Environmental Exposures in Early Childhood Education Environments

Agreement Number 08-305

Principal Investigator: Asa Bradman, PhD, MS

Center for Environmental Research and Children's Health (CERCH)

Berkeley, CA

October 24, 2012

Acknowledgements

Co-Authors
- Fraser Gaspar, MPH, UCB
- Randy Maddalena, PhD, LBL
- Rosemary Castorina, PhD, UCB
- Elodie Tong-Lin, BS, UCB
- Thomas McKone, PhD, UCB

Project Officers
- Peggy Jenkins, MS, CARB
- Jeff Williams, PhD, CARB

Other Laboratories
- Marcia Nishioka, MS, Battelle
- Mark Strynar, PhD, US EPA
- Walter Weathers, MS, US EPA
- Peter Egeghy, PhD, US EPA

Today's Talk

- Brief overview of environmental concerns in child care

- Research highlights from environmental monitoring study

- Future research needs.

California's Child Care Facilities

- Regulated by the Community Care Licensing Division, Cal. DSS.

➢ Center License (~10,000 facilities)

(school, non profit, religious, for-profit, etc., various structures)

➢ Family Daycare in Homes (~40,000 facilities)

- Small
- Large

Research & Children's Health

Why is the quality of the environment in ECE facilities so important?

- ~13,000,000 children in child care nationally

In California:

- ~50,000 licensed facilities
- ~1,000,000+ children in child care
- 146,000 staff

cerch
Center for Environmental Research & Children's Health

Child care and preschool environments may be better than where the child lives

- Substandard housing is common, especially in low-income communities
- Child care/preschool environments may offer healthier environment to children.

CHAMACOS

Cockroach feces in home environment.

cerch
Center for Environmental Research & Children's Health

Why Concerns About Children?

- Higher exposures:
  - Frequent contact with the ground or floor
  - Hand-to-mouth activity
  - Less varied diet
  - Eat, drink, and breathe more per kg
  - Spend most of their time indoors
- Physiologically immature
  - Metabolic pathways undeveloped
- Neural architecture not yet in place

Children are more vulnerable than adults.

cerch
Center for Environmental Research & Children's Health

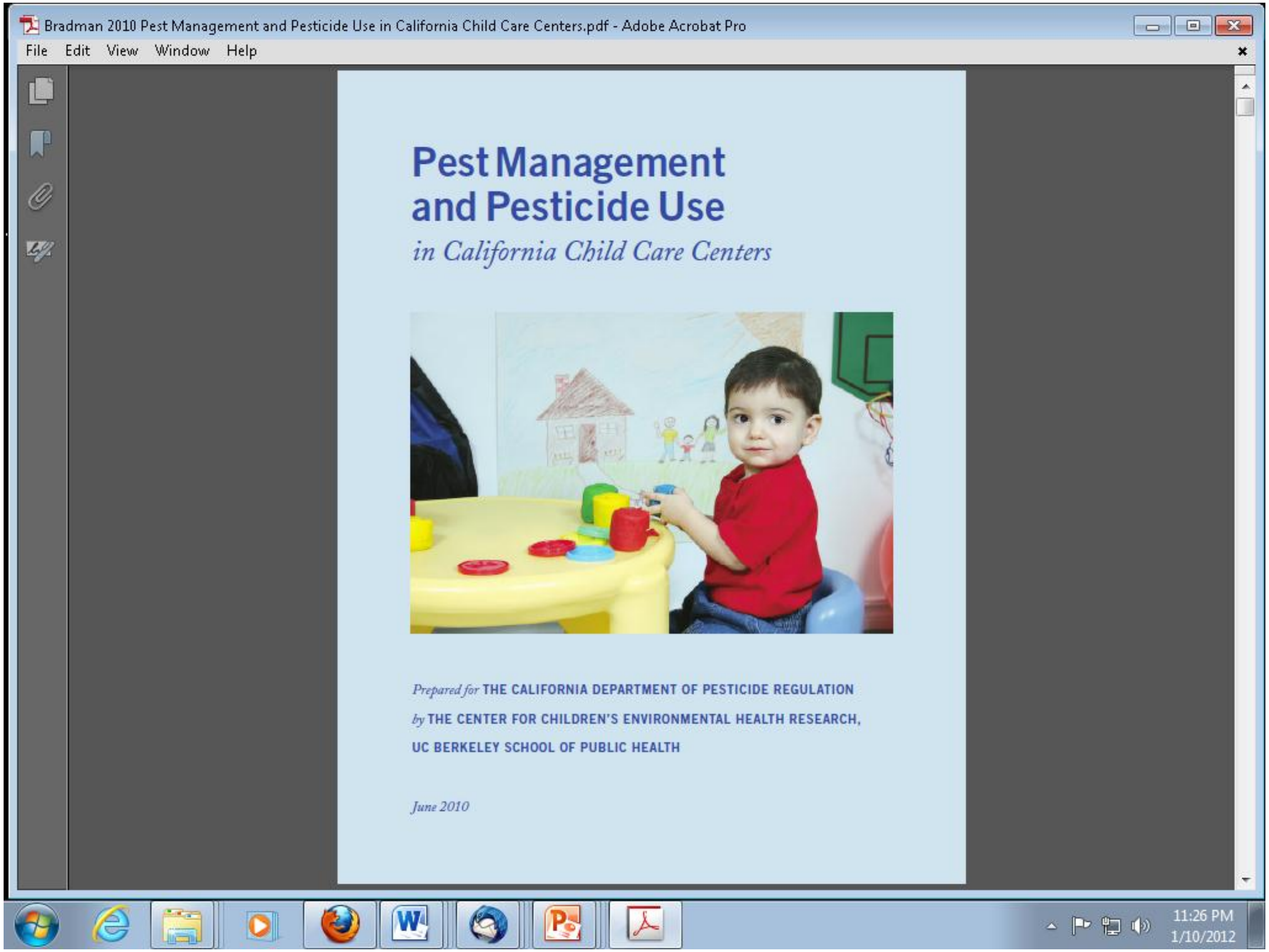
Specific Environmental Concerns

- Asthma
- Chemical Hazards
- Environmental Tobacco Smoke
- Green Cleaning
- Indoor Air Quality
- Lead
- Mercury
- Mold
- Pesticides
- Plastics
- Disinfectants

cerch
Center for Environmental Research & Children's Health

Little Data on Exposures in Child Care

cerch
Center for Environmental Research & Children's Health



No environmental monitoring in California.

Current Study:

Environmental Exposures in Early Childhood Education Environments

Objectives

1. Complete measurements of environmental contaminants in 40 ECE facilities (n=20 each in Alameda and Monterey Counties)
2. Utilize questionnaires and inspections to assess environment
3. Estimate potential health risks.

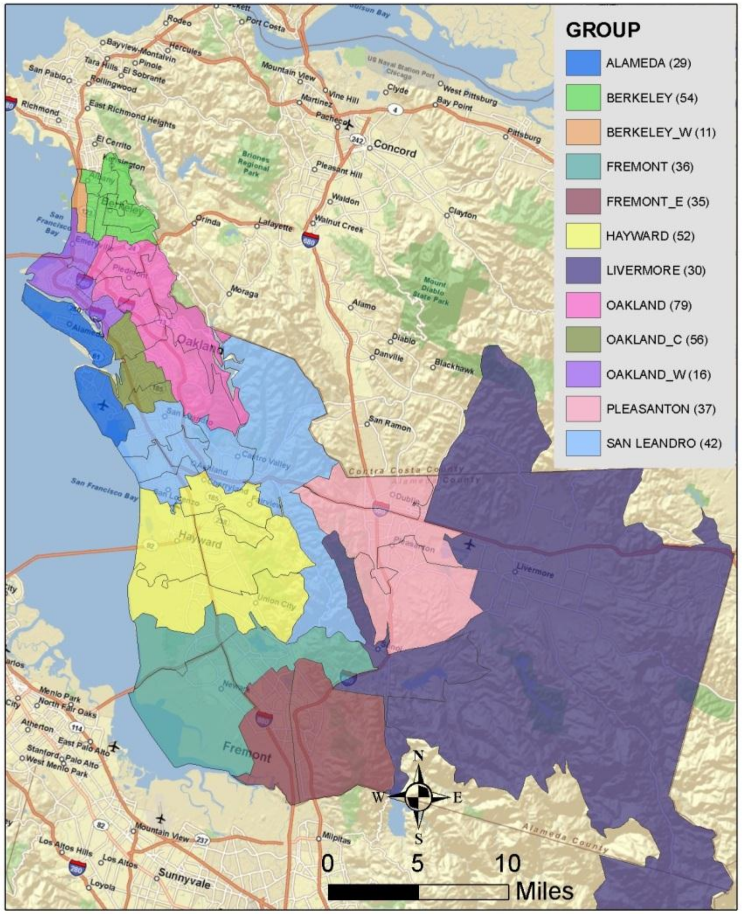
cerch
Center for Environmental Research & Children's Health

Recruitment

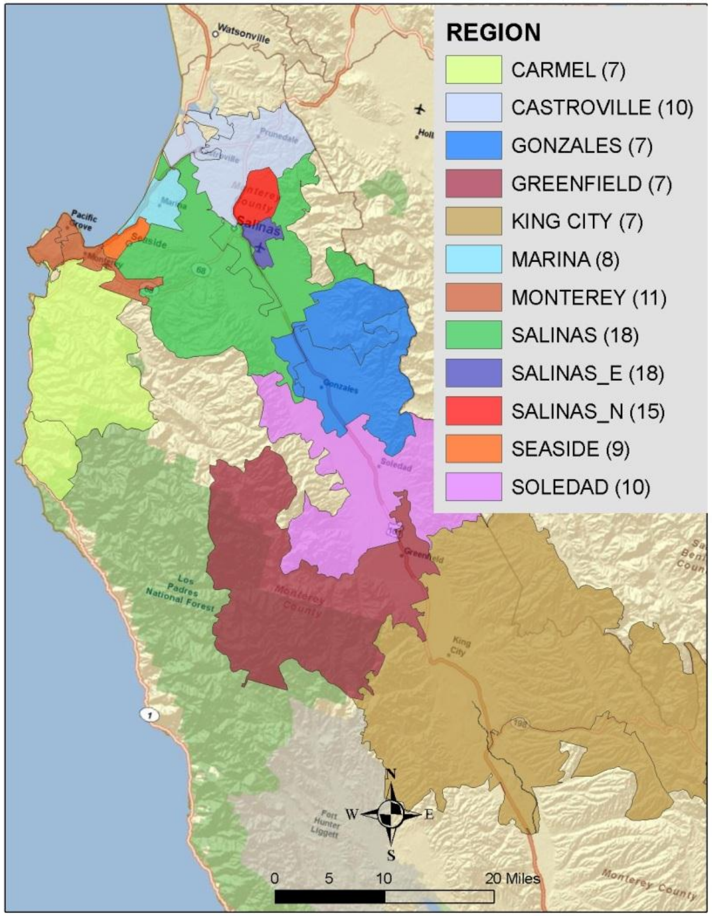
- Geographically stratified random sample
- Use Dept. Social Services database
- Work with local referral agencies and planning councils to recruit family-licensed facilities.

Recruitment

ALAMEDA COUNTY CHILD CARE CENTERS



MONTEREY COUNTY CHILD CARE CENTERS



cerch
Center for Environmental Research & Children's Health

Questionnaires and Inspections

- Synthesized from existing instruments targeting schools and homes –
  - Environmental Assessment
  - Behaviors – e.g., cleaning, maintenance
  - Education/attitudes
  - Recorded building/location characteristics
  - Inventoried chemicals on site

Samples Collected

Air and dust samples collected from 40 childcare facilities. Tested for:

Chemicals

- Phthalates
- VOCs*
- Carbonyls*
- Pesticides
- Flame Retardants
- PFCs
- Metals

Particles*

- PM_{10}
- $PM_{2.5}$
- Real-Time PM
- Ultrafine Particles

*Air only.

Other Data Collected

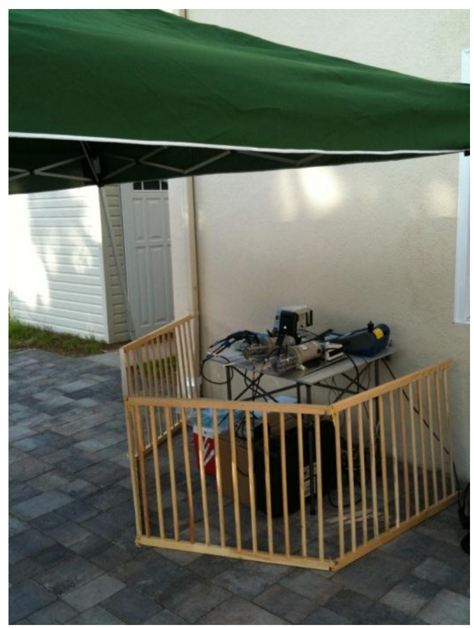
- Temperature
- Carbon dioxide
- Occupancy
- Air exchange rates
- Opening and closing of windows and doors

cerch

- Access
- Equipment/child safety
- Noise
- Technical Challenges

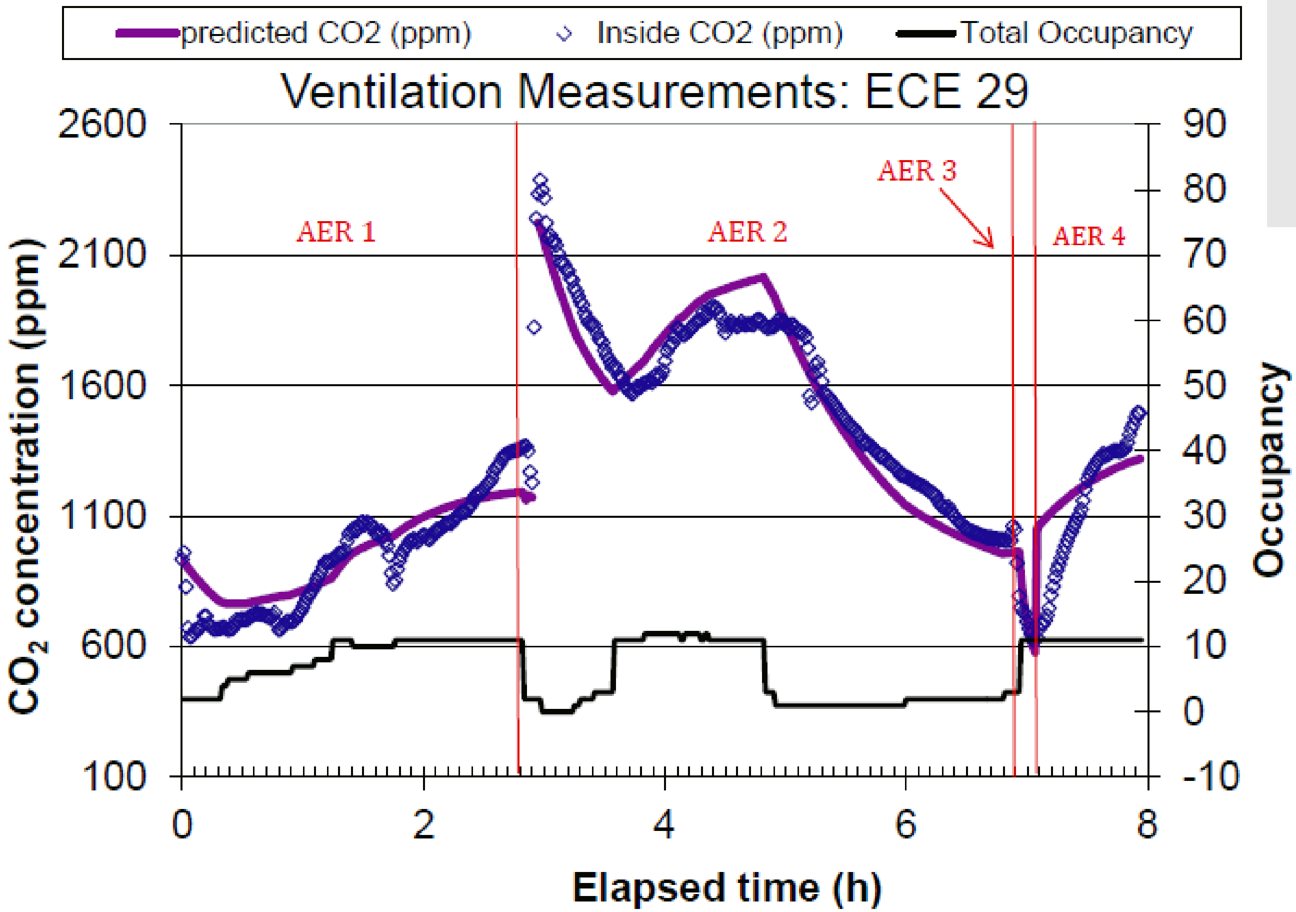
cerch
Center for Environmental Research & Children's Health

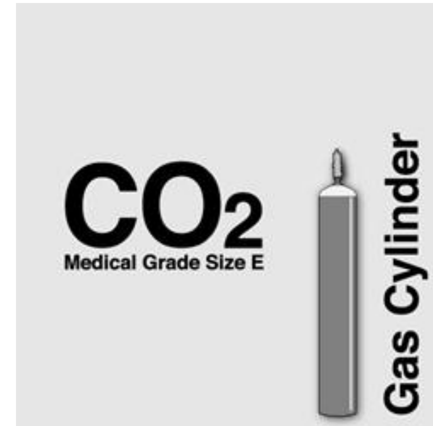
CHAMACOS



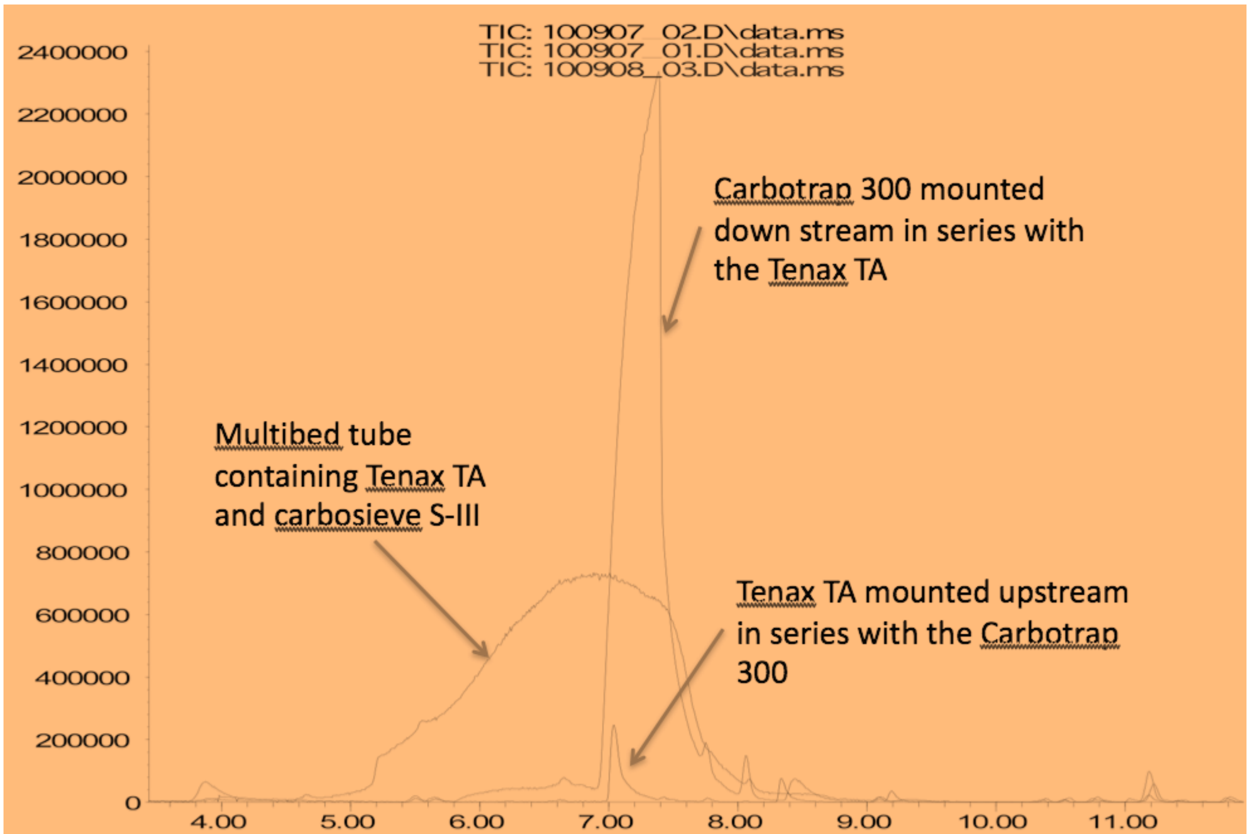
cerch
Center for Environmental Research & Children's Health

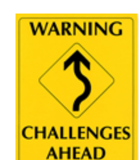
Technical Challenges: Air Exchange Rates



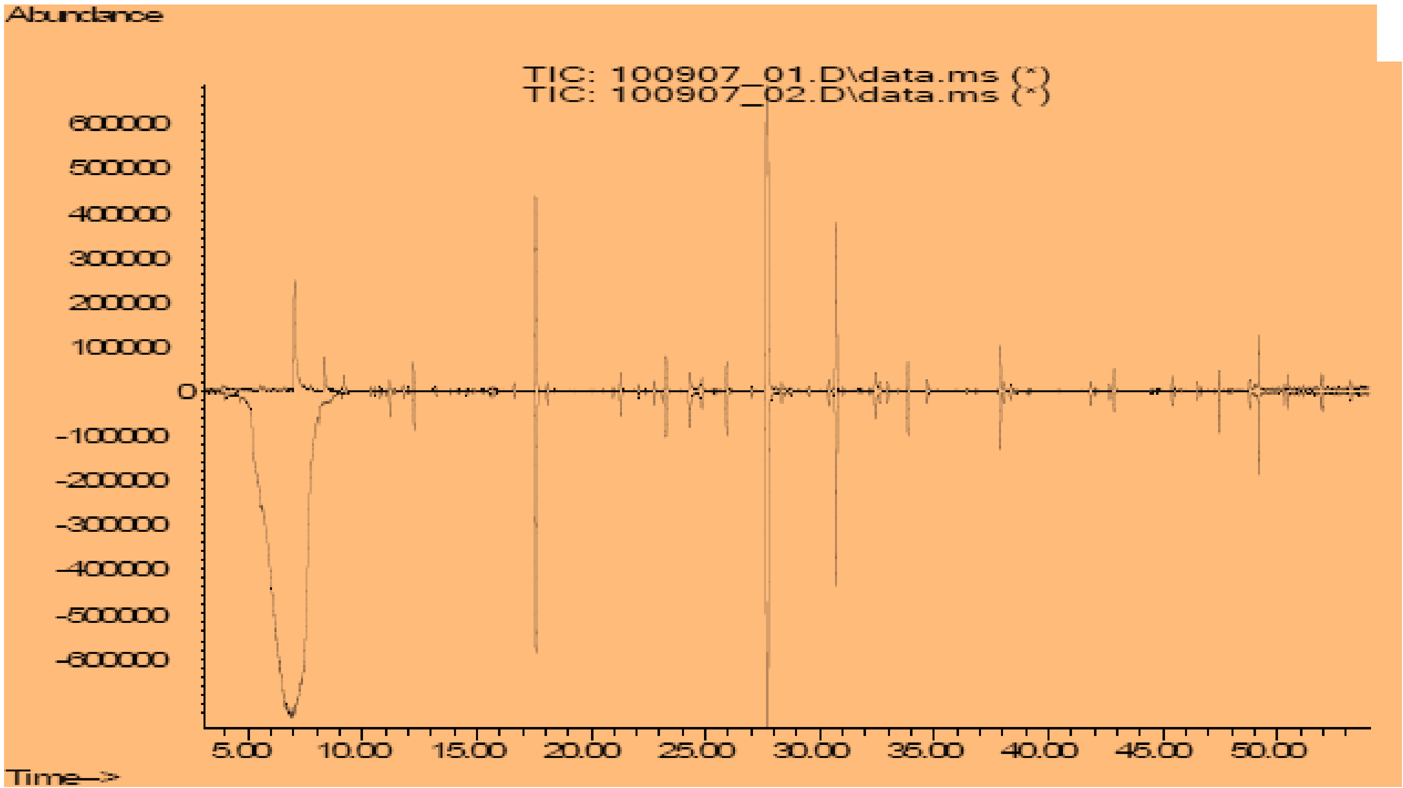


Technical Challenges





Technical Challenges



Methods

• VOCs	Tenax and CarboTrap sorbent tubes
• Carbonyls	Silica gel cartridges (XPoSure Aldehyde Sampler)
• Semi-Volatile Compounds (phthalates, pesticides, flame retardants)	Polyurethane foam (PUF) cartridges
• Ultrafine Particles	Condensation Particle Counter (CPC)
• Particulate Matter	Gravimetric and Real Time Dustrak
• Dust Collections	Vacuum Samples (HVS3)

cerch
Center for Environmental Research & Children's Health

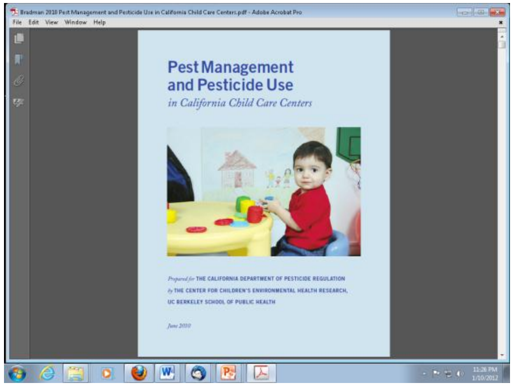
Study Findings

Building Type

Building Type	N
Single Family Detached Home	15
School (traditional)	11
School (portable)	9
Office building	3
Church	2

Child care facilities were in good physical condition

- Mold, mildew, rotting wood, etc., minimal
- HVAC systems well maintained; 93% compliant with Cal. Building Code minimum of 0.35 air changes/hour
- Pests common, mostly ants/invertebrates, some rodents
- 58% used pesticides (with 45% using sprays)
- These issues are typical of other California facilities (Bradman et al. 2010).



Study Findings

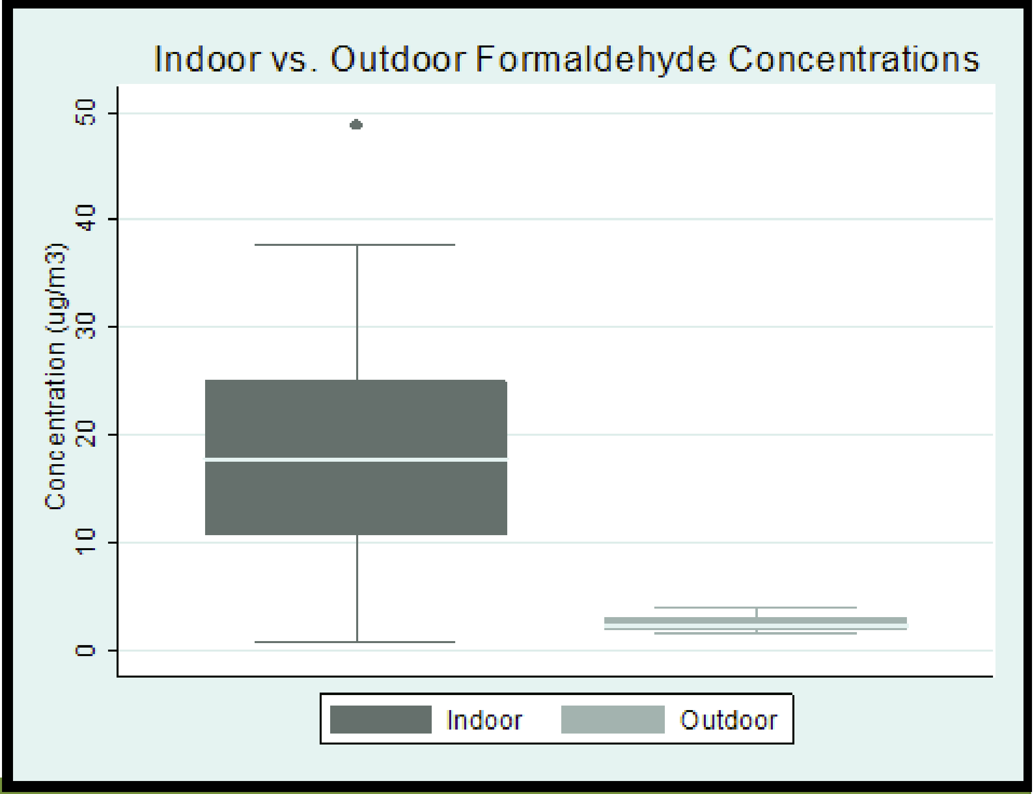
135 chemical ingredients identified in paints, solvents, cleaners, etc., stored on site.

32 pesticide active ingredients stored or used on site.

Note: Storage on site does not necessarily imply exposure.

Volatile Organic Compounds

- ~ 40 VOCs quantified
- Trend of higher levels inside:
  - Average indoor/outdoor ratio: 37
  - Range of ratios: 1.1 (benzene) to 1600 (d-limonene)
  - Higher ventilation reduced VOC levels (correlation of formaldehyde and air exchange = - 0.6)



Volatile Organic Compounds

- Highest levels associated with cleaning and personal care products:

	Median ($\mu g/m^3$)
d-Limonene	33
Decamethylcyclopentasiloxane	51

Traffic associated with some outdoor VOCs

For example, correlation with outdoor hexane, benzene, ethyl benzene:
r = 0.6-0.7

Weaker correlations with indoor levels:
r = 0.3-0.4

cerch
Center for Environmental Research & Children's Health

VOC Risk Evaluation

Note: VOCs are many different compounds. Some are respiratory irritants, potentially neurotoxic, carcinogenic, or have other health endpoints.

Formaldehyde

Formaldehyde, known respiratory irritant and Prop 65 carcinogen, commonly exceeded reference exposure level (REL):

- Median Formaldehyde: 17.7 $\mu g/m^3$
- OEHHA 8-hour and chronic REL: 9 $\mu g/m^3$
- N = 35 (88%) exceeded these RELs.
- None exceeded acute REL

Other Carbonyls

- Acetaldehyde exceeded the EPA RFC in 30% of facilities
- Lower than California RELs.

Carbonyls: Comparison to Other Studies

	Formaldehyde (means: µg/m³)	Acetaldehyde (means: µg/m³)
Child Care Facilities	19	8.5
New California Homes[1]	43	25
Portable Classrooms[2]	19	13
Traditional Classrooms[2]	16	11

1. Source: Offermann et al. 2009
2. Source: CARB 2004 (Whitmore, RTI, final report, 2003)

Comparison of Child VOC Exposures to Prop. 65 Thresholds

- OEHHA No Significant Risk Level (NSRL) defined for lifetime exposures:

$$NSRL\left(\frac{\mu g}{day}\right) = \frac{[Cancer\ Risk\ \times Body\ Weight\ (kg)]}{Cancer\ Potency\ Estimate\ (\frac{mg}{kg-day})^{-1}} * (\mathrm{CF})$$

- Guidelines developed to account for vulnerability of children
  - Age-specific sensitivity factor
  - Lower body weight
- Compare child exposures to child-specific NSRL.

Center for Environmental Research & Children's Health

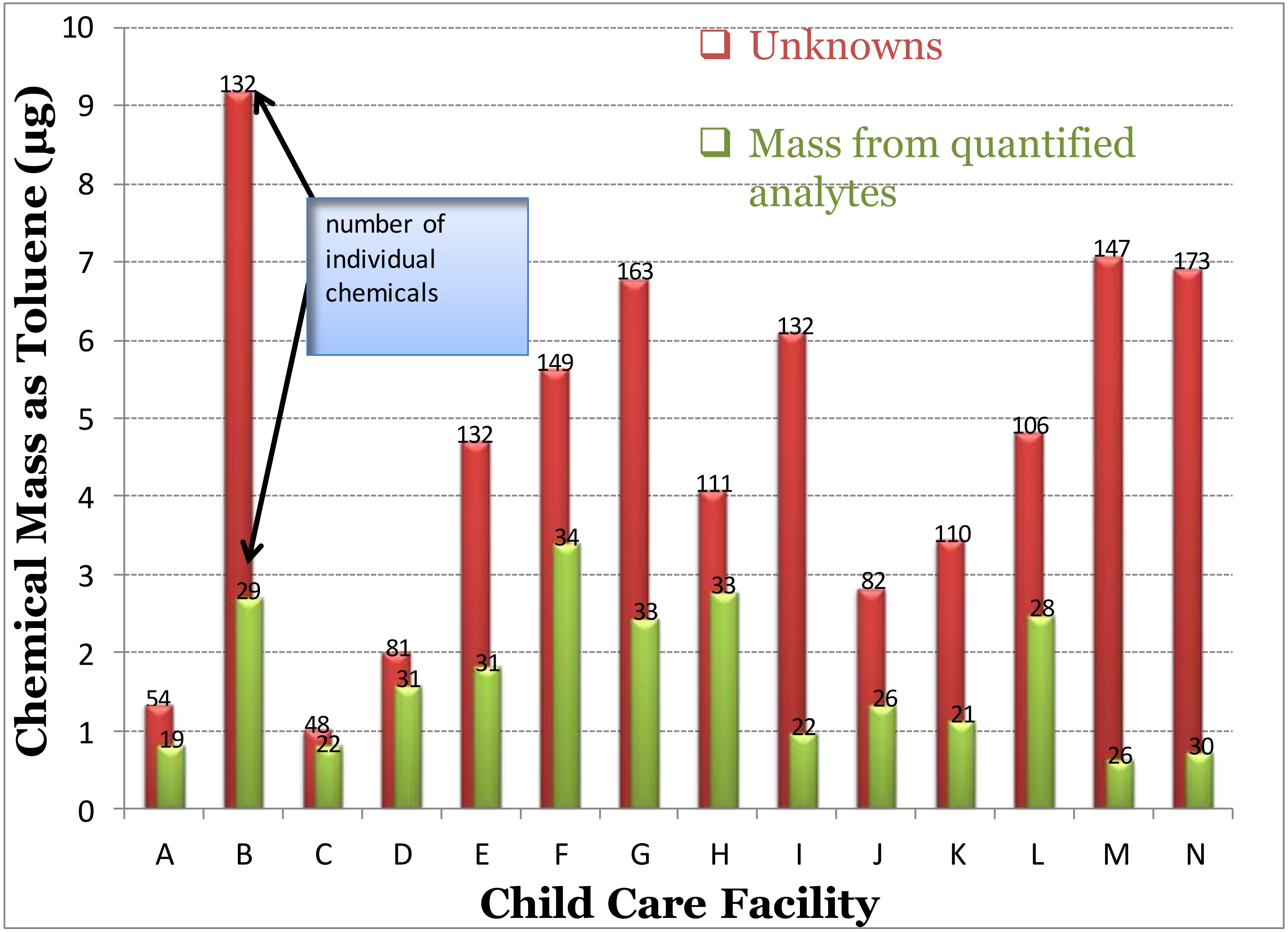
Exposures to several VOCs may exceed Prop. 65 thresholds based on child-adjusted NSRLs

- Benzene
- Chloroform
- Ethylbenzene
- Acetaldehyde
- Formaldehyde

Unknown VOCs

- Up to 60% or more of VOC mass not identifiable
- Many unknown peaks in chromatograms.

Identifying Unknown VOCs



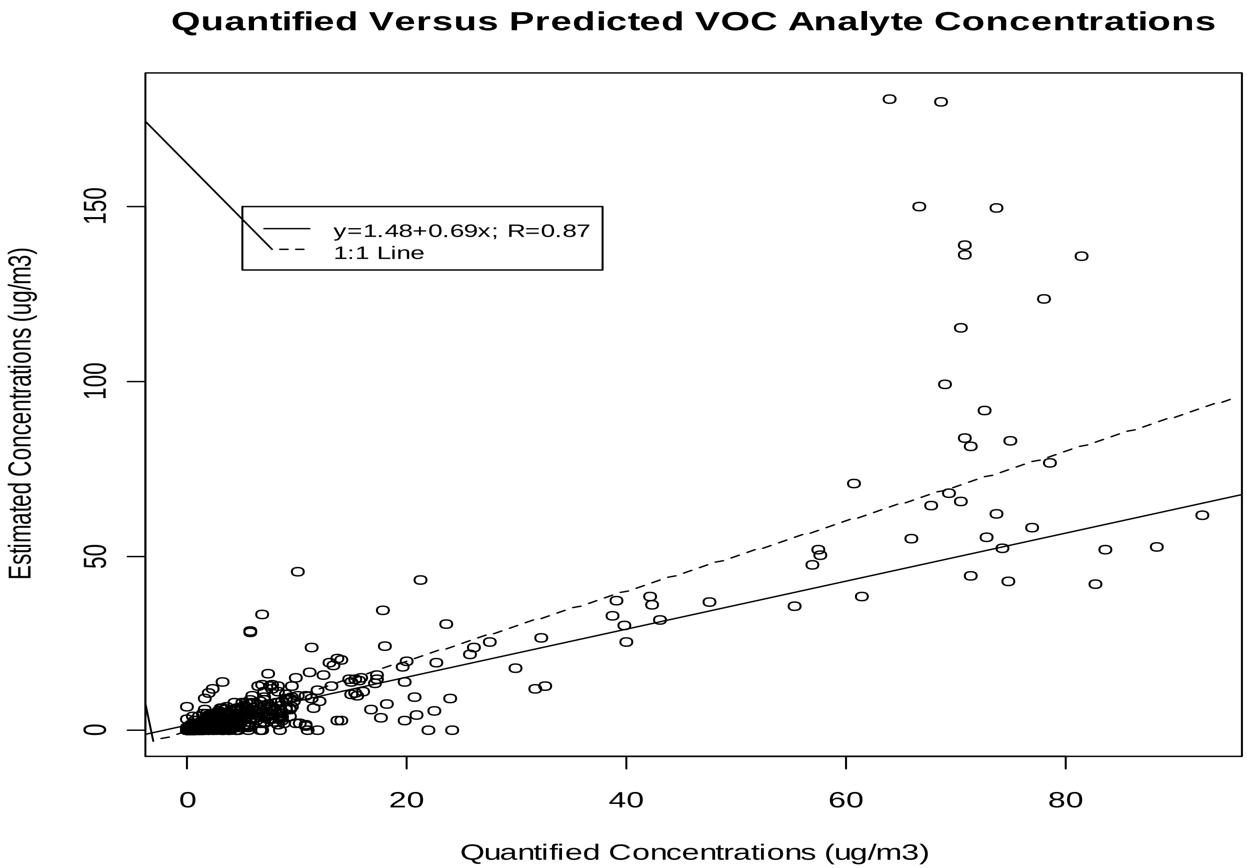
Identifying Unknown VOCs

Quantification Strategy

- Linked to NIST spectral library
- Accepted if >80% certainty of match
- Quantified using toluene calibration model

130 Additional VOCs Likely Present

For subset with quantified levels, good correlation between measured values and predicted levels: r = 0.87



130 Additional VOCs Likely Present

Table 152. Summary of Unknown VOC Concentrations (ng/m³) Using Semi-Quantitative Method of Analysis

Analyte	Det. Freq. (%)	N	Min	25th %	Median	75th %	90th %	95th %	Max
Pentane	54.5	22	0.0	0.0	40.9	95.0	187.5	394.0	417.8
1,3-Pentadiene, (Z)-	95.5	22	0.0	246.4	367.3	614.3	753.2	951.8	1,959.8
Ethanol	95.5	22	0.0	82.9	215.6	901.1	2,906.2	3,547.4	8,537.7
Isopropyl Alcohol	100.0	32	262.9	731.7	1,551.8	3,821.4	6,045.7	12,673.5	485,339
Hexane, 2-methyl-	100.0	32	50.4	111.9	242.3	598.9	1,100.3	1,532.1	1,858.1
Cyclohexane	100.0	32	40.3	96.8	221.0	403.9	645.8	1,403.3	1,514.9
Hexane, 3-methyl-	96.9	32	0.0	141.5	275.3	593.4	1,232.0	1,725.2	1,852.1
Ethyl Acetate	96.9	32	0.0	143.3	250.5	628.7	2,302.7	3,242.2	3,411.6
Silanol, trimethyl-	100.0	32	62.4	102.9	140.5	181.3	281.7	1,775.4	2,538.7
Cyclohexane, methyl-	100.0	32	47.6	95.0	292.5	410.8	905.7	1,118.9	2,372.1
2-Propanol, 1-methoxy-	71.9	32	0.0	0.0	131.3	319.7	933.4	2,176.0	11,417.8
1-Butanol	100.0	32	168.6	638.3	847.5	1,316.0	2,115.1	3,504.6	3,949.7
Pentanal	100.0	32	199.7	331.8	410.9	581.8	896.2	1,156.9	3,697.7
Acetic acid	87.5	32	0.0	215.4	764.9	1,954.4	4,146.1	7,142.1	10,550.8
Acetic acid, 2-methylpropyl ester	75.0	32	0.0	13.2	106.5	357.3	505.1	955.7	1,492.4
Acetic acid, butyl ester	96.9	32	0.0	245.8	389.4	777.2	1,862.1	6,490.0	6,997.0
Nonane	100.0	32	89.3	147.6	241.2	397.4	635.8	1,017.1	1,102.5
2-Pentanol, acetate	78.1	32	0.0	23.3	63.5	292.4	450.2	622.1	744.6

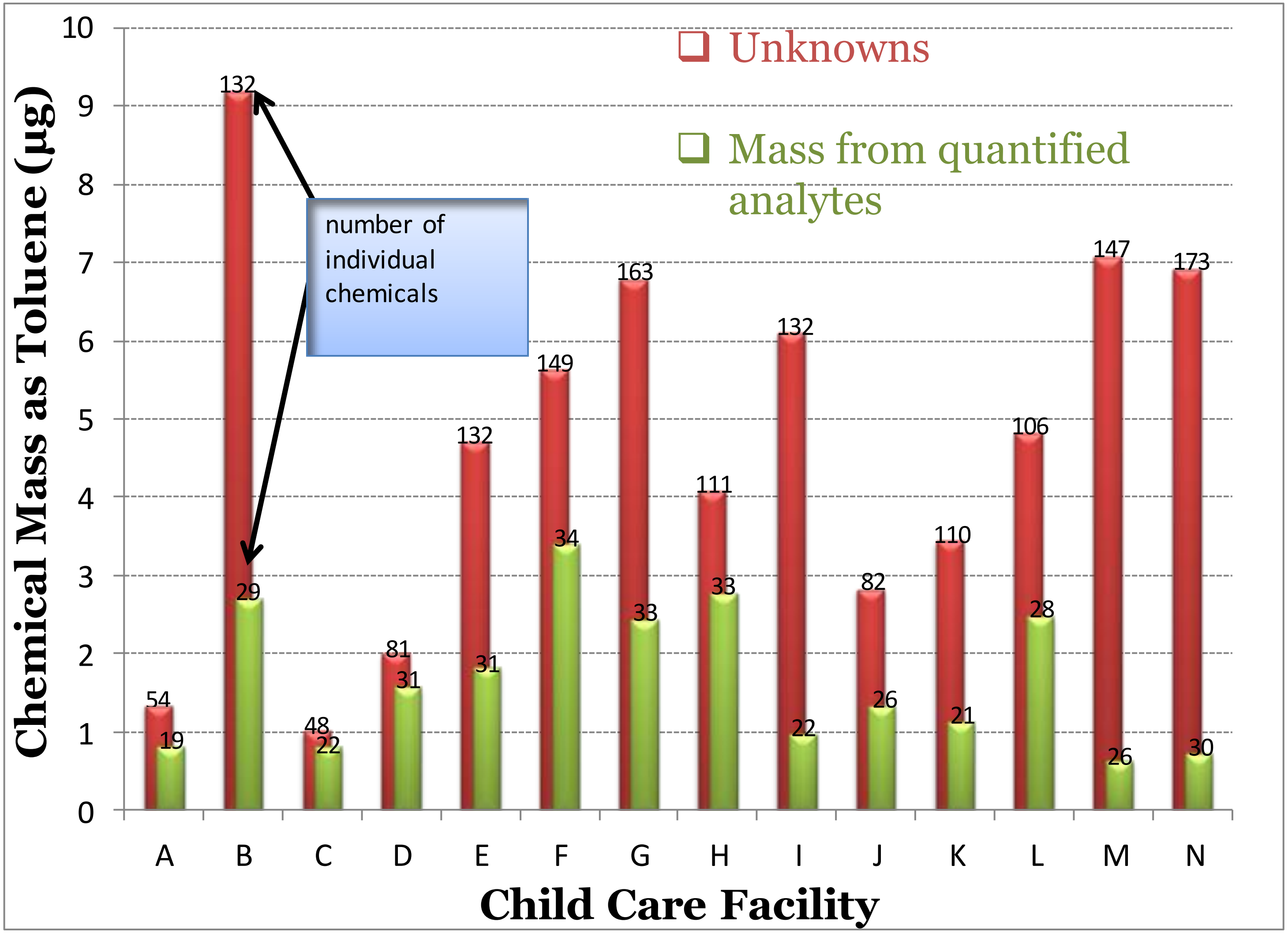
Table 152 Continued. Summary of Unknown VOC Concentrations (ng/m³) using Semi-Quantitative Method of Analysis

Analyte	Det. Freq. (%)	N	Min	25th %	Median	75th %	90th %	95th %	Max
Cyclohexanone	100.0	32	159.9	366.5	517.1	868.0	1,368.5	2,688.7	12,195.6
beta-Myrcene	90.6	32	0.0	291.3	789.6	2,147.6	3,455.3	6,103.0	7,876.5
2-Propanol, 1-butoxy-	78.1	32	0.0	28.1	121.4	510.9	1021.1	3,507.9	17,086.2
Decamethyl Tetrasiloxane	50.0	32	0.0	0.0	17.3	193.8	765.4	6,185.9	68,645.5
.alpha.-Phellandrene	70.0	10	0.0	0.0	89.1	425.9	470.0	502.5	502.5
Methyltris(trimethylsiloxy)silane	37.5	32	0.0	0.0	0.0	132.2	752.0	2,915.5	6,185.9
Trisiloxane, octamethyl-	43.8	32	0.0	0.0	0.0	106.5	1,186.2	1,873.6	81,221.3
Eucalyptol	100.0	32	83.9	158.6	327.9	1,072.5	1,967.9	2,670.1	66,970.3
5-Hepten-2-one, 6-methyl-	68.8	32	0.0	0.0	82.8	209.1	446.1	817.2	1,061.8
1,4-Cyclohexadiene, 1-methyl-4-(1-methylethyl)	68.8	32	0.0	0.0	484.5	710.0	2,459.4	7,611.5	11,510.7
2-Propanol, 1-(2-methoxy-1-methylethoxy)	96.7	30	0.0	125.3	253.6	719.0	1,494.3	2,363.4	2,469.2
Dipropylene glycol monomethyl ether	96.8	31	0.0	134.9	268.5	803.0	1,525.8	2,542.7	16,100.1
Benzene, 1-ethyl-3,5-dimethyl-	20.0	5	0.0	0.0	0.0	0.0	172.0	172.0	172.0
2-Propanol, 1-(2-methoxypropoxy)-	100.0	32	99.4	603.0	1,229.9	5,517.0	6,637.2	11,049.1	27,623.9
7-Octen-2-ol, 2,6-dimethyl-	100.0	32	163.0	637.9	1,656.7	3,214.4	9,019.4	11,492.5	15,495.2
3-Octanol, 3,7-dimethyl-, (±)-	65.6	32	0.0	0.0	86.3	217.3	390.2	1,334.0	11,475.8
1 Octane, 2,6-dimethyl-	0.0	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,8-Nonanediol, 8-methyl-	100.0	10	126.7	190.0	403.2	518.1	593.0	653.4	653.4
1-Octanol	100.0	10	1,450.7	2,343.3	2,768.9	3,294.2	4,594.3	4,653.7	4,653.7
Pentasiloxane, dodecamethyl-	100.0	10	23.7	37.5	139.9	411.1	14,153.5	27,748.0	27,748.0
Acetophenone	100.0	32	478.3	971.4	1,099.9	1,162.2	1,405.1	1,950.3	2,144.3
Benzyl Alcohol	100.0	32	72.0	285.4	483.3	894.2	1,226.7	3,339.9	6,853.1

…

cerch

Rich Area for Future Research



Flame Retardants

- Levels in air were low, often below detection at the median or less than 1 nanogram/m^3
- Consistent with vapor pressure
- For several flame retardants indoor air levels were higher than outdoor levels, likely associated with volatilization or suspension of contaminated dust particles.

Flame Retardants

- In addition to the BDE flame retardants, residues of organophosphate flame retardants and Firemaster 550 were also present.

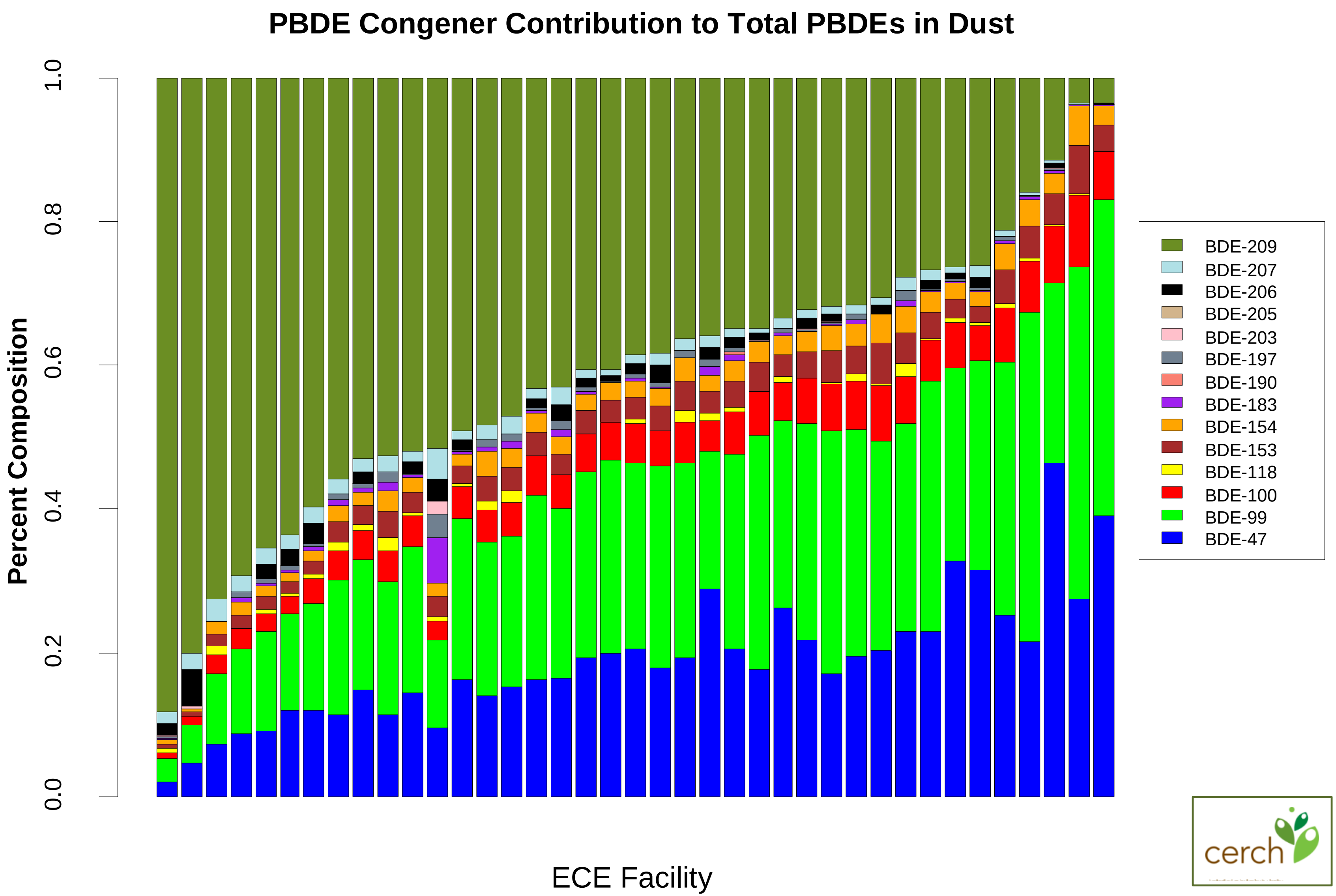
Median Flame Retardant Levels

(n = 39, Detection Frequencies = 100%)

Analyte (ng/g)	Median	Max
BDE-47	769	15,116
BDE-99	1,031	25,522
BDE-100	212	55,250
BDE-209	1,443	16,792
∑ BDE	4,206	55,155
Tris (2-chloroethyl) phosphate (TCEP)	319	6,835
Tris (1,3-dichloro-2-propyl) phosphate (TDCPP)	2,265	70,931
2-Ethylhexyl tetrabromo-benzoate (EHTBB)	362	14,812
Bis(2-ethylhexyl)tetrabromo-phthalate (BEHTBP)	133	7,490

cerch

BDE-209 was the dominant PBDE congener in dust



cerch

Brominated Flame Retardants

- Potential endocrine disruptors and neurotoxic.
- Child intake based on EPA non-dietary ingestion assumptions exceed reference dose for children <1 year.

Phthalates

- Median levels in indoor air all below 1 µg/m^3
- Outdoor levels mostly below detection limits
- Higher indoor levels suggest volatilization or re-suspension of contaminated dust particles
- Consistent with moderate correlation of indoor air and dust levels.

- Frequently detected in dust
- Median levels range from 1.4-172 µg/g.

➢ Phthalate developmental toxins; potential respiratory irritants and endocrine disruptors. Estimated exposures did not exceed health guidelines, when available.

cerch

Pesticides

Compounds measured:

- Organophosphorous insecticides (chlorpyrifos and diazinon)
- Pyrethroid insecticides
- Piperonyl butoxide (synergist)
- Dacthal - herbicide

Pesticide Results

- 32 active ingredients stored or used on site
- Pyrethroids (*trans-, cis*-permethrin) frequently detected at highest levels in dust, commonly present in air
- OPs also frequently detected in air and dust
- Dacthal higher in dust and air in agricultural areas
- OP pesticide levels in ag. areas were not higher than non-ag areas.

cerch

Pesticide Results (cont.)

- Moderate correlations between indoor air levels and pesticide dust concentrations/loadings suggest that reducing indoor pesticide use could reduce air levels.
- Pyrethroids and OP pesticides are neurotoxic. Pesticide exposure estimates were below risk benchmarks.

Perfluorinated Compounds

- Ten compounds measured (PFOS, PFOA, PFBA, PFPeA, PFHxA, PFHpA, PFNA, PFDA, PFBS, PFHS)
- Air measurements not successful
- PFOS and PFOA present in >50% of dust samples
- Perfluorinated compounds are potential carcinogens (currently under review by the National Toxicology Program (NTP) and OEHHA). No health-based benchmarks available.

Lead in Dust

Median = 36 µg/g

Max = 805 µg/g

- Lead is neurotoxic
- No lead standard for dust concentrations
- Overall, levels lower than standards for soil that children play in.

cerch

Particulate Matter

Measured:

- Ultrafine particles (UFP) (> 6 nm)
- Particulate Matter
  - less than 10 microns (PM_{10})
  - less than 2.5 microns ($PM_{2.5}$)

- Particulate matter is a respiratory irritant. May affect cardiovascular and other systems.

$PM_{2.5}$ and PM_{10} (μg/m³)

Indoor $PM_{2.5}$	15
Outdoor $PM_{2.5}$	16.2
Indoor PM_{10}	47.6
Outdoor PM_{10}	28.9

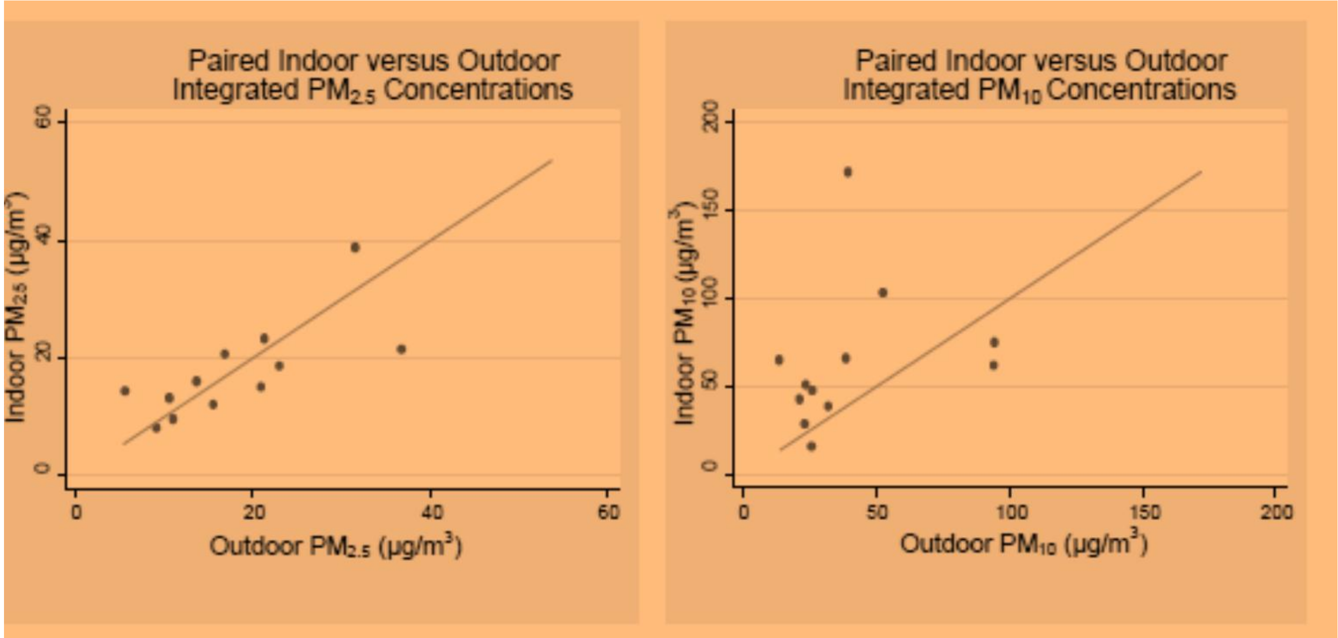
California and US EPA Standards

$PM_{2.5}$ US EPA 24-hour standard: 35 μg/m³
(11% > than this level*)

PM_{10} CARB 24-hour standard: 50 μg/m³
(46% > than this level*)

*Study samples collected over 8 hours

$PM_{2.5}$ and PM_{10}



Median Ratio $PM_{2.5}$ 1.0

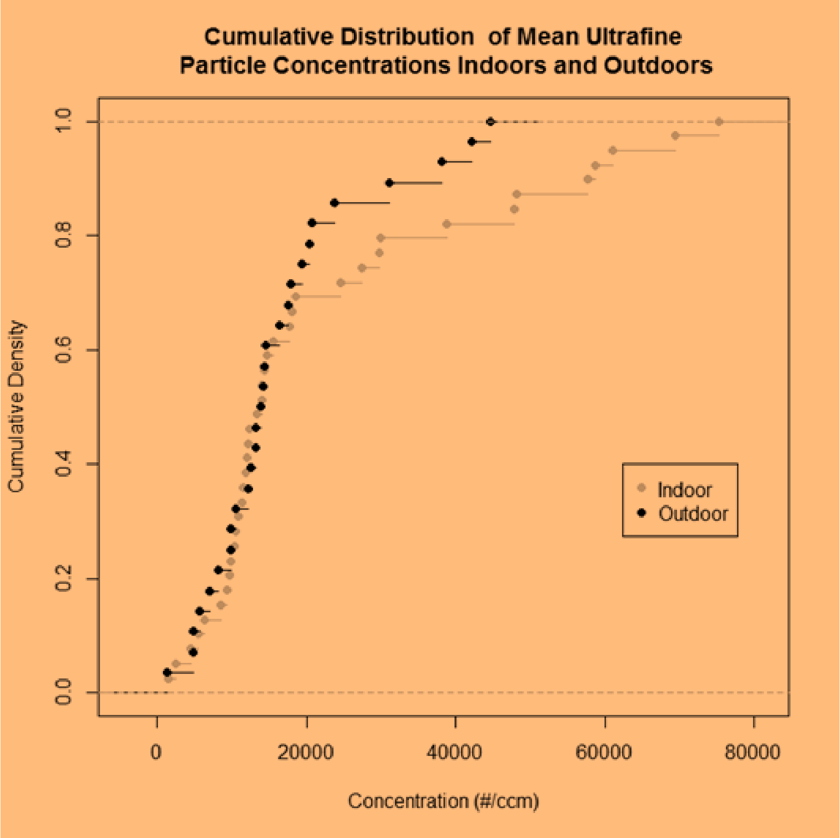
Median Ratio PM_{10} 1.8

Tendency for higher PM_{10} indoors compared to outdoors.

cerch

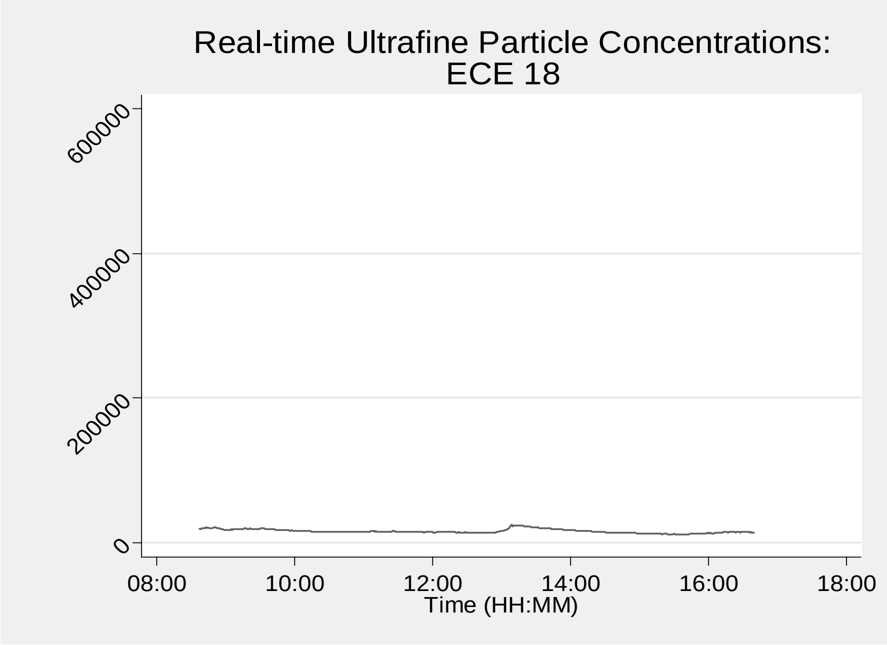
Ultrafine Particle Levels (#/ccm)

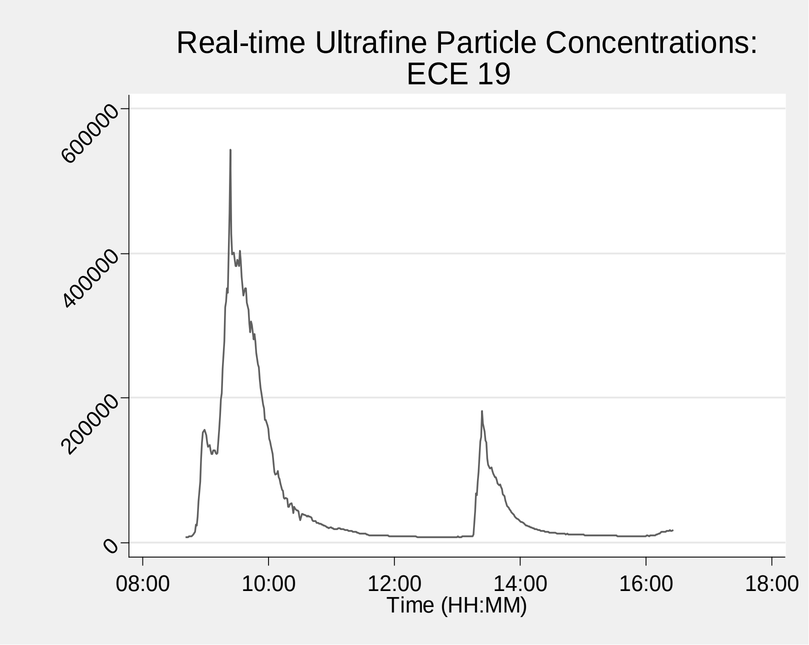
	Indoor	Outdoor
Median	14,120	14,054
75th %	29,717	19,907
95th %	69,439	42,096



Ultrafine Particles

Cooking Events were Key Determinants of Ultrafine Particle Levels:





Summary

- First study to perform extensive environmental monitoring of ECE facilities in California.
- Facilities in good physical condition and child care providers interested and concerned about quality of environment.
- Contaminant levels similar to other indoor environments, and most exposures were below health-based benchmarks (when available).
- Highest levels of VOCs measured in indoor air were from cleaning agents or personal care products.
- Formaldehyde levels in air exceeded OEHHA RELs.

cerch

Summary

- Exposure to several VOCs exceeded child-specific No Significant Risk Levels under Prop. 65.
- 130 additional VOCs potentially identified; rich area for future research.
- Ultrafine particle levels increased dramatically when gas stoves were used, often with poor ventilation.
- Indoor particulate matter (especially PM_{10}) may contribute to daily exposures over levels defined in the 24 hour standards.
- Other chemicals detected included phthalates, flame retardants, pesticides, perfluorinated compounds and lead.

Recommendations

1. **Additional research on contaminants in ECE facilities is needed. In particular, studies to quantify previously unknown VOCs are needed.**

2. **Complete evaluations of compounds without formal health-based benchmarks to identify chemicals for further toxicological review.**

3. **More research is needed to assess the health impacts of ultrafine particle exposure.**

4. **Encourage steps to reduce exposures to compounds that exceeded health-based benchmarks. For example, when purchasing wood products, purchase those that meet California's low formaldehyde emission regulation; additional regulatory actions may also be warranted.**

cerch

Recommendations

5. Increase outreach to child care providers and professional groups to increase awareness of indoor air quality and inexpensive ways to improve indoor environments. For example, use of range hoods reduces indoor levels of ultrafine particles, formaldehyde and other cooking emissions.

cerch

Thanks to our funders

California Environmental Protection Agency
Air Resources Board

Other work on child care supported by:

NIEHS

United States Environmental Protection Agency

California Department of
Pesticide Regulation

cerch
Center for Environmental
Research & Children's Health

Additional Resources

CERCH
http://cerch.org/research-programs/child-care/

UCSF California Child Care Health Program
http://www.ucsfchildcarehealth.org/index.htm

California Department of Pesticide Regulation
http://apps.cdpr.ca.gov/schoolipm/

Children's Environmental Health Network
http://www.cehn.org/ehcc

Green Care For Children
http://www.greencareforchildren.org/greencareforchildren_home

U.S. EPA Child Care Web Site
http://epa.gov/childcare/

CARB
http://www.arb.ca.gov/toxics/compwood/factsheet.pdf and
http://www.arb.ca.gov/toxics/compwood/naf_ulef/naf_ulef.htm