.2	n/a	n/a
		1	0.1	6188	n/a	n/a	0.36	n/a	0.1	0.1
AER	3, P, 1	2	0.1	6218	0.1	6218	1.00	0.0	n/a	n/a
		1	0.1	6130	n/a	n/a	1.00	n/a	0.0	0.1
AER	3, P, 2	2	0.3	6240	0.4	2372	0.38	0.2	n/a	n/a
		1	0.4	6135	n/a	n/a	0.38	n/a	0.3	0.6
AER	3, P, 3/LIB	2	0.6	6227	1.3	2350	0.38	0.1	n/a	n/a
		1	0.4	6226	n/a	n/a	0.38	n/a	0.1	0.9

A.4.3.2 (CONTINUED): Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD A Portable Classrooms, UCLA PCS.

NOTE: for VOC samples with duplicates, used average concentration of pair

used/regarding 1stsampling data ---->>

Compound or Measure	School #, Classroom Type & #	Sampling # or Season	SWIA	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR)	OUPIA, 2nd sampling	OUPIA 1st sampling	SDIA, 1st sampling
	(#, M.B. or P, #)	(1 or 2)	(conc. in ug/m3, AER in hr-1)				SDIA sampling duration/SWIA sampling duration	INTERPOLATED (SWIA - (SDR*SDIA)) / (1-SDR)	INTERPOLATED L(x-1)*D(x)	INTERPOLATED (SWIA -(OUPIA 1st sampling)*(1-SDR))/SDR
VOC 2	1, P, 1	2	0.66	6260	0.98	2496	0.40	0.45	n/a	n/a
		1	0.75	6272	n/a	n/a	0.40	n/a	0.51	1.12
VOC 2	2, P, 1	2	0.62	6189	0.84	2225	0.36	0.50	n/a	n/a
		1	1.06	6184	n/a	n/a	0.36	n/a	0.85	1.44
VOC 2	3, P, 1	2	0.33	6220	1.89	2358	0.38	-0.62	n/a	n/a
		1	0.88	6132	n/a	n/a	0.38	n/a	-1.66	5.03
VOC 2	3, P, 2	2	0.57	6241	0.96	2368	0.38	0.33	n/a	n/a
		1	0.81	6132	n/a	n/a	0.38	n/a	0.47	1.37
VOC 2	3, P, 3/LIB	2	0.57	6227	1.10	2349	0.38	0.25	n/a	n/a
		1	0.76	6220	n/a	n/a	0.38	n/a	0.33	1.46
VOC 3	1, P, 1	2	4.41	6260	4.71	2496	0.40	4.21	n/a	n/a
		1	4.97	6272	n/a	n/a	0.40	n/a	4.75	5.31
VOC 3	2, P, 1	2	4.66	6189	4.56	2225	0.36	4.72	n/a	n/a
		1	5.12	6184	n/a	n/a	0.36	n/a	5.18	5.01
VOC 3	3, P, 1	2	1.71	6220	11.44	2358	0.38	-4.23	n/a	n/a
		1	4.75	6132	n/a	n/a	0.38	n/a	-11.75	31.77
VOC 3	3, P, 2	2	4.27	6241	4.56	2368	0.38	4.09	n/a	n/a
		1	5.66	6132	n/a	n/a	0.38	n/a	5.43	6.05
VOC 3	3, P, 3/LIB	2	5.67	6227	5.47	2349	0.38	5.79	n/a	n/a
		1	4.87	6220	n/a	n/a	0.38	n/a	4.97	4.70
VOC 5	1, P, 1	2	0.00	6260	0.00	2496	0.40	0.00	n/a	n/a
		1	0.16	6272	n/a	n/a	0.40	n/a	0.00	0.41
VOC 5	2, P, 1	2	0.20	6189	0.00	2225	0.36	0.31	n/a	n/a
		1	0.10	6184	n/a	n/a	0.36	n/a	0.16	0.00
VOC 5	3, P, 1	2	0.11	6220	0.31	2358	0.38	-0.01	n/a	n/a
		1	0.28	6132	n/a	n/a	0.38	n/a	-0.03	0.78
VOC 5	3, P, 2	2	0.15	6241	1.00	2368	0.38	-0.37	n/a	n/a
		1	0.18	6132	n/a	n/a	0.38	n/a	-0.44	1.18
VOC 5	3, P, 3/LIB	2	0.00	6227	0.00	2349	0.38	0.00	n/a	n/a
		1	0.00	6220	n/a	n/a	0.38	n/a	0.00	0.00

A.4.3.2 (CONTINUED): Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD A Portable Classrooms, UCLA PCS.
NOTE: for VOC samples with duplicates, used average concentration of pair

Compound or Measure	School #, Classroom Type & # (#, M,B, or P, #)	Sampling # or Season (1 or 2)	SWIA (conc. in ug/m3, AER in hr-1)	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR) (SDIA sampling duration/SWIA sampling duration)	INTERPOLATED OUPIA, 2nd sampling (SWIA - (SDR*SDIA)) / (1-SDR)	INTERPOLATED OUPIA 1st sampling L(x-1)*D(x)	INTERPOLATED SDIA, 1st sampling (SWIA -(OUPIA 1st sampling)*(1-SDR))/SDR
VOC 6	1, P, 1	2	0.47	6260	0.55	2496	0.40	0.42	n/a	n/a
		1	0.44	6272	n/a	n/a	0.40	n/a	0.39	0.51
VOC 6	2, P, 1	2	0.44	6189	0.50	2225	0.36	0.41	n/a	n/a
		1	0.47	6184	n/a	n/a	0.36	n/a	0.43	0.53
VOC 6	3, P, 1	2	0.18	6220	1.10	2358	0.38	-0.38	n/a	n/a
		1	0.40	6132	n/a	n/a	0.38	n/a	-0.85	2.44
VOC 6	3, P, 2	2	0.41	6241	0.53	2368	0.38	0.34	n/a	n/a
		1	0.46	6132	n/a	n/a	0.38	n/a	0.37	0.59
VOC 6	3, P, 3/LIB	2	0.51	6227	0.58	2349	0.38	0.47	n/a	n/a
		1	0.38	6220	n/a	n/a	0.38	n/a	0.35	0.43
VOC 7	1, P, 1	2	1.44	6260	1.36	2496	0.40	1.49	n/a	n/a
		1	1.48	6272	n/a	n/a	0.40	n/a	1.53	1.40
VOC 7	2, P, 1	2	1.38	6189	1.11	2225	0.36	1.53	n/a	n/a
		1	1.54	6184	n/a	n/a	0.36	n/a	1.71	1.24
VOC 7	3, P, 1	2	0.66	6220	4.37	2358	0.38	-1.61	n/a	n/a
		1	1.32	6132	n/a	n/a	0.38	n/a	-3.20	8.72
VOC 7	3, P, 2	2	1.13	6241	1.21	2368	0.38	1.08	n/a	n/a
		1	1.51	6132	n/a	n/a	0.38	n/a	1.45	1.62
VOC 7	3, P, 3/LIB	2	1.64	6227	1.55	2349	0.38	1.69	n/a	n/a
		1	1.18	6220	n/a	n/a	0.38	n/a	1.22	1.12
VOC 9	1, P, 1	2	5.45	6260	5.70	2496	0.40	5.28	n/a	n/a
		1	7.37	6272	n/a	n/a	0.40	n/a	7.14	7.70
VOC 9	2, P, 1	2	6.60	6189	5.65	2225	0.36	7.13	n/a	n/a
		1	8.55	6184	n/a	n/a	0.36	n/a	9.24	7.32
VOC 9	3, P, 1	2	3.38	6220	21.37	2358	0.38	-7.60	n/a	n/a
		1	9.98	6132	n/a	n/a	0.38	n/a	-22.45	63.10
VOC 9	3, P, 2	2	5.90	6241	7.83	2368	0.38	4.72	n/a	n/a
		1	4.67	6132	n/a	n/a	0.38	n/a	3.74	6.20
VOC 9	3, P, 3/LIB	2	6.67	6227	5.87	2349	0.38	7.15	n/a	n/a
		1	4.19	6220	n/a	n/a	0.38	n/a	4.49	3.69

A.4.3.2 (CONTINUED): Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD A Portable Classrooms, UCLA PCS.
NOTE: for VOC samples with duplicates, used average concentration of pair

Compound or Measure	School # Classroom Type & # (#, M,B or P, #)	Sampling # or Season (1 or 2)	SWIA (conc. in ug/m3, AER in hr-1)	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR) (SDIA sampling duration/SWIA sampling duration)	INTERPOLATED OUPIA 2nd sampling ((SWIA - (SDR*SDIA)) / (1-SDR))	INTERPOLATED OUPIA 1st sampling (L(x-1)*D(x))	INTERPOLATED SDIA 1st sampling ((SWIA -(OUPIA 1st sampling)*(1-SDR))/SDR)
VOC 10	1, P, 1	2	1.13	6260	1.29	2496	0.40	1.02	n/a	n/a
		1	5.45	6272	n/a	n/a	0.40	n/a	4.94	6.23
VOC 10	2, P, 1	2	0.77	6189	0.81	2225	0.36	0.74	n/a	n/a
		1	0.94	6184	n/a	n/a	0.36	n/a	0.91	0.99
VOC 10	3, P, 1	2	0.36	6220	2.05	2358	0.38	-0.67	n/a	n/a
		1	0.71	6132	n/a	n/a	0.38	n/a	-1.33	4.07
VOC 10	3, P, 2	2	0.62	6241	0.89	2368	0.38	0.45	n/a	n/a
		1	0.65	6132	n/a	n/a	0.38	n/a	0.48	0.93
VOC 10	3, P, 3/LIB	2	0.83	6227	1.20	2349	0.38	0.61	n/a	n/a
		1	0.54	6220	n/a	n/a	0.38	n/a	0.39	0.77
VOC 11	1, P, 1	2	1.37	6260	1.08	2496	0.40	1.56	n/a	n/a
		1	1.02	6272	n/a	n/a	0.40	n/a	1.17	0.81
VOC 11	2, P, 1	2	0.94	6189	0.82	2496	0.40	1.02	n/a	n/a
		1	1.38	6184	n/a	n/a	0.40	n/a	1.50	1.21
VOC 11	3, P, 1	2	0.36	6220	2.54	2358	0.38	-0.97	n/a	n/a
		1	1.19	6132	n/a	n/a	0.38	n/a	-3.22	8.41
VOC 11	3, P, 2	2	0.98	6241	1.02	2368	0.38	0.96	n/a	n/a
		1	1.10	6132	n/a	n/a	0.38	n/a	1.07	1.15
VOC 11	3, P, 3/LIB	2	1.40	6227	1.15	2349	0.38	1.55	n/a	n/a
		1	1.17	6220	n/a	n/a	0.38	n/a	1.29	0.96
VOC 12	1, P, 1	2	3.05	6260	3.23	2496	0.40	2.93	n/a	n/a
		1	3.71	6272	n/a	n/a	0.40	n/a	3.57	3.93
VOC 12	2, P, 1	2	3.08	6189	3.04	2225	0.36	3.10	n/a	n/a
		1	4.45	6184	n/a	n/a	0.36	n/a	4.48	4.39
VOC 12	3, P, 1	2	1.23	6220	7.75	2358	0.38	-2.75	n/a	n/a
		1	4.21	6132	n/a	n/a	0.38	n/a	-9.42	26.53
VOC 12	3, P, 2	2	2.60	6241	2.82	2368	0.38	2.47	n/a	n/a
		1	3.82	6132	n/a	n/a	0.38	n/a	3.62	4.14
VOC 12	3, P, 3/LIB	2	3.24	6227	3.05	2349	0.38	3.36	n/a	n/a
		1	3.83	6220	n/a	n/a	0.38	n/a	3.96	3.60

A.4.3.2 (CONTINUED): Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD A Portable Classrooms, UCLA PCS.

NOTE: for VOC samples with duplicates, used average concentration of pair

								INTERPOLATED	INTERPOLATED	INTERPOLATED
VOC 15 not included, 2nd sampling values < MDL	(#, M.B. or P, #)	(1 or 2)	(conc. in ug/m3, AER in hr-1)				SDIA sampling duration/SWIA sampling duration	(SWIA - (SDR*SDIA)) / (1-SDR)	L(x-1)*D(x)	(SWIA -(OUPIA 1st sampling)*(1-SDR))/SDR
Compound or Measure	School #, Classroom Type & #	Sampling # or Season	SWIA	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR)	OUPIA, 2nd sampling	OUPIA 1st sampling	SDIA, 1st sampling
VOC 14	1, P, 1	2	1.06	6260	1.08	2496	0.40	1.05	n/a	n/a
		1	1.36	6272	n/a	n/a	0.40	n/a	1.34	1.38
VOC 14	2, P, 1	2	1.02	6189	0.96	2225	0.36	1.05	n/a	n/a
		1	1.46	6184	n/a	n/a	0.36	n/a	1.51	1.37
VOC 14	3, P, 1	2	0.42	6220	2.81	2358	0.38	-1.04	n/a	n/a
		1	1.52	6132	n/a	n/a	0.38	n/a	-3.76	10.18
VOC 14	3, P, 2	2	0.91	6241	1.01	2368	0.38	0.85	n/a	n/a
		1	1.37	6132	n/a	n/a	0.38	n/a	1.28	1.52
VOC 14	3, P, 3/LIB	2	1.22	6227	1.17	2349	0.38	1.25	n/a	n/a
		1	1.96	6220	n/a	n/a	0.38	n/a	2.01	1.88
VOC 16	1, P, 1	2	2.20	6260	0.98	2496	0.40	3.01	n/a	n/a
		1	8.42	6272	n/a	n/a	0.40	n/a	11.52	3.75
VOC 16	2, P, 1	2	3.41	6189	2.99	2225	0.36	3.65	n/a	n/a
		1	16.40	6184	n/a	n/a	0.36	n/a	17.53	14.38
VOC 16	3, P, 1	2	4.93	6220	34.64	2358	0.38	-13.21	n/a	n/a
		1	30.99	6132	n/a	n/a	0.38	n/a	-83.04	217.75
VOC 16	3, P, 2	2	0.92	6241	0.91	2368	0.38	0.93	n/a	n/a
		1	0.81	6132	n/a	n/a	0.38	n/a	0.82	0.81
VOC 16	3, P, 3/LIB	2	0.79	6227	0.71	2349	0.38	0.84	n/a	n/a
		1	1.06	6220	n/a	n/a	0.38	n/a	1.12	0.95

A.4.3.2 (CONTINUED): Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD A Portable Classrooms, UCLA PCS.
NOTE: for VOC samples with duplicates, used average concentration of pair

	(#, M.B. or P, #)	(1 or 2)	(conc. in ug/m3, AER in hr-1)				SDIA sampling duration/SWIA sampling duration	INTERPOLATED (SWIA-(SDR*SDIA))/(1-SDR)	INTERPOLATED L(x-1)*D(x)	INTERPOLATED (SWIA-(OUPIA 1st sampling)*(1-SDR))/SDR
Compound or Measure	School #, Classroom Type & #	Sampling # or Season	SWIA	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR)	OUPIA, 2nd sampling	OUPIA 1st sampling	SDIA, 1st sampling
VOC 17	1, P, 1	2	0.46	6260	0.00	6260	1.00	0.00	n/a	n/a
		1	1.46	6272	n/a	n/a	1.00	n/a	n/a	n/a
VOC 17	2, P, 1	2	0.46	6189	0.00	2225	0.36	0.72	n/a	n/a
		1	1.84	6184	n/a	n/a	0.36	n/a	2.88	0.00
VOC 17	3, P, 1	2	0.93	6220	7.35	2358	0.38	-2.99	n/a	n/a
		1	8.35	6132	n/a	n/a	0.38	n/a	-26.84	65.98
VOC 17	3, P, 2	2	0.37	6241	0.54	2368	0.38	0.27	n/a	n/a
		1	0.00	6132	n/a	n/a	0.38	n/a	0.00	0.00
VOC 17	3, P, 3/LIB	2	0.00	6227	0.00	2349	0.38	0.00	n/a	n/a
		1	0.00	6220	n/a	n/a	0.38	n/a	0.00	0.00
VOC 18	1, P, 1	2	1.63	6260	1.14	2496	0.40	1.95	n/a	n/a
		1	6.27	6272	n/a	n/a	0.40	n/a	7.52	4.39
VOC 18	2, P, 1	2	2.25	6189	2.59	2225	0.36	2.06	n/a	n/a
		1	8.30	6184	n/a	n/a	0.36	n/a	7.60	9.55
VOC 18	3, P, 1	2	2.82	6220	17.93	2358	0.38	-6.41	n/a	n/a
		1	12.97	6132	n/a	n/a	0.38	n/a	-29.46	82.47
VOC 18	3, P, 2	2	2.47	6241	3.12	2368	0.38	2.07	n/a	n/a
		1	14.42	6132	n/a	n/a	0.38	n/a	12.10	18.22
VOC 18	3, P, 3/LIB	2	1.49	6227	1.56	2349	0.38	1.45	n/a	n/a
		1	1.84	6220	n/a	n/a	0.38	n/a	1.79	1.93
VOC 19	1, P, 1	2	0.37	6260	0.44	2496	0.40	0.32	n/a	n/a
		1	1.16	6272	n/a	n/a	0.40	n/a	1.02	1.38
VOC 19	2, P, 1	2	0.40	6189	0.31	2225	0.36	0.45	n/a	n/a
		1	1.46	6184	n/a	n/a	0.36	n/a	1.64	1.13
VOC 19	3, P, 1	2	0.53	6220	3.28	2358	0.38	-1.15	n/a	n/a
		1	1.82	6132	n/a	n/a	0.38	n/a	-3.94	11.26
VOC 19	3, P, 2	2	0.32	6241	0.44	2368	0.38	0.25	n/a	n/a
		1	0.84	6132	n/a	n/a	0.38	n/a	0.65	1.15
VOC 19	3, P, 3/LIB	2	0.31	6227	0.25	2349	0.38	0.35	n/a	n/a
		1	0.62	6220	n/a	n/a	0.38	n/a	0.69	0.50

A.4.3.3 Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD B Main Building Control Classrooms, Los Angeles County, 2000-01.

NOTE: for DNSH aldehyde samples with duplicates, used average concentration of pair

Compound or Measure	School #, Classroom Type & # (#, M.B. or P. #)	Sampling # or Season (1 or 2)	SWIA (conc. in ug/m3, AER in hr-1)	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR) SDIA sampling duration/SWIA sampling duration	INTERPOLATED OUPIA, 2nd sampling (SWIA-(SDR*SDIA)) / (1-SDR)	INTERPOLATED OUPIA 1st sampling L(x-1)*D(x)	INTERPOLATED SDIA, 1st sampling (SWIA-(OUPIA 1st sampling)*(1-SDR))/SDR
H2CO	1, MB, 1	2	20.12	6234	23.65	2427	0.39	17.87	n/a	n/a
		1	26.82	6191	n/a	n/a	0.39	n/a	23.82	31.53
H2CO	2, MB, 1	2	16.48	6264	22.52	2439	0.39	12.63	n/a	n/a
		1	22.38	6263	n/a	n/a	0.39	n/a	17.15	30.58
H2CO	3, MB, 1	2	18.95	6209	20.47	2345	0.38	18.03	n/a	n/a
		1	22.02	6231	n/a	n/a	0.38	n/a	20.95	23.79
CH3CHO	1, MB, 1	2	4.52	6234	7.75	2427	0.39	2.46	n/a	n/a
		1	6.09	6191	n/a	n/a	0.39	n/a	3.32	10.44
CH3CHO	2, MB, 1	2	4.48	6264	7.98	2439	0.39	2.25	n/a	n/a
		1	7.04	6263	n/a	n/a	0.39	n/a	3.53	12.54
CH3CHO	3, MB, 1	2	4.36	6209	7.05	2345	0.38	2.73	n/a	n/a
		1	2.76	6231	n/a	n/a	0.38	n/a	1.73	4.46
		1	3.41	6252	n/a	n/a	0.38	n/a	2.13	5.51
AER	1, MB, 1	2	0.6	6228	1.2	2421	0.39	0.3	n/a	n/a
		1	0.6	6193	n/a	n/a	0.39	n/a	0.3	1.0
AER	*2, MB, 1*	*2*	*0.3*	*6262*	*0.5*	*2434*	*0.39*	*0.1*	*n/a*	*n/a*
		1	*0.3*	*6261*	*n/a*	*n/a*	*0.39*	*n/a*	*0.1*	*0.6*
AER	3, MB, 1	2	0.4	6213	0.6	2349	0.38	0.3	n/a	n/a
		1	0.3	6229	n/a	n/a	0.38	n/a	0.2	0.5
VOC 2	1, MB, 1	2	0.86	6236	1.043	2426	0.39	0.75	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.39	n/a	n/a	n/a
VOC 2	2, MB, 1	2	0.50	6270	2.759	2440	0.39	-0.94	n/a	n/a
		1	0.68	6266	n/a	n/a	0.39	n/a	-1.27	3.75
VOC 2	3, MB, 1	2	0.65	6211	0.831	2344	0.38	0.54	n/a	n/a
		1	0.27	6232	n/a	n/a	0.38	n/a	0.22	0.34
VOC 3	1, MB, 1	2	4.52	6236	4.277	2426	0.39	4.68	n/a	n/a
		1	1.75	6191	n/a	n/a	0.39	n/a	1.81	1.65
VOC 3	2, MB, 1	2	1.75	6270	9.566	2440	0.39	-3.23	n/a	n/a
		1	2.27	6266	n/a	n/a	0.39	n/a	-4.18	12.38
VOC 3	3, MB, 1	2	4.28	6211	3.502	2344	0.38	4.75	n/a	n/a
		1	4.15	6232	n/a	n/a	0.38	n/a	4.61	3.40

A.4.3.3 (CONTINUED): Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD B Main Building Control Classrooms, Los Angeles County, 2000-01.

								INTERPOLATED	INTERPOLATED	INTERPOLATED
	(#, M,B, or P, #)	(1 or 2)	(conc. in ug/m3, AER in hr-1)				SDIA sampling duration/SWIA sampling duration	(SWIA-(SDR*SDIA))/(1-SDR)	L(x-1)*D(x)	(SWIA-(OUPIA 1st sampling)*(1-SDR))/SDR
Compound or Measure	School #, Classroom Type & #	Sampling # or Season	SWIA	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR)	OUPIA, 2nd sampling	OUPIA 1st sampling	SDIA, 1st sampling
VOC 5	1, MB, 1	2	0.22	6236	0.187	2426	0.39	0.24	n/a	n/a
		1	0.18	6191	n/a	n/a	0.39	n/a	0.20	0.15
VOC 5	2, MB, 1	2	0.08	6270	0.448	2440	0.39	-0.15	n/a	n/a
		1	0.18	6266	n/a	n/a	0.39	n/a	-0.32	0.97
VOC 5	3, MB, 1	2	0.14	6270	0.011	2344	0.37	0.21	n/a	n/a
		1	0.20	6232	n/a	n/a	0.37	n/a	0.31	0.02
VOC 6	1, MB, 1	2	0.45	6236	0.477	2426	0.39	0.44	n/a	n/a
		1	0.39	6191	n/a	n/a	0.39	n/a	0.37	0.41
VOC 6	2, MB, 1	2	0.20	6270	1.011	2440	0.39	-0.32	n/a	n/a
		1	0.37	6266	n/a	n/a	0.39	n/a	-0.60	1.88
VOC 6	3, MB, 1	2	0.39	6270	0.386	2344	0.37	0.40	n/a	n/a
		1	0.38	6232	n/a	n/a	0.37	n/a	0.38	0.37
VOC 7	1, MB, 1	2	2.09	6236	1.975	2426	0.39	2.16	n/a	n/a
		1	0.50	6191	n/a	n/a	0.39	n/a	0.51	0.47
VOC 7	2, MB, 1	2	0.86	6270	4.641	2440	0.39	-1.54	n/a	n/a
		1	0.63	6266	n/a	n/a	0.39	n/a	-1.12	3.38
VOC 7	3, MB, 1	2	1.86	6270	1.628	2344	0.37	1.99	n/a	n/a
		1	0.97	6232	n/a	n/a	0.37	n/a	1.04	0.85
VOC 8	1, MB, 1	2	0.07	6236	0.056	2426	0.39	0.08	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.39	n/a	n/a	n/a
VOC 8	2, MB, 1	2	0.05	6270	0.247	2440	0.39	-0.08	n/a	n/a
		1	0.10	6266	n/a	n/a	0.39	n/a	-0.17	0.52
VOC 8	3, MB, 1	2	0.06	6270	0.016	2344	0.37	0.09	n/a	n/a
		1	0.06	6232	n/a	n/a	0.37	n/a	0.09	0.02
VOC 9	1, MB, 1	2	7.86	6236	8.468	2426	0.39	7.47	n/a	n/a
		1	2.60	6191	n/a	n/a	0.39	n/a	2.47	2.80
VOC 9	2, MB, 1	2	3.30	6270	14.163	2440	0.39	-3.63	n/a	n/a
		1	2.99	6266	n/a	n/a	0.39	n/a	-3.29	12.86
VOC 9	3, MB, 1	2	5.17	6270	3.635	2344	0.37	6.08	n/a	n/a
		1	3.07	6232	n/a	n/a	0.37	n/a	3.61	2.16

A.4.3.3 (CONTINUED): Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD B Main Building Control Classrooms, Los Angeles County, 2000-01.

								INTERPOLATED	INTERPOLATED	INTERPOLATED
	(#, M.B. or P, #)	(1 or 2)	(conc. in ug/m3, AER in hr-1)				SDIA sampling duration/SWIA sampling duration	(SWIA-(SDR*SDIA))/(1-SDR)	L(x-1)*D(x)	(SWIA-(OUPIA 1st sampling)*(1-SDR))/SDR
Compound or Measure	School #, Classroom Type & #	Sampling # or Season	SWIA	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR)	OUPIA, 2nd sampling	OUPIA 1st sampling	SDIA, 1st sampling
VOC 10	1, MB, 1	2	1.14	6236	1.39	2426	0.39	0.98	n/a	n/a
		1	0.23	6191	n/a	n/a	0.39	n/a	0.20	0.28
VOC 10	2, MB, 1	2	0.65	6270	3.564	2440	0.39	-1.20	n/a	n/a
		1	0.63	6266	n/a	n/a	0.39	n/a	-1.16	3.43
VOC 10	3, MB, 1	2	1.01	6270	1.088	2344	0.37	0.96	n/a	n/a
		1	0.62	6232	n/a	n/a	0.37	n/a	0.59	0.67
VOC 11	1, MB, 1	2	1.16	6236	1.232	2426	0.39	1.11	n/a	n/a
		1	0.38	6191	n/a	n/a	0.39	n/a	0.36	0.40
VOC 11	2, MB, 1	2	0.50	6270	2.471	2440	0.39	-0.76	n/a	n/a
		1	0.36	6266	n/a	n/a	0.39	n/a	-0.54	1.78
VOC 11	3, MB, 1	2	0.95	6270	0.78	2344	0.37	1.04	n/a	n/a
		1	0.59	6232	n/a	n/a	0.37	n/a	0.65	0.49
VOC 12	1, MB, 1	2	4.28	6236	4.455	2426	0.39	4.17	n/a	n/a
		1	1.16	6191	n/a	n/a	0.39	n/a	1.13	1.21
VOC 12	2, MB, 1	2	1.85	6270	9.289	2440	0.39	-2.89	n/a	n/a
		1	1.28	6266	n/a	n/a	0.39	n/a	-2.01	6.45
VOC 12	3, MB, 1	2	3.60	6270	3.06	2344	0.37	3.93	n/a	n/a
		1	2.16	6232	n/a	n/a	0.37	n/a	2.35	1.83
VOC 14	1, MB, 1	2	1.45	6236	1.549	2426	0.39	1.39	n/a	n/a
		1	0.40	6191	n/a	n/a	0.39	n/a	0.38	0.42
VOC 14	2, MB, 1	2	0.60	6270	3.042	2440	0.39	-0.95	n/a	n/a
		1	0.49	6266	n/a	n/a	0.39	n/a	-0.77	2.47
VOC 14	3, MB, 1	2	1.25	6270	1.078	2344	0.37	1.35	n/a	n/a
		1	0.73	6232	n/a	n/a	0.37	n/a	0.79	0.63
VOC 16	1, MB, 1	2	0.59	6236	0.595	2426	0.39	0.59	n/a	n/a
		1	0.22	6191	n/a	n/a	0.39	n/a	0.22	0.23
VOC 16	2, MB, 1	2	0.26	6270	1.285	2440	0.39	-0.39	n/a	n/a
		1	0.29	6266	n/a	n/a	0.39	n/a	-0.44	1.44
VOC 16	3, MB, 1	2	0.58	6270	0.496	2344	0.37	0.63	n/a	n/a
		1	0.49	6232	n/a	n/a	0.37	n/a	0.53	0.41
VOC 18	1, MB, 1	2	6.53	6236	8.377	2426	0.39	5.36	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.39	n/a	n/a	n/a
VOC 18	2, MB, 1	2	3.48	6270	24.263	2440	0.39	-9.76	n/a	n/a
		1	8.08	6266	n/a	n/a	0.39	n/a	-22.68	56.36
VOC 18	3, MB, 1	2	1.33	6270	1.257	2344	0.37	1.38	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.37	n/a	n/a	n/a
VOC 19	1, MB, 1	2	0.32	6236	0.362	2426	0.39	0.29	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.39	n/a	n/a	n/a
VOC 19	2, MB, 1	2	0.19	6270	0.541	2440	0.39	-0.03	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.39	n/a	n/a	n/a
VOC 19	3, MB, 1	2	0.35	6270	0.192	2344	0.37	0.44	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.37	n/a	n/a	n/a

A.4.3.4 Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD B Portable Classrooms, UCLA PCS

NOTE: for VOC and DNSH aldehyde samples with duplicates, used average concentration of pair

								INTERPOLATED	INTERPOLATED	INTERPOLATED
	(#, M,B, or P, #)	(1 or 2)	(conc. in ug/m3, AER in hr-1)				SDIA sampling duration/SWIA sampling duration	(SWIA-(SDR*SDIA))/(1-SDR)	L(x-1)*D(x)	(SWIA-(OUPIA 1st sampling)*(1-SDR))/SDR
Compound or Measure	School #, Classroom Type & #	Sampling # or Season	SWIA	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR)	OUPIA 2nd sampling	OUPIA 1st sampling	SDIA, 1st sampling
H2CO	1, P, 1	2	20.94	6223	22.94	2363	0.38	19.72	n/a	n/a
		1	31.65	6150	n/a	n/a	0.38	n/a	29.80	34.67
H2CO	1, P, 2	2	23.08	6214	24.78	2354	0.38	22.04	n/a	n/a
		1	33.83	6168	n/a	n/a	0.38	n/a	32.31	36.32
H2CO	2, P, 1	2	18.86	6226	21.91	2382	0.38	16.97	n/a	n/a
		1	32.37	6259	n/a	n/a	0.38	n/a	29.13	37.60
H2CO	2, P, 2	2	21.15	6222	24.21	2380	0.38	19.25	n/a	n/a
		1	35.03	6259	n/a	n/a	0.38	n/a	31.89	40.10
H2CO	3, P, 1	2	18.08	6211	21.19	2344	0.38	16.19	n/a	n/a
		1	23.60	6225	n/a	n/a	0.38	n/a	21.14	27.66
H2CO	3, P, 2	2	22.35	6226	22.45	2397	0.38	22.29	n/a	n/a
		1	27.56	6227	n/a	n/a	0.38	n/a	27.48	27.68
CH3CHO	1, P, 1	2	5.01	6223	8.5	2363	0.38	2.87	n/a	n/a
		1	11.85	6150	n/a	n/a	0.38	n/a	6.80	20.10
CH3CHO	1, P, 2	2	5.23	6214	8.35	2354	0.38	3.33	n/a	n/a
		1	8.27	6168	n/a	n/a	0.38	n/a	5.26	13.20
CH3CHO	2, P, 1	2	4.77	6226	7.79	2382	0.38	2.90	n/a	n/a
		1	8.32	6259	n/a	n/a	0.38	n/a	5.06	13.59
CH3CHO	2, P, 2	2	9.38	6222	7.22	2380	0.38	10.72	n/a	n/a
		1	7.30	6259	n/a	n/a	0.38	n/a	8.34	5.62
CH3CHO	3, P, 1	2	3.89	6211	6.69	2344	0.38	2.19	n/a	n/a
		1	6.50	6225	n/a	n/a	0.38	n/a	3.66	11.18
CH3CHO	3, P, 2	2	5.22	6226	7.37	2397	0.38	3.87	n/a	n/a
		1	8.03	6227	n/a	n/a	0.38	n/a	5.96	11.34
AER	1, P, 1	2	0.2	6212	0.3	2356	0.38	0.2	n/a	n/a
		1	0.2	6149	n/a	n/a	0.38	n/a	0.2	0.3
AER	1, P, 2	2	0.2	6225	0.5	2364	0.38	0.0	n/a	n/a
		1	0.2	6169	n/a	n/a	0.38	n/a	0.0	0.4
AER	2, P, 1	2	0.2	6225	0.3	2381	0.38	0.1	n/a	n/a
		1	0.2	6257	n/a	n/a	0.38	n/a	0.1	0.4
AER	2, P, 2	2	0.2	6219	0.3	2380	0.38	0.2	n/a	n/a
		1	0.3	6257	n/a	n/a	0.38	n/a	0.2	0.5
AER	3, P, 1	2	1.4	6210	2.9	2345	0.38	0.4	n/a	n/a
		1	5.4	6226	n/a	n/a	0.38	n/a	1.6	11.6
AER	3, P, 2	2	0.1	6218	0.2	2389	0.38	0.1	n/a	n/a
		1	0.2	6226	n/a	n/a	0.38	n/a	0.2	0.3

A.4.3.4 (CONTINUED): Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD B Portable Classrooms, UCLA PCS

NOTE: for VOC samples with duplicates, used average concentration of pair

Compound or Measure	School #, Classroom Type & # (# M,B, or P, #)	Sampling # or Season (1 or 2)	SWIA (conc. in ug/m3, AER in hr-1)	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR) (SDIA sampling duration/SWIA sampling duration)	INTERPOLATED OUPIA 2nd sampling ((SWIA - (SDR*SDIA))/(1-SDR))	INTERPOLATED OUPIA 1st sampling (L(x-1)*C(x))	INTERPOLATED SDIA 1st sampling ((SWIA -(OUPIA 1st sampling)*(1-SDR))/SDR)
VOC 2	1, P, 1	2	0.84	6232	0.953	2370	0.38	0.77	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.38	n/a	n/a	n/a
VOC 2	1, P, 2	2	0.73	6213	0.914	2351	0.38	0.61	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.38	n/a	n/a	n/a
VOC 2	2, P, 1	2	0.71	6229	0.949	2383	0.38	0.56	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.38	n/a	n/a	n/a
VOC 2	2, P, 2	2	1.11	6225	1.234	2379	0.38	1.04	n/a	n/a
		1	1.34	6259	n/a	n/a	0.38	n/a	1.24	1.48
VOC 2	3, P, 1	2	0.60	6220	0.746	2351	0.38	0.52	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.38	n/a	n/a	n/a
VOC 2	3, P, 2	2	0.65	6225	0.967	2391	0.38	0.45	n/a	n/a
		1	0.51	6222	n/a	n/a	0.38	n/a	0.35	0.76
VOC 3	1, P, 1	2	1.46	6232	3.043	2370	0.38	0.48	n/a	n/a
		1	1.71	6150	n/a	n/a	0.38	n/a	0.56	3.57
VOC 3	1, P, 2	2	4.28	6213	4.617	2351	0.38	4.08	n/a	n/a
		1	1.56	6168	n/a	n/a	0.38	n/a	1.48	1.68
VOC 3	2, P, 1	2	3.64	6229	4.617	2383	0.38	3.03	n/a	n/a
		1	1.95	6258	n/a	n/a	0.38	n/a	1.63	2.47
VOC 3	2, P, 2	2	3.67	6225	4.53	2379	0.38	3.13	n/a	n/a
		1	2.04	6259	n/a	n/a	0.38	n/a	1.74	2.52
VOC 3	3, P, 1	2	1.27	6220	3.759	2351	0.38	-0.24	n/a	n/a
		1	6.78	6229	n/a	n/a	0.38	n/a	-1.30	20.09
VOC 3	3, P, 2	2	4.22	6225	4.615	2391	0.38	3.97	n/a	n/a
		1	4.17	6222	n/a	n/a	0.38	n/a	3.93	4.56
VOC 5	1, P, 1	2	0.17	6232	0.179	2370	0.38	0.16	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.38	n/a	n/a	n/a
VOC 5	1, P, 2	2	0.18	6213	0.222	2351	0.38	0.16	n/a	n/a
		1	0.30	6168	n/a	n/a	0.38	n/a	0.26	0.37
VOC 5	2, P, 1	2	0.20	6229	0.225	2383	0.38	0.18	n/a	n/a
		1	0.16	6258	n/a	n/a	0.38	n/a	0.15	0.18
VOC 5	2, P, 2	2	0.17	6225	0.207	2379	0.38	0.14	n/a	n/a
		1	0.16	6259	n/a	n/a	0.38	n/a	0.14	0.20
VOC 5	3, P, 1	2	0.14	6220	0.011	2351	0.38	0.21	n/a	n/a
		1	0.22	6229	n/a	n/a	0.38	n/a	0.34	0.02
VOC 5	3, P, 2	2	0.20	6225	0.217	2391	0.38	0.19	n/a	n/a
		1	0.25	6222	n/a	n/a	0.38	n/a	0.24	0.27

A.4.3.4 (CONTINUED): Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD B Portable Classrooms, UCLA PCS

NOTE: for VOC samples with duplicates, used average concentration of pair

Compound or Measure	School # Classroom Type & # (# M,B or P, #)	Sampling # or Season (1 or 2)	SWIA (conc in ug/m3, AER in hr-1)	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR) (SDIA sampling duration/SWIA sampling duration)	INTERPOLATED OUPIA 2nd sampling (SWIA-(SDR*SDIA))/(1-SDR)	INTERPOLATED OUPIA 1st sampling L(x-1)*O(x)	INTERPOLATED SDIA 1st sampling (SWIA-(OUPIA 1st sampling)*(1-SDR))/SDR
VOC 6	1, P, 1	2	0.48	6232	0.479	2370	0.38	0.49	n/a	n/a
		1	0.42	6150	n/a	n/a	0.38	n/a	0.42	0.42
VOC 6	1, P, 2	2	0.41	6213	0.457	2351	0.38	0.39	n/a	n/a
		1	0.33	6168	n/a	n/a	0.38	n/a	0.31	0.37
VOC 6	2, P, 1	2	0.43	6229	0.496	2383	0.38	0.39	n/a	n/a
		1	0.39	6258	n/a	n/a	0.38	n/a	0.35	0.45
VOC 6	2, P, 2	2	0.38	6225	0.512	2379	0.38	0.30	n/a	n/a
		1	0.47	6259	n/a	n/a	0.38	n/a	0.37	0.63
VOC 6	3, P, 1	2	0.47	6220	0.433	2351	0.38	0.49	n/a	n/a
		1	0.43	6229	n/a	n/a	0.38	n/a	0.45	0.40
VOC 6	3, P, 2	2	0.45	6225	0.513	2391	0.38	0.42	n/a	n/a
		1	0.43	6222	n/a	n/a	0.38	n/a	0.40	0.49
VOC 7	1, P, 1	2	2.20	6232	2.024	2370	0.38	2.30	n/a	n/a
		1	0.50	6150	n/a	n/a	0.38	n/a	0.53	0.46
VOC 7	1, P, 2	2	1.95	6213	2.13	2351	0.38	1.83	n/a	n/a
		1	0.41	6168	n/a	n/a	0.38	n/a	0.39	0.45
VOC 7	2, P, 1	2	3.34	6229	3.042	2383	0.38	3.53	n/a	n/a
		1	2.72	6258	n/a	n/a	0.38	n/a	2.87	2.47
VOC 7	2, P, 2	2	2.18	6225	2.405	2379	0.38	2.05	n/a	n/a
		1	1.04	6259	n/a	n/a	0.38	n/a	0.97	1.14
VOC 7	3, P, 1	2	2.27	6220	1.722	2351	0.38	2.60	n/a	n/a
		1	1.41	6229	n/a	n/a	0.38	n/a	1.62	1.07
VOC 7	3, P, 2	2	2.98	6225	2.467	2391	0.38	3.29	n/a	n/a
		1	2.49	6222	n/a	n/a	0.38	n/a	2.76	2.07
VOC 9	1, P, 1	2	7.39	6232	6.423	2370	0.38	7.98	n/a	n/a
		1	1.70	6150	n/a	n/a	0.38	n/a	1.84	1.48
VOC 9	1, P, 2	2	10.41	6213	9.26	2351	0.38	11.10	n/a	n/a
		1	3.84	6168	n/a	n/a	0.38	n/a	4.10	3.42
VOC 9	2, P, 1	2	8.42	6229	10.133	2383	0.38	7.36	n/a	n/a
		1	2.42	6258	n/a	n/a	0.38	n/a	2.12	2.91
VOC 9	2, P, 2	2	8.13	6225	7.7245	2379	0.38	8.39	n/a	n/a
		1	4.38	6259	n/a	n/a	0.38	n/a	4.52	4.16
VOC 9	3, P, 1	2	6.26	6220	4.693	2351	0.38	7.21	n/a	n/a
		1	4.61	6229	n/a	n/a	0.38	n/a	5.31	3.46
VOC 9	3, P, 2	2	6.67	6225	7.026	2391	0.38	6.44	n/a	n/a
		1	5.66	6222	n/a	n/a	0.38	n/a	5.46	5.96

A.4.3.4 (CONTINUED): Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD B Portable Classrooms, Los Angeles County, 2000-01.

NOTE: for VOC samples with duplicates, used average concentration of pair

								INTERPOLATED	INTERPOLATED	INTERPOLATED
	(#, M.B. or P, #)	(1 or 2)	(conc. in ug/m3, AER in hr-1)				SDIA sampling duration/SWIA sampling duration	(SWIA-(SDR*SDIA))/(1-SDR)	[(x-1)*D(x)]	(SWIA-(OUPIA 1st sampling)*(1-SDR))/SDR
Compound or Measure	School #, Classroom Type & #	Sampling # or Season	SWIA	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR)	OUPIA, 2nd sampling	OUPIA 1st sampling	SDIA, 1st sampling
VOC 10	1, P, 1	2	1.22	6232	1.412	2370	0.38	1.10	n/a	n/a
		1	0.26	6150	n/a	n/a	0.38	n/a	0.24	0.31
VOC 10	1, P, 2	2	1.46	6213	1.815	2351	0.38	1.25	n/a	n/a
		1	0.42	6168	n/a	n/a	0.38	n/a	0.36	0.52
VOC 10	2, P, 1	2	1.87	6229	1.881	2383	0.38	1.86	n/a	n/a
		1	0.78	6258	n/a	n/a	0.38	n/a	0.78	0.79
VOC 10	2, P, 2	2	1.21	6225	1.594	2379	0.38	0.97	n/a	n/a
		1	0.39	6259	n/a	n/a	0.38	n/a	0.31	0.52
VOC 10	3, P, 1	2	1.15	6220	1.195	2351	0.38	1.13	n/a	n/a
		1	0.88	6229	n/a	n/a	0.38	n/a	0.86	0.91
VOC 10	3, P, 2	2	1.35	6225	1.567	2391	0.38	1.22	n/a	n/a
		1	0.81	6222	n/a	n/a	0.38	n/a	0.73	0.94
VOC 11	1, P, 1	2	1.40	6232	1.361	2370	0.38	1.43	n/a	n/a
		1	0.31	6150	n/a	n/a	0.38	n/a	0.32	0.30
VOC 11	1, P, 2	2	2.42	6213	2.624	2351	0.38	2.29	n/a	n/a
		1	0.38	6168	n/a	n/a	0.38	n/a	0.36	0.41
VOC 11	2, P, 1	2	1.46	6229	1.697	2383	0.38	1.31	n/a	n/a
		1	0.56	6258	n/a	n/a	0.38	n/a	0.50	0.65
VOC 11	2, P, 2	2	1.13	6225	1.234	2379	0.38	1.06	n/a	n/a
		1	0.48	6259	n/a	n/a	0.38	n/a	0.45	0.52
VOC 11	3, P, 1	2	1.18	6220	1.302	2351	0.38	1.11	n/a	n/a
		1	0.93	6229	n/a	n/a	0.38	n/a	0.87	1.03
VOC 11	3, P, 2	2	1.17	6225	1.156	2391	0.38	1.18	n/a	n/a
		1	1.41	6222	n/a	n/a	0.38	n/a	1.42	1.39
VOC 12	1, P, 1	2	5.06	6232	4.779	2370	0.38	5.23	n/a	n/a
		1	0.98	6150	n/a	n/a	0.38	n/a	0.99	0.90
VOC 12	1, P, 2	2	7.04	6213	8.498	2351	0.38	6.15	n/a	n/a
		1	1.09	6168	n/a	n/a	0.38	n/a	0.95	1.31
VOC 12	2, P, 1	2	5.14	6229	6.32	2383	0.38	4.41	n/a	n/a
		1	1.98	6258	n/a	n/a	0.38	n/a	1.70	2.44
VOC 12	2, P, 2	2	3.90	6225	4.6	2379	0.38	3.47	n/a	n/a
		1	1.52	6259	n/a	n/a	0.38	n/a	1.35	1.79
VOC 12	3, P, 1	2	4.51	6220	3.793	2351	0.38	4.94	n/a	n/a
		1	3.48	6229	n/a	n/a	0.38	n/a	3.81	2.93
VOC 12	3, P, 2	2	4.23	6225	4.438	2391	0.38	4.09	n/a	n/a
		1	5.50	6222	n/a	n/a	0.38	n/a	5.33	5.78

A.4.3.4 (CONTINUED): Measured and interpolated "school week integrated average (SWIA)," "school day integrated average (SDIA)," and interpolated "overnight, unoccupied period integrated average (OUPIA)" concentrations, SD B Portable Classrooms, Los Angeles County, 2000-01.

NOTE: for VOC samples with duplicates, used average concentration of pair

VOC 19 not included, < MDL @ 1st sampling	(#, M,B, or P, #)	(1 or 2)	(conc. in ug/m3, AER in hr-1)				SDIA sampling duration/SWIA sampling duration	INTERPOLATED (SWIA-(SDR*SDIA))/(1-SDR)	INTERPOLATED L(x+1)*D(x)	INTERPOLATED (SWIA-(OUPIA 1st sampling)*(1-SDR))/SDR
Compound or Measure	School # Classroom Type & #	Sampling # or Season	SWIA	SWIA Sampling Duration (minutes)	SDIA	SDIA Sampling Duration (minutes)	Sampling Duration Ratio (SDR)	OUPIA 2nd sampling	OUPIA 1st sampling	SDIA 1st sampling
VOC 14	1, P, 1	2	1.80	6232	1.714	2370	0.38	1.85	n/a	n/a
		1	0.35	6150	n/a	n/a	0.38	n/a	0.36	0.33
VOC 14	1, P, 2	2	2.39	6213	2.74	2351	0.38	2.17	n/a	n/a
		1	0.48	6168	n/a	n/a	0.38	n/a	0.44	0.56
VOC 14	2, P, 1	2	1.65	6229	2.126	2383	0.38	1.35	n/a	n/a
		1	0.74	6258	n/a	n/a	0.38	n/a	0.61	0.95
VOC 14	2, P, 2	2	1.30	6225	1.56	2379	0.38	1.13	n/a	n/a
		1	0.55	6259	n/a	n/a	0.38	n/a	0.48	0.66
VOC 14	3, P, 1	2	1.50	6220	1.283	2351	0.38	1.63	n/a	n/a
		1	1.14	6229	n/a	n/a	0.38	n/a	1.24	0.98
VOC 14	3, P, 2	2	1.49	6225	1.853	2391	0.38	1.27	n/a	n/a
		1	1.82	6222	n/a	n/a	0.38	n/a	1.55	2.26
VOC 16	1, P, 1	2	0.67	6232	0.71	2370	0.38	0.64	n/a	n/a
		1	0.35	6150	n/a	n/a	0.38	n/a	0.34	0.37
VOC 16	1, P, 2	2	1.66	6213	0.978	2351	0.38	2.07	n/a	n/a
		1	1.24	6168	n/a	n/a	0.38	n/a	1.55	0.73
VOC 16	2, P, 1	2	1.85	6229	1.575	2383	0.38	2.02	n/a	n/a
		1	2.12	6258	n/a	n/a	0.38	n/a	2.31	1.80
VOC 16	2, P, 2	2	2.21	6225	1.83	2379	0.38	2.45	n/a	n/a
		1	1.61	6259	n/a	n/a	0.38	n/a	1.78	1.33
VOC 16	3, P, 1	2	0.60	6220	0.44	2351	0.38	0.70	n/a	n/a
		1	0.57	6229	n/a	n/a	0.38	n/a	0.67	0.42
VOC 16	3, P, 2	2	3.73	6225	3.062	2391	0.38	4.14	n/a	n/a
		1	3.17	6222	n/a	n/a	0.38	n/a	3.52	2.60
VOC 18	1, P, 1	2	8.65	6232	15.513	2370	0.38	4.44	n/a	n/a
		1	11.81	6150	n/a	n/a	0.38	n/a	6.06	21.17
VOC 18	1, P, 2	2	2.48	6213	2.244	2351	0.38	2.62	n/a	n/a
		1	1.14	6168	n/a	n/a	0.38	n/a	1.20	1.03
VOC 18	2, P, 1	2	14.08	6229	17.007	2383	0.38	12.27	n/a	n/a
		1	1.66	6258	n/a	n/a	0.38	n/a	1.44	2.00
VOC 18	2, P, 2	2	31.78	6225	18.88	2379	0.38	39.76	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.38	n/a	n/a	n/a
VOC 18	3, P, 1	2	2.98	6220	4.313	2351	0.38	2.17	n/a	n/a
		1	BELOW MDL		n/a	n/a	0.38	n/a	n/a	n/a
VOC 18	3, P, 2	2	128.70	6225	121.02	2391	0.38	133.50	n/a	n/a
		1	2.04	6222	n/a	n/a	0.38	n/a	2.11	1.92

APPENDIX A.4

Field Data and Related Calculations

A.4.4 H_2CO and CH_3CHO Concentrations, LBNL RCS

A.4.4.1 Active sampling system pump performance, cooling season
A.4.4.2 Active sampling system pump performance, heating season
A.4.4.3 Concentration data by RC, SD, and week, cooling season
A.4.4.4 Concentration data by RC, SD, and week, heating season
A.4.4.5 Field duplicates for overall precision, cooling season
A.4.4.6 Field duplicates for overall precision, heating season
A.4.4.7 Analytic duplicates for analytic method precision, cooling season
A.4.4.8 Analytic duplicates for analytic method precision, heating season

A.4.6.1 Pump performance evaluation by change in flow rates from near start to near end of sampling period, SD 3 and 4, LBNL RCS, fall 2001 cooling season (**bold** type, 5-10% change; *italicized* type, see notes)

School District	Date	RC A Initial Measured Flow, cc/min	Final Measured Flow, cc/min	Change in Measured Flow, cc/min (%)	Average Measured Flow Used for Conc.	RC B Initial Measured Flow, cc/min	Final Measured Flow, cc/min	Change in Measured Flow, cc/min (%)	Average Measured Flow Used for Conc.	Outdoor Initial Measured Flow, cc/min	Final Measured Flow, cc/min	Change in Measured Flow, cc/min (%)	Average Measured Flow Used for Conc.
3, CUSD	9/6	153.3	152.8	-0.3	153.0	162.0	149.4	**-7.8**	155.7	167.2	163.2	-2.4	165.2
	9/12	148.0	152.4	3.0	150.2	147.3	145.1	-1.5	146.2	149.0	148.2	-0.5	148.6
	9/18	141.9	148.5	4.7	145.2	135.4	149.0	**10.0**	142.2	136.0	145.3	**6.8**	140.6
	9/27	141.6	146.1	3.2	143.8	142.6	145.1	1.8	143.8	146.8	153.2	4.4	150.0
	10/4	144.6	147.7	2.1	146.2	136.5	145.1	**6.3**	140.8	139.7	150.7	**7.9**	145.2
	10/11	138.3	144.3	4.3	141.3	142.6	144.2	1.1	143.4	152.4	151.5	-0.6	152.0
	10/16	145.5	145.0	-0.3	145.2	142.1	142.4	0.2	142.2	142.5	142.9	0.3	142.7
	10/23	138.2	144.8	4.8	141.5	135.7	143.7	**5.9**	139.7	137.8	144.0	4.5	140.9
4, MCS	9/5	180.6	162.8	**-9.9**	171.7	163.7	151.3	**-7.6**	157.5	159.2	160.5	0.8	159.8
	09/14*	140.6	152.3	**8.3**	146.4	136.0	152.4	*12.1*	144.2	129.3	154.3	*19.3*	141.8
	9/20	147.9	144.4	-2.4	146.2	146.3	150.7	3.0	148.5	147.5	144.5	-2.0	146.0
	9/25	146.4	155.3	**6.1**	150.8	146.0	143.8	-1.5	144.9	145.7	148.1	1.6	146.9
	10/2	149.2	157.0	**5.2**	153.1	142.6	147.2	3.2	144.9	142.7	149.6	4.8	146.2
	10/9	146.8	153.6	4.6	150.2	143.1	143.7	0.4	143.4	158.3	148.1	**-6.4**	153.2
	10/18	156.2	163.3	4.5	159.8	152.4	144.6	**-5.1**	148.5	140.5	144.4	2.8	142.4
	10/25	143.6	141.9	-1.2	142.8	137.2	143.3	4.4	140.2	*173.3*	141.6	*-18.3*	157.4

* = AM measurements made with Gilibrator electronic bubble meter, PM measurements made with BIOS DryCal low flow cell

High initial flow for outdoors sampling pump 10/25/01 relative to other weeks AM measurements.

NOTES: 9/20/01 duplicate pump performance good (159.4 cc/min to 153.9 cc/min, 5.5 cc/min or -3.45% difference);
9/27/01 duplicate sample, pump performance good (142.7 cc/min to 144.6 cc/min, 1.9 cc/min or 1.33% difference);
10/2/01 duplicate sample, pump performance acceptable (140.2 cc/min to 148.2 cc/min, 8.0 cc/min or 5.71% difference);
10/4/01 duplicate sample, pump performance acceptable (134.5 cc/min to 142.5 cc/min, 8.0 cc/min or 5.95% difference);
10/9/01 duplicate sample, pump performance acceptable (136.3 cc/min to 145.2 cc/min, 8.9 cc/min or 6.53% difference);
10/11/01 duplicate sample, pump performance good (135.9 cc/min to 141.6 cc/min, 5.7 cc/min or 4.19% difference).

A.4.6.2 Pump performance evaluation by change in flow rates from near start to near end of sampling period, SD 3 and 4, LBNL RCS, winter 2002 heating season (**bold** type, 5-10% change)

		RC A				RC B				Outdoor			
School District	Date	Initial Measured Flow, cc/min	Final Measured Flow, cc/min	Change in Measured Flow, cc/min (%)	Average Measured Flow Used for Conc.	Initial Measured Flow, cc/min	Final Measured Flow, cc/min	Change in Measured Flow, cc/min (%)	Average Measured Flow Used for Conc.	Initial Measured Flow, cc/min	Final Measured Flow, cc/min	Change in Measured Flow, cc/min (%)	Average Measured Flow Used for Conc.
3, CUSD	1/10	138.3	141.7	2.5	140.0	136.3	140.2	2.9	138.2	143.1	142.2	-0.6	142.6
	1/17	138.4	139.9	1.1	139.2	134.2	126.8	**-5.5**	130.5	135.8	141.2	4.0	138.5
	1/23	138.2	142.0	2.7	140.1	129.7	139.3	**7.4**	132.2	138.2	139.8	1.2	139.0
	1/29	135.6	138.4	2.1	137.0	131.4	136.4	3.8	133.9	141.3	138.9	-1.7	140.1
	2/5	135.6	139.8	3.1	137.7	136.3	139.5	2.3	137.9	134.1	138.9	3.6	136.5
	2/12	140.9	144.8	2.8	142.9	139.2	144.4	3.7	141.8	141.7	143.9	1.6	142.8
	2/28	139.7	142.3	1.9	141.0	136.3	142.2	4.3	139.2	150.2	146.4	-2.5	148.3
	3/5	138.1	143.7	4.1	140.9	138.9	143.7	3.5	141.3	139.0	143.2	3.0	141.1
4, MCS	1/8	142.5	143.9	1.0	143.2	136.7	138.1	1.0	137.4	133.4	137.5	3.1	135.4
	1/15	139.5	143.2	2.7	141.4	133.3	136.2	2.2	134.8	133.6	134.4	0.6	134.0
	1/24	157.9	152.5	-3.4	155.2	135.9	139.0	2.3	137.4	134.7	139.9	3.9	137.3
	1/31	148.6	136.9	**-7.9**	142.8	131.6	137.3	4.3	134.4	147.7	136.5	**-7.6**	142.1
	2/7	136.6	146.3	**7.1**	141.5	134.3	137.6	2.5	136.0	134.5	135.6	0.8	135.1
	2/14	152.8	147.7	-3.3	150.3	144.0	141.2	-1.9	142.6	137.2	135.5	-1.2	136.4
	2/20	148.2	148.0	-0.1	148.1	148.2	142.0	-4.2	145.1	141.2	136.6	-3.3	138.9
	2/26	144.8	145.2	0.3	145.0	138.9	144.6	4.1	141.8	134.3	139.4	3.8	136.8
	3/7	133.5	137.2	2.8	135.4	141.5	139.4	-1.5	140.4	139.9	136.0	-2.8	138.0

NOTES: 1/10/02 duplicate sample, pump performance good (134.2 cc/min to 140.3 cc/min, 6.1 cc/min or 4.54% difference);
1/15/02 duplicate sample, pump performance excellent (137.4 cc/min to 137.9 cc/min, 0.5 cc/min or 0.36% difference);
1/17/02 duplicate sample, pump performance excellent (137.1 cc/min to 138.3 cc/min, 1.2 cc/min or 0.88% difference);
1/23/02 duplicate sample, pump performance good (134.6 cc/min to 139.6 cc/min, 5.0 cc/min or 3.70% difference);
1/24/02 duplicate sample, pump performance good (134.1 cc/min to 140.5 cc/min, 6.4 cc/min or 4.77% difference);
1/31/02 duplicate sample, pump performance good (135.0 cc/min to 139.2 cc/min, 4.2 cc/min or 3.11% difference);
2/5/02 duplicate sample, pump performance good (134.0 cc/min to 137.8 cc/min, 3.8 cc/min or 2.84% difference).

A.6.3 Summary of measured formaldehyde (H_2CO) and acetaldehyde (CH_3CHO) concentrations (ug m^{-3}) indoors and outdoors, fall 2001 cooling season (September 5-October 25), SD 3 (CUSD) and 4 (MCS), LBNL RCS

C= cooling
H= heating

HVAC: I = IDEC, advanced; B = Bard, conventional

			SD 3						SD 4					Outdoors	
Season	Week	HVAC system operating	RC A (Rm 31)	RC A - outdoor	RC B (Rm 30)	RC B - outdoor	HVAC system operating	HVAC system operating	RC A (Rm 28)	RC A - outdoor	RC B (Rm 29)	RC B - outdoor	HVAC system operating	at CUSD school	at MCS school
C	3	B	25.2	21.7	32.1	28.6	B	B	40.0	34.0	34.9	28.9	B	3.5	6.0
C	5	B	29.6	27.1	28.4	25.9	B	B	37.1	30.8	28.5	22.2	B	2.5	6.3
C	7	B	20.2	16.5	26.0	22.3	B	B	39.5	34.2	15.0	9.7	B	3.7	5.3
C	1	B	31.2	27.1	31.0	26.9	B	B	34.8	28.3			B	4.1	6.5
C	1	I					I	I			11.6	5.1	I	4.1	6.5
C	2	I	8.3	5.8	16.9	14.4	I	I	29.5	21.4	17.1	9.0	I	2.5	8.1
C	4	I	8.1	5.7	25.9	23.5	I	I	18.9	14.9	16.5	12.5	I	2.4	4.0
C	6	I	9.2	5.3	10.2	6.3	I	I	14.2	10.3	7.3	3.4	I	3.9	3.9
C	8	I	7.0	3.6	7.6	4.2	I	I	19.5	12.5	14.1	7.1	I	3.4	7.0
H_2CO		arith. mean	17.4	14.1	22.3	19.0			29.2	23.3	18.1	12.2	arith. mean	3.3	6.0
		std. dev.	10.4	10.2	9.5	9.5			10.3	9.8	9.1	8.9	std. dev.	0.7	1.4
		median	14.7	11.2	26.0	22.9			32.2	24.9	15.8	9.4	median	3.5	6.3
		min	7.0	3.6	7.6	4.2			14.2	10.3	7.3	3.4	min	2.4	3.9
		max	31.2	27.1	32.1	28.6			40.0	34.2	34.9	28.9	max	4.1	8.1
C	3	B	9.6	6.0	12.2	8.6	B	B	17.2	12.2	18.2	13.2	B	3.6	5.0
C	5	B	11.2	9.7	9.1	7.6	B	B	15.0	9.6	13.9	8.5	B	1.5	5.4
C	7	B	7.2	4.7	11.0	8.5	B	B	17.1	13.0	14.7	10.6	B	2.5	4.1
C	1	B	12.6	6.1	12.6	6.1	B	B	20.3	12.4			B	6.5	7.9
C	1	I					I	I			7.5	-0.4	I	6.5	7.9
C	2	I	5.2	0.3	6.8	1.9	I	I	17.5	9.3	12.0	3.8	I	4.9	8.2
C	4	I	2.8	2.3	8.9	8.4	I	I	6.6	3.6	6.8	3.8	I	0.5	3.0
C	6	I	3.7	1.4	4.2	1.9	I	I	4.4	0.7	3.8	0.1	I	2.3	3.7
C	8	I	3.8	1.3	2.6	0.1	I	I	9.9	**2.6**	12.5	5.2	I	2.5	7.3
CH_3CHO		arith. mean	7.0	4.0	8.4	5.4			13.5	7.9	11.2	5.6	arith. mean	3.4	5.8
		std. dev.	3.7	3.2	3.7	3.5			5.8	4.9	4.8	4.8	std. dev.	2.1	2.0
		median	6.2	3.5	9.0	6.9			16.1	9.5	12.3	4.5	median	2.5	5.4
		min	2.8	0.3	2.6	0.1			4.4	0.7	3.8	-0.4	min	0.5	3.0
		max	12.6	9.7	12.6	8.6			20.3	13.0	18.2	13.2	max	6.5	8.2

A.6.4 Summary of measured formaldehyde (H_2CO) and acetaldehyde (CH_3CHO) concentrations (ug m^{-3}) indoors and outdoors, winter 2002 heating season (January 8-March 7), SD 3 (CUSD) and 4 (MCS), LBNL RCS

C= cooling
H= heating

HVAC: I = IDEC, advanced; B = Bard, conventional

			SD 3						SD 4					Outdoors	
Season	Week	**HVAC** system operating	RC A (Rm 31)	RC A - outdoor	RC B (Rm 30)	RC B - outdoor	**HVAC** system operating	**HVAC** system operating	RC A (Rm 28)	RC A - outdoor	RC B (Rm 29)	RC B - outdoor	**HVAC** system operating	at CUSD school	at MCS school
H	1	B	13.2	10.4	16.2	13.4	B	B	35.1	32.6	29.8	27.3	B	2.8	2.5
H	2	B					B	B			23.0	20.0	B	2.3	3.0
H	4	B	13.8	12.3	12.1	10.6	B	B	17.2	15.1	15.4	13.3	B	1.5	2.1
H	5	B	22.1	17.6	15.4	10.9	B	B	30.1	28.0	26.7	24.6	B	4.5	2.1
H	8	B	8.2	5.9	6.7	4.4	B	B	45.2	41.4	34.3	30.5	B	3.5	3.8
H	2	I	5.7	3.4	5.6	3.3	I	I	13.2	10.2			I	2.3	3.0
H	3	I	4.4	2.3	4.2	2.1	I	I	9.2	6.5	10.8	8.1	I	2.1	2.7
H	6	I	6.3	2.8	7.2	3.7	I	I	11.6	8.6	12.8	9.8	I	3.5	3.0
H	7	I	N/A	N/A	N/A	N/A	I	I	9.8	7.8	9.2	7.2	I	N/A	2.0
H	9	I	8.3	5.5	7.1	4.3	I	I	5.3	5.0	5.3	5.0	I	2.9	0.3
H_2CO		arith. mean	10.2	7.5	9.3	6.6			19.6	17.2	18.6	16.2	arith. mean	2.8	2.5
NO WEEK 7		std. dev.	5.9	5.4	4.6	4.3			13.8	13.3	10.2	9.6	std. dev.	0.9	0.9
DATA FOR		median	8.3	5.7	7.2	4.3			13.2	10.2	15.4	13.3	median	2.8	2.6
SD 3,		min	4.4	2.3	4.2	2.1			5.3	5.0	5.3	5.0	min	1.5	0.3
VACATION		max	22.1	17.6	16.2	13.4			45.2	41.4	34.3	30.5	max	4.5	3.8
H	1	B	6.3	3.4	6.0	3.1	B	B	10.1	6.7	12.7	9.3	B	2.9	3.4
H	2	B					B	B			12.4	8.7	B	1.5	3.7
H	4	B	6.0	4.5	5.2	3.7	B	B	6.8	5.4	7.3	5.9	B	1.5	1.4
H	5	B	10.9	7.2	7.6	3.9	B	B	14.1	10.9	20.0	16.8	B	3.7	3.2
H	8	B	4.5	2.3	3.7	1.5	B	B	24.0	20.3	22.7	19.0	B	2.2	3.7
H	2	I	2.8	1.3	3.3	1.8	I	I	5.5	1.8			I	1.5	3.7
H	3	I	2.6	1.2	2.6	1.2	I	I	4.4	2.1	5.6	3.3	I	1.4	2.3
H	6	I	3.7	0.9	4.2	1.4	I	I	4.6	-0.3	6.7	1.8	I	2.8	4.9
H	7	I	N/A	N/A	N/A	N/A	I	I	3.5	0.6	4.3	1.4	I	N/A	2.9
H	9	I	3.8	1.7	4.7	2.6	I	I	1.4	0.4	1.9	0.9	I	2.1	1.0
CH_3CHO		arith. mean	5.1	2.8	4.7	2.4			8.3	5.3	10.4	7.5	arith. mean	2.2	3.0
NO WEEK 7		std. dev.	2.7	2.2	1.6	1.1			7.0	6.7	7.1	6.7	std. dev.	0.8	1.2
DATA FOR		median	4.1	2.0	4.5	2.2			5.5	2.1	7.3	5.9	median	2.1	3.3
SD 3,		min	2.6	0.9	2.6	1.2			1.4	-0.3	1.9	0.9	min	1.4	1.0
VACATION		max	10.9	7.2	7.6	3.9			24.0	20.3	22.7	19.0	max	3.7	4.9

A.4.6.5 Evaluation of field duplicates for overall sampling and analytical methods precision, cooling season samples, SD 3 (CUSD) and 4 (MCS), LBNL RCS. Values were corrected for mean of field blanks for this season. The arithmetic mean of the pair of values was used for final measured concentrations.

CAS No	
50-00-0	H_2CO
75-07-0	CH_3CHO

Week	CUSD Wk4			CUSD Wk5			CUSD Wk6			MCS Wk5			MCS Wk6							
Sample Location	RC B			RC B			RC B			RC B			RC B							
Compound	ug/m3	ug/m3	Abs Diff, ug m^{-3}	ug/m3	ug/m3	Abs Diff, ug m^{-3}	ug/m3	ug/m3	Abs Diff, ug m^{-3}	ug/m3	ug/m3	Abs Diff, ug m^{-3}	ug/m3	ug/m3	Abs Diff, ug m^{-3}	Sum of (Abs Diff)^2	Variance (std dev)^2	Std Dev (square root of variance)	Study Median ug m^{-3}	Coefficient of Variation, %
H2CO	26.0	25.8	0.23	28.1	28.8	0.67	10.2	10.3	0.10	27.9	29.2	1.31	7.7	6.9	0.83	2.92	0.29	0.54	19.9	2.7
CH3CHO	9.4	8.5	0.97	8.8	9.4	0.63	3.9	4.5	0.60	13.4	14.4	0.99	3.9	3.7	0.20	2.72	0.27	0.52	9.8	5.3

A.4.6.6 Evaluation of field duplicates for overall sampling and analytical methods precision, heating season samples, SD 3 (CUSD) and 4 (MCS), LBNL RCS. Values for each SD were corrected for mean of field blanks for this season. The arithmetic mean of the pair of values was used for final measured concentrations.

CAS No	
50-00-0	H2CO
75-07-0	CH3CHO

Week	CUSD Wk1			CUSD Wk3			CUSD Wk5			MCS Wk2			MCS Wk3			MCS Wk4		
Sample Location	RC B			RC B			RC B			RC B			RC B			RC B		
Compound	ug/m3	ug/m3	Abs Diff, ug m^{-3}	ug/m3	ug/m3	Abs Diff, ug m^{-3}	ug/m3	ug/m3	Abs Diff, ug m^{-3}	ug/m3	ug/m3	Abs Diff, ug m^{-3}	ug/m3	ug/m3	Abs Diff, ug m^{-3}	ug/m3	ug/m3	Abs Diff, ug m^{-3}
H_2CO	18.6	13.9	4.70	4.4	4.1	0.30	15.4	15.4	0.00	23.9	22.1	1.80	10.3	11.3	1.00	15.1	15.6	0.50
CH_3CHO	6.7	5.2	1.50	2.6	2.7	0.10	7.6	7.6	0.00	12.5	12.3	0.20	5.0	6.2	1.20	7.2	7.4	0.20

Sum of (Abs Diff)^2	Variance, as (std dev)^2	Std Dev (as square root of variance)	Study Median, ug m-3	Coefficient of Variation, %	Compound
26.67	2.67	1.63	11.9	13.7	H2CO
3.78	0.38	0.61	5.4	11.4	CH3CHO

Sum of (Abs Diff)^2	Variance, as (std dev)^2	Std Dev (as square root of variance)	Study Median, ug m-3	Coefficient of Variation, %	Compound
4.58	0.46	0.68	11.9	5.7	H2CO
VALUES ABOVE EXCLUDED WEEK 1 H2CO DATA					

NOTE: The absolute difference for CUSD week 1 sample and field duplicate may be due to sampling pump performance.
The field protocol's 20 minute pump warm-up time may have not been sufficient for the duplicate sampling pump, given near freezing morning temperatures and this pump was being used for only second time since October 2001.

A.4.6.7 Evaluation of analytical duplicates for analytical method precision, cooling season samples, SD 3 (CUSD) and 4 (MCS), LBNL RCS.
Analytical method was extraction in acetonitrile followed by HPLC with UV detection.

CAS No	
50-00-0	H_2CO
75-07-0	CH_3CHO

	Vol. air collected, L		68.4		Vol. air collected, L		63.3		Vol. air collected, L		63.3	
	CUSD Wk1				**CUSD Wk3**				**CUSD Wk4**			
Compound	Date of HPLC-UV detection analysis	Pair of Values ng	Pair of Values ug m^{-3}	Abs Diff, ug m^{-3}	Date of HPLC-UV detection analysis	Pair of Values ng	Pair of Values ug m^{-3}	Abs Diff, ug m^{-3}	Date of HPLC-UV detection analysis	Pair of Values ng	Pair of Values ug m^{-3}	Abs Diff, ug m^{-3}
H2CO [2]	09/06/2001	2136	31.2	0.06	09/18/2001	2050	32.4	0.03	09/27/2001	1673	26.4	0.27
		2140	31.3			2048	32.4			1656	26.2	
	arithmetic mean [1]	*2138*	*31.3*			*2049*	*32.4*			*1665*	*26.3*	
CH3CHO [2]	09/06/2001	840	12.3	3.04	09/18/2001	864	13.6	0.38	09/27/2001	708	11.2	0.95
		1048	15.3			840	13.3			648	10.2	
	arithmetic mean [1]	*944*	*13.8*			*852*	*13.5*			*678*	*10.7*	

	Vol. air collected, L		60.3		Vol. air collected, L		32.6	
	MCS Wk8				**MCS Wk9**			
Compound	Date of HPLC-UV detection analysis	Pair of Values ng	Pair of Values ug m^{-3}	Abs Diff, ug m^{-3}	Date of HPLC-UV detection analysis	Pair of Values ng	Pair of Values ug m^{-3}	Abs Diff ug m^{-3}
H2CO [2]	10/25/2001	852	14.1	0.48	11/01/2001	1301	39.9	0.46
		881	14.6			1316	40.4	
		866	*14.4*			*1309*	*40.2*	
CH3CHO [2]	10/25/2001	822	13.6	0.46	11/01/2001	183	5.6	0.18
		850	14.1			177	5.4	
		836	*13.9*			*180*	*5.5*	

[1] arithmetic mean of the pair of values was used for final measured concentrations
[2] values, including arithmetic mean of each pair, were not corrected for mean of field blanks, 18 ng for H2CO and 82 ng for CH3CHO, as was done with final measured concentrations, e.g., study median

Compound	Sum of (Abs Diff)^2	Variance, as (std dev)^2	Std Dev (as square root of variance)	Study Median, ug m^{-3}	Coefficient of Variation, %	Compound	Sum of (Abs Diff)^2	Variance, as (std dev)^2	Std Dev (as square root of variance)	Study Median, ug m^{-3}	Coefficient of Variation, %
H_2CO	0.52	0.05	0.23	19.9	1.1						
						VALUES BELOW EXCLUDED WEEK 1 CH_3CHO DATA					
CH_3CHO	10.54	1.05	1.03	9.8	10.5	CH_3CHO	1.29	0.16	0.40	9.8	4.1

A.4.6.8 Evaluation of analytical duplicates for analytical method precision, heating season samples, SD 3 (CUSD) and 4 (MCS), LBNL RCS.
Analytical method was extraction in acetonitrile followed by HPLC with UV detection.

CAS No	
50-00-0	H2CO
75-07-0	CH3CHO

	Vol. air collected, L		61.32		Vol. air collected, L		58.46		Vol. air collected, L		62.20		Vol. air collected, L		63.74		Vol. air collected, L		61.71	
	CUSD Wk1				**CUSD Wk2**				**CUSD Wk5 (RC A)**				**CUSD Wk5 (RC B)**				**CUSD Wk9**			
Compound	Date of HPLC-UV detection analysis	Pair of Values ng	Pair of Values ug m^{-3}	Abs Diff, ug m^{-3}	Date of HPLC-UV detection analysis	Pair of Values ng	Pair of Values ug m^{-3}	Abs Diff, ug m^{-3}	Date of HPLC-UV detection analysis	Pair of Values ng	Pair of Values ug m^{-3}	Abs Diff, ug m^{-3}	Date of HPLC-UV detection analysis	Pair of Values ng	Pair of Values ug m^{-3}	Abs Diff, ug m^{-3}	Date of HPLC-UV detection analysis	Pair of Values ng	Pair of Values ug m^{-3}	Abs Diff ug m^{-3}
H_2CO [2]	01/28/2002	827.25	13.5	0.09	01/28/2002	352.66	6.0	0.26	02/13/2002	1393.95	22.4	0.10	02/06/2002	996.52	15.6	0.15	03/07/2002	528.14	8.6	0.03
		821.59	13.4			337.36	5.8			1388.01	22.3			1005.91	15.8			526.03	8.5	
	arithmetic mean [1]	*824.4*	*13.4*			*345.0*	*5.9*			*1391.0*	*22.4*			*1001.2*	*15.7*			*527.1*	*8.5*	
CH_3CHO [2]	01/28/2002	404.82	6.6	0.10	01/28/2002	170.87	2.9	0.32	02/13/2002	667.46	10.7	1.01	02/06/2002	507.07	8.0	0.04	03/07/2002	251.02	4.1	0.06
		398.76	6.5			189.51	3.2			730.46	11.7			504.8	7.9			254.55	4.1	
	arithmetic mean [1]	*401.79*	*6.6*			*180.2*	*3.1*			*699.0*	*11.2*			*505.9*	*7.9*			*252.8*	*4.1*	

[1] arithmetic mean of the pair of values was used for final measured concentrations
[2] CUSD values, including arithmetic mean of each pair, were not corrected for mean of field blanks, 16.3 ng for H2CO and 21.5 ng for CH3CHO, as was done with final measured concentrations, e.g., study median

	Vol. air collected, L		66.74		Vol. air collected, L		61.97		Vol. air collected, L		63.98							
	MCS Wk3				**MCS Wk4**				**MCS Wk7**									
Compound	Date of HPLC-UV detection analysis	Pair of Values ng	Pair of Values ug m^{-3}	Abs Diff, ug m^{-3}	Date of HPLC-UV detection analysis	Pair of Values ng	Pair of Values ug m^{-3}	Abs Diff, ug m^{-3}	Date of HPLC-UV detection analysis	Pair of Values ng	Pair of Values ug m^{-3}	Abs Diff, ug m^{-3}	Sum of (Abs Diff)^2	Variance, as (std dev)^2	Std Dev (as square root of variance)	Study Median, ug m^{-3}	Coefficient of Variation, %	Compound
H_2CO [3]	01/30/2002	645.53	9.7	0.05	02/06/2002	1002.04	16.2	0.18	02/27/2002	673.48	10.5	0.43	0.32	0.03	0.18	11.9	1.5	H_2CO
		642.35	9.6			991.16	16.0			646.16	10.1							
	arithmetic mean [1]	*643.9*	*9.6*			*996.6*	*16.1*			*659.8*	*10.3*							
CH_3CHO [3]	01/30/2002	334.56	5.0	0.06	02/06/2002	498.91	8.1	0.19	02/27/2002	244.26	3.8	0.55	1.49	0.15	0.39	5.4	7.1	CH_3CHO
		330.54	5.0			486.87	7.9			279.71	4.4							
	arithmetic mean [1]	*332.6*	*5.0*			*492.9*	*8.0*			*262.0*	*4.1*							

[1] arithmetic mean of the pair of values was used for final measured concentrations
[3] MCS values, including arithmetic mean of each pair, were not corrected for mean of field blanks, 33.5 ng for H2CO and 39.3 ng for CH3CHO, as was done with final measured concentrations, e.g., study median

APPENDIX A.4

Field Data and Related Calculations

A.4.5 T Data (deg F) by Classroom, School, SD, and Season, UCLA PCS

Descriptive statistics for AM and PM time periods, by day and week, can be made available by author upon request for:

A.4.5.1 *Cooling season, SD 1 and 2*
A.4.5.2 *Heating season, SD 2*

APPENDIX A.4

Field Data and Related Calculations

A.4.6 RH Data (%) by Classroom, School, SD, and Season, UCLA PCS

Descriptive statistics for AM and PM time periods, by day and week, can be made available by author upon request for:

A.4.6.1 *Cooling season, SD 1 and 2*
A.4.6.2 *Heating season, SD 2*

APPENDIX A.4

Field Data and Related Calculations

A.4.7 T and RH Data, LBNL RCS

Descriptive statistics for AM and PM time periods, by day and week, can be made available by author upon request for:

A.4.7.1 T data (deg F) by week, RC A, SD 3, cooling season
A.4.7.2 RH data (%) by week, RC A, SD 3, cooling season
A.4.7.3 T data (deg F) by week, RC B, SD 3, cooling season
A.4.7.4 RH data (%) by week, RC B, SD 3, cooling season
A.4.7.5 T data (deg F) by week, RC A, SD 4, cooling season
A.4.7.6 RH data (%) by week, RC A, SD 4, cooling season
A.4.7.7 T data (deg F) by week, RC B, SD 4, cooling season
A.4.7.8 RH data (%) by week, RC B, SD 4, cooling season
A.4.7.9 T data (deg F) by week, RC A, SD 3, heating season
A.4.7.10 RH data (%) by week, RC A, SD 3, heating season
A.4.7.11 T data (deg F) by week, RC B, SD 3, heating season
A.4.7.12 RH data (%) by week, RC B, SD 3, heating season
A.4.7.13 T data (deg F) by week, RC A, SD 4, heating season
A.4.7.14 RH data (%) by week, RC A, SD 4, heating season
A.4.7.15 T data (deg F) by week, RC B, SD 4, heating season
A.4.7.16 RH data (%) by week, RC B, SD 4, heating season

ADDENDUM TO DISSERTATION ON STATISTICAL ANALYSES

Details are provided to clarify and justify the use of described statistical analyses (section 2.5, pages 59-60) with quantitative data from indoor air and environmental quality (IEQ) measurements conducted to investigate primary and secondary hypotheses (sections 1.5-1.6, pages 14-20) for the school studies comprising this dissertation.

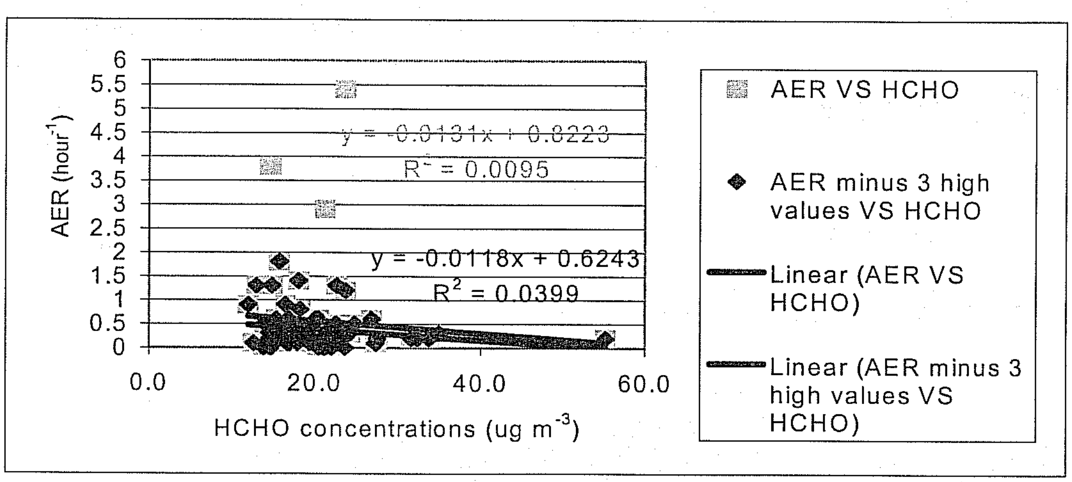
Student t-tests

Tables 3.1.1.5.1, 3.2.1.7.1, and 3.2.1.7.2 summarize results of t-tests of mean target aldehyde concentrations. To conduct this statistic, the researcher must justify the assumption the data are simple random samples from a well-defined population, with independence as a special feature. As described in section 2.1 (pages 21-25), the target school districts and schools were recruited, but the main building and portable classrooms at each participating school were randomly selected, with data analyses generalizing only to the school from which they were selected. Although classrooms within a school are more alike than classrooms across schools in the same or different school districts, the surveys and interview questionnaires developed and implemented in this dissertation (sections 2.2.3, 3.1.6, 3.3) proved the concern was negligible, given each study classroom had a different teacher, was of a different age and/or interior finish material composition, and was a different distance from adjacent, nearby ambient sources of target pollutants. Each individual teacher had to operate the HVAC system, including temperature set point, and teacher behavior introduced variability and uncertainty due to the frequency, duration, types and amount of cleaning and teaching products used even if the same custodian served each school's classrooms. The reader should also note the "no. of obs."

refers to the number of samples collected, with each classroom only being represented once for each sample type (section 2.3, pages 43-49), each of which was an integrated average, in the given sampling event; field duplicate pairs were averaged for statistics. This prevented intra-classroom correlation.

Pearson Correlation Coefficient Analyses

To justify calculating Pearson correlation coefficient (R) values, the researcher must be able to reasonably demonstrate the data are linear. Tables 3.1.1.5.2, 3.1.2.6.1, 3.2.1.7.3, and 3.2.1.7.4 presented R-values for the IEQ measurements, as integrated averages over defined time periods (section 2.3, pages 43-49), including temperature (T); relative humidity (RH); air exchange rate (AER); target volatile organic compounds (VOCs); formaldehyde and acetaldehyde. These statistical analyses were justified because these data, viewed in scatter plots and in consideration of high but valid measures of AER and target compound concentrations, were approximately linear. The scatter plot for formaldehyde (x-axis) versus AER (y-axis) provides an example.



Stepwise Multiple Linear Regressions, Forward and Backward

Table 3.1.2.6.2 presented the summary of results from stepwise multiple linear regressions, using forward and backward selection procedures in SAS v.6.12 (Cary, NC), with IEQ measurements, continuous variables as integrated averages over defined time periods (section 2.3, pages 43-49), including target VOCs, T, RH, and AER. The data for continuous variables T and RH, from measurements conducted every 5-6 minutes for a week in each classroom each season, were reduced to the integrated averages (morning, afternoon, overnight periods) to reduce the risk of auto-correlation. No qualitative data from the surveys and interview questionnaire (section 2.2.3, pages 38-42), as summary statistics for percent response or percent time observed, were included in these models. The interest in conducting these statistical analyses was the ability to predict target VOC and aldehyde concentrations as a function of T, RH and AER measures because of physicochemical properties driving volatility and the hypothesized importance of AER driven mainly by the mechanical HVAC system. Although the author used stepwise multiple linear regression based on the number and types of variables, observations per variable, and nature of the IEQ data, there exists more advanced and/or modern thinking with respect to potential shortcomings of the technique and alternative statistics.

Future studies should create dummy variables at the school, or observation, level to hold constant natural variation between schools in the same school district, i.e., community or geographic region, due to regional background ambient air pollution.

Some issues which may be found with using stepwise multiple linear regression can be mitigated using more modern techniques, such as those presented by Cook and

Weisberg (1999), in future school IEQ studies. The main problem is determining which variables, i.e., relevant predictors, should remain in the overall final model, referred to by Cook and Weisberg as the mean function, to maximize incorporation of relevant information. In this dissertation, we attempted to minimize auto-correlation, which Cook and Weisburg state can inflate the variances of estimates and predicted values, by using integrated averages over shorter, defined time periods-- morning, afternoon, overnight-- for the continuously monitored IEQ variables T and RH. Cook and Weisberg state methods of variable selection strive to minimize the sum of the mean squared errors, and suggest this value can be well estimated by Mallows' C_I statistic. C_I can help screen out bad candidate models ($C_I \leq k_I$, k_I = number of variables in candidate model); with k variables, there are 2^k possible candidate models. In the UCLA pilot Portable Classrooms Study (UCLA PCS), there were thus 2^7 or 128 possible candidate models for each of the thirteen target VOCs examined in the models. According to Cook and Weisberg, to maximize limited resources, stepwise linear regression can be used, but only a fraction of possible candidate models are examined by the statistical software package so optimal results are not guaranteed even if results obtained with this approach can be useful in practice. Furthermore, results from forward selection and backward selection procedures are not guaranteed to agree; this was identified and cited on Table 3.1.2.6.2 for the UCLA PCS upon careful examination of the output. In addition, computer programs can vary as to specific rules for selecting the best candidate model (e.g., SAS v.6.12 uses overall F statistic p-value ≤ 0.05), possibly rejecting reasonable candidate models from further consideration and overstating significance, i.e., overfitting the model, especially when the dependent variable is independent of each potential predictor. In conclusion, stepwise multiple linear regression methods must be used and interpreted with care. Future school studies with larger data sets must consider the use of standard linear regression models or other multivariate modeling techniques in consideration of the numbers of observations per IEQ attribute, number of potential predictors, and nature and quality of the IEQ measures. With stepwise multiple linear regression, techniques such as "bootstrap" (Efron and Tibshirani, 1993), or cross-validation which splits the data set in two, must be used to reduce overfitting and to better understand the role of chance.

The final column of Table 3.1.2.6.2 is titled "most important predictor variable in model." This is a common term used in the field of environmental health sciences and exposure assessment to present multiple linear regression model results summaries, but the trained statistician does not understand the findings unless the term is externally defined (Berk, 2003). Berk states the problem is variables may come in different units, so the researcher cannot directly compare regression coefficients and thus cannot judge relative importance. This can even be true for a series of variables presented as measured concentrations, because the environmental media (air versus water or soil) and system of measurement (ppb versus $\mu g\ m^{-3}$, by volume or by weight) may vary. In the UCLA PCS, the variables had the units of degrees Fahrenheit, percent, $\mu g\ m^{-3}$, or hr^{-1}. Berk further states, however, a definition outside the data, such as "variance explained" from the R^2 value, is still not sufficient because the importance of a potential predictor of the dependent variable also depends on the variability, i.e., standard deviation, of one or both terms. Therefore, with a definition for this dissertation, the message from Table 3.1.2.6.2

becomes it is more important to spend more resources for education on the use of, and for improvement of, HVAC systems to provide adequate ventilation (AER) and thermal comfort (T, RH) than on alternative consumer products and interior finish materials.

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