EXHIBIT A

SCOPE OF WORK

☒ Contract ☐ Grant

Does this project include Research (as defined in the UTC)? ☒ Yes ☐ No

PI Name: Elizabeth Noth

Project Title: Total Exposures to Air Pollutants and Noise in Disadvantaged Communities

Project Summary/Abstract

Many adverse health outcomes are associated with exposure to air pollution (WHO, 2020; Kelly et al. 2015; Becerra et al. 2013; Payne-Sturges et al. 2019). Children in particular are vulnerable to these exposures, which exacerbate respiratory illness and also neurodevelopmental and learning deficits. Assessing exposure to air pollution is complex. Community-level air monitoring provides an indicator of regional exposure, but may not reflect smaller-scale variability due to local sources (e.g., a busy road or even intersection), meteorology, geography, and the built environment. For example, recent studies have shown that traffic-related air pollution (TRAP) exposures may vary from one block to the next, with differential impacts onhealth outcomes (Apte et al. 2017; Alexeeff et al. 2018). Household or personal air monitoring provides betterindividual-level exposure data from a variety of sources including consumer products, cooking emissions, and appliances, such as gas burning gas stoves, and is necessary to complement ambient air monitoring, but fewer studies have focused on total air pollution exposures to individuals.

Ambient noise is also an important environmental stressor that disproportionately affects people living in disadvantaged communities (DACs). Environmental noise can emanate from a wide range of sources, but commonly results from mechanized sources, such as vehicles, airplanes, industrial activity (machinery), power generation, and the use of tools or heavy equipment. Anthropogenic noise, defined as “unwanted or disturbing sounds,” is present in everyday life. According to the United States Environmental Protection Agency (U.S. EPA), noise is one of the most common environmental exposures in the United States (U.S.). The health impacts of noise include sleep disturbance, annoyance, noise-induced hearing loss (NIHL), cardiovascular disease, endocrine effects, increased incidence of diabetes, poorer school performance, stress, and child misconduct (Hammer et al., 2013; Lercher et al. 2003; Stansfeld et al. 2005). Many of these impacts are similar to the effects of air pollution, highlighting the need to understand the cumulative impacts of multiple exposures to guide mitigation.

The overall goal of this project is to plan and conduct studies assessing air pollution and noise exposure to residents in DACs in the San Joaquin Valley (SJV); increase understanding of the sources of these exposures and potential health risks; and inform policies to reduce these exposures.

The specific goals of this contract are to:

1. Conduct literature reviews focusing on disparities in air and noise pollution exposures forresidents in DACs and non-DACs. The literature review will also focus on the impacts of personal behaviors (cooking, cleaning, etc.) and external factors such as building characteristics on exposure.

2. Identify vulnerable communities for air monitoring and noise exposure studies in the SJV.

3. Conduct studies assessing total exposures to air pollutants and noise to residents of DACs, including household-level indoor and outdoor exposures and personal exposures;

4. Identify sources of exposure and other determinants that affect pollutant levels and exposure (e.g., building characteristics, appliance types, and personal behaviors).

5. Evaluate associations between air pollutant and noise exposure and reported health.

6. Inform recommendations and policies to reduce noise exposure and improve indoor air quality (IAQ) and health, if indicated.

Assembly Bill (AB) 617, signed into law in 2017, requires development of new community-based programs to reduce exposures to air pollution and protect public health. In particular, AB 617 directs agencies regulating air quality to engage with communities and take measures to protect those disproportionately impacted by air pollution. Central components of AB 617 require community-level air monitoring and exposure assessment, and the development of community emission reduction plans. The results of this study will provide new quantitative information on air pollution and noise exposures and health risks to residents in disadvantaged communities and, by identifying sources of exposure and the relative importance of indoor versus outdoor exposures for specific pollutants and noise, and inform mitigation strategies to improve public health.

If Third-Party Confidential Information is to be provided by the State:

☐ Performance of the Scope of Work is anticipated to involve use of third-party Confidential Information and is subject to the terms of this Agreement; ***OR***

☐ A separate CNDA between the University and third-party is required by the third-party and is incorporated in this Agreement as Exhibit A7.

Statement of Significance

Exposure to particulate and toxic air pollutants such as particulate matter $(PM)_{2.5}$, ultrafine particles, and Volatile Organic Compounds (VOCs) is associated with adverse health effects including asthma, respiratory disease, cardiovascular disease, lung cancer, and poorer neurodevelopmental outcomes in children (WHO, 2020; Kelly et al. 2015; Becerra et al. 2013; Payne-Sturges et al. 2019). CalEnviroScreen (CES), a geographically-based mapping tool developed by the California Office of Environmental Health Hazard Assessment (OEHHA) that ranks communities by potential exposure, vulnerability, and social economic indicators, shows that many low income and disadvantaged California communities experience higher air pollution and consequent health impacts compared with more affluent neighborhoods (OEHHA, 2020). In particular, neighborhoods in the SJV along State Highway 99 and Stockton Cross-Town Highway 4 are often ranked in the highest percentiles of census tract with poorair quality indicators, including for diesel and other traffic related exposures. The SJV has some of the nation's worst air quality, often failing to meet federal health standards for ozone (O_3) and particulate pollution. These pollutants put residents at risk. Children in particular are more vulnerable to the health impacts of these exposures. Children eat more food, drink more water, and breathe more air per kilogram ofbodyweight compared with adults, and their immature and rapidly developing respiratory, neurological, and other body systems can be permanently and adversely impacted by early life exposures (Landrigan et al.2011).

Ambient noise is also an important environmental stressor that disproportionately affects people living in DACs. Environmental noise emanates from a wide range of sources, including mechanized sources, such as vehicles, airplanes, industrial activity (machinery), power generation, and the use of tools or heavy equipment. Anthropogenic noise, defined as “unwanted or disturbing sounds”, is ubiquitous: according to the U.S. EPA, noise is one of the most common environmental exposures in the U.S. The health impacts of noise include sleep disturbance, annoyance, NIHL, cardiovascular disease, endocrine effects, increased incidence of diabetes, poorer school performance, stress, and child misconduct (Hammer et al. 2013).

AB 617, signed into law in 2017, requires development of community-based programs to reduce exposures to air pollution and protect public health in California. In particular, AB 617 directs agencies regulating air quality to engage with communities and take measures to protect those disproportionately impacted by air pollution. This study will be the first in California to measure indoor and outdoor noise levels concurrent with air quality and develop cumulative exposure metrics characterizing exposures to mixtures of air pollutants and noise. Importantly, the study will also compare exposures in the SJV, which is highly impacted by air pollution, with more urban coastal regions that also experience disproportionate environmental exposures. This research will also address knowledge gaps by providing information on how behaviors (cooking, cleaning, smoking, etc.) affect personal and total pollutant exposures to residents. The study will also examine the degree to which other determinants (building characteristics, types of appliances, ventilation and filtration systems, etc.), modes of transportation, and participant location affect exposure and IAQ and potential health risks to DAC residents. One particular focus of the study will compare diesel exhaust exposures along interstate highways where large trucks are not permitted versus heavy truck transportation corridors. Finally, the University of California Berkeley (UCB) will also examine associations between environmental exposures and participant health, including respiratory health and family stress, sleep habits, and, for children, behavioral challenges. The information collected, including real time and time-integrated measurements of many key indoor and outdoor air pollutants, will foster unique insight into how disparities in air quality and noise exposures affect the health of California residents in DACs.

In summary, results from the study will provide new quantitative information on air pollution and noise exposures and health risks to residents in disadvantaged communities and suggest best practices for reducing total exposure to air pollution and noise in these areas. This information can be used by the

California Air Resources Board (CARB) in the development of guidance documents or in the crafting of regulations, and thus it will inform strategies to improve public health (e.g., decarbonization, high-efficiency filtration, support of electrification strategies, building setbacks, window placement or type, etc.).

Technical Plan

The primary aim of this research is to conduct studies assessing total exposures to air pollutants and noise in DAC.

The Center for Environmental Research and Children's Health (CERCH) in the School of Public Health, UCB will conduct studies in the SJV assessing exposures to air pollutants and noise in DACs. UCB will enroll **64 households (128** ~~90~~ participants**)** (approximately **52** ~~45~~ households in **Fresno and 12 in Stockton** ~~each of the two locations~~, a subset of **8** ~~30~~ homes will be visited twice for a total of **136 days of** ~~120~~ home samples **collected**). Note, based on the timeline and sample collection over warm and cold seasons, UCB expects to conduct monitoring over nine months (~~fall 2022 –~~ spring 2023 **– winter 2023**), which would require **~5-10 households (or 10-20** ~~15-20~~ participants**)** a month. Cancellations or other challenges might reduce the final total. The studies will utilize real-time sensor monitors to measure particulate matter (PM)2.5, black carbon (BC), and criteria pollutants. UCB will also measure exposure to formaldehyde and VOCs detectable using U.S. EPA Method TO-17 (see Appendix I). UCB will also prioritize compounds in a previous UCB childcare study, e.g.,benzene, chloroform, ethylbenzene, naphthalene, etc. (Hoang et al. 2016 (Appendix I)), and use National Institute of Standards and Technology spectral libraries to identify unknown air contaminants. **UCB will also provide selected polycyclic aromatic hydrocarbons (PAH) data collected at the homes in conjunction with funding from the Office of Environmental Health Hazard Assessment (21-E0016).** Finally, in collaboration with Dr. Wagner at the California Department of Public Health (CDPH), UCB will use passive PM sampling devices to determine particle morphology and chemistry, information not obtainable with conventional air sampling methods. These methods have been successfully used to identify the relative contribution of local sources of PM in air (Wagner et al. 2019 and 2012; Castillo et al. 2019). This information is particularly useful in regions where specific regional source controls need to be prioritized, such as AB 617 selected communities.

Project Tasks

Task 1: Complete Literature Reviews

a. Literature Review of Air Pollution Exposures for residents in DAC and non-DACs

   UCB will conduct a literature review of population and community studies examining air pollution exposures nationally and in California DACs and non-DACs. The review will summarize information on disparities based on CES scores, historical information on pollution trends by region in California, and the impact of regulatory approaches to reduce disparities, such as diesel emission regulations. The review will also focus on the impacts of personal behaviors (cooking, cleaning, etc.) and external factors, such as building characteristics on air pollution exposures. UCB will identify the literature for review through searches of medical and public health databases (e.g., PubMed) and web or other searches to identify statements and findings by governmental agencies and other authoritative bodies. The expected outcome for this task is to provide background for the identification of vulnerable communities, ensure that the methods used to assess air pollution exposures are up-to-date, and inform preparation of reports and publications.

b. Literature Review of Studies Focusing on Disparities in Noise Exposures forResidents in DACs and non-DACs

UCB will conduct a literature review examining noise exposures and health impacts nationally and in California DACs and non-DACs with a particular focus on disparities in noise exposure by social-economic factors. UCB will also examine the utility of national geographic information system (GIS) noise-mapping tools and how they might be used in relation to studies planned for this study. UCB will identify the literature for review through searches of medical and public health databases (e.g., PubMed) and web or other searches to identify statements and findings by governmental agencies and other authoritative bodies. The expectedoutcome for this objective is to provide background for the identification of vulnerable communities, ensure that the methods used to assess noise exposure are up-to-date, and inform preparation of reports and publications.

c. Integration of Literature Review Results

The key outcomes of the literature reviews are to provide background for the identification of vulnerable communities for air pollutants and noise, ensure that the methods used to assess air and noise exposure are up-to-date, and inform preparation of reports and publications. UCB will produce a report synthesizing this information, including literature simultaneously examining cumulative exposure to both stressors. To date, relatively few exposure studies have examined both air pollutants and noise, although exposure to both are often linked because noise and traffic-related air pollutants both originate from cars and truck traffic along transportation corridors. Studies simultaneously examining exposure to both air pollutants and noise will also be used to inform statistical analyses for the current study (Lalloué et al. 2015) (see Task 7d. Data Analysis).

Task 2: Identify Vulnerable Communities for Exposure Studies and Develop Outreach Plan

UCB will identify and confer with potential study partners in the SJV and identify AB 617 selected communities to focus the study activities. UCB will also consider other locations based on CES air pollution scores and study logistics. Based on preliminary discussions, studies will likely focus on neighborhoods between Interstate highway 5 and State highway 99 and along the Stockton Cross-Town Highway 4 in Stockton and South-Central Fresno AB 617 selected communities.

The outreach plan to engage with community partners and stakeholders will include a website and/or Facebook page and use of email distribution lists and newsletters to maintain relationships with key stakeholders. The UCB Principal Investigator (PI), Co-PI, and University of California, Merced (UCM) will reach out to community planning groups, air pollution officials, and other stakeholders to establish relationships with stakeholders and obtain input on study methods and goals. UCB staff have extensive relationships with community groups in the SJV and have presented their work to AB 617 planning committees. Dr. Noth is also conducting long-term studies examining child asthma and air pollution exposures in the Fresno area and has extensive community contacts. Study staff will develop web resources for the study and an email distribution list to inform stakeholders about study milestones and results.

Task 3: Develop Sampling and Project Protocols

Project protocols for recruitment, data collection, and sampling will be developed to document study procedures and methods and ensure training of study staff. The protocols will describe recruitment, consent, and confidentiality procedures; questionnaire and home inspection procedures; detailed information on collection of real-time monitoring data, including equipment operation, calibration between devices, labeling, transmission, storage, data back-up and security; and quality assurance and quality control (QA/QC) procedures. All study staff will be trained on the operation of the study equipment and sampling and data collection methods.

All sampling and project protocols will be piloted two to three times. For questionnaire and home inspection procedures, each project staff member will conduct and complete several mock visits and will be reviewed by senior investigators to ensure consistency. UCB will also pilot all real-time air pollutant and noise monitoring devices (see Task 6) to validate field procedures and identify challenges that require resolution. Finally, UCB will collect pilot VOC samples to be measured in the laboratory to ensure that collection and analytical procedures are fully validated and identify interferences or other factors that might interfere with analyte quantification.

A binder will be created for each participant that includes all protocols, instruments, and checklists to ensure that all phases of their participation can be tracked until completion. All data will be stored on CERCH servers, which are backed-up on the UCB campus and offsite in Southern California to ensure recovery in the event of a disaster. Templates for these protocols from prior CERCH studies will be adapted for this project. These protocols will form the core of a quality assurance project plan (QAPP) that will be developed for the project. Core components of the QAPP will include:

a. Descriptions of how tracking of study progress against funding will be conducted to ensure study completion within budget and on time.

b. A description of QA/QC procedures for data collection, including error and range checks of real time data and calibration of instruments to ensure data consistency.

c. Descriptions of laboratory QA/QC review steps, including error and range change checks of laboratory results and assessment of calibration curves, linearity, detection limits, recovery, precision, and accuracy of data flags.

d. A Project Management Plan describing key roles and responsibilities among the research team.

Task 4: Develop Study Instruments and Obtain Human Subjects Approval

a. Home Inspection Form

Existing home-inspection instruments from prior CERCH air quality studies will be adapted for the current study (see Appendix I). The data collected from the home inspection form will include information on building quality, ventilation and filtration systems, sources of VOCs, e.g., presence of gas burning stoves and other appliances, stored fuels, and automotive products, etc., and noise. Inspection forms will be reviewed by CARB and other interested stakeholders, and piloted in SJV and Merced. The UCB PI and Co-I will train UCM and other study staff, including simultaneous completion of inspections to compare consistency and resolve differences. Inspection instruments will be formatted in Qualtrics using a tablet or laptop so data will be recordedelectronically and immediately backed up. A pilot study of two homes to practice administering the Qualtrics home inspection form will be conducted to provide training opportunities to study staff and identify any technical difficulties with the electronic format.

b. Participant Questionnaire

Existing questionnaires from prior CERCH air quality and health studies and instruments from other studies will be adapted for the current study. Questionnaires will be reviewed by CARB and other interested stakeholders, and piloted in the SJV and Merced in English and Spanish. Information collected from the questionnaire will include:

Demographics: Household enumeration, age, ethnicity, income, and occupation

Sources and Determinants of Exposure: Questions will assess sources of VOCs and particulate matter exposure in the home, e.g., cooking behaviors, wood burning, hobbies, use of tobacco products and cleaning products, and proximity of the home to ambient sources of VOCs and noise pollution, e.g., auto, truck, buses, and other traffic. UCB will also collect information about sources and determinants of exposures in occupational settings, including work Standard Industrial Classification (SIC) codes, specific tasks, chemicals used at work, use of tools and equipment, and whether work is inside or outside.
Health Status: UCB will also adapt validated instruments from The Center for the Health Assessment of Mothers and Children of Salinas, the Inner-City Asthma Study, and other studies to collect health information about the adult parent participant, the index child, and other family members. Information collected will assess respiratory health, stress, sleep habits, child behaviors, general health, and awareness of noise and its impacts.
The PI and Co-PI will train study staff on questionnaire administration. Questionnaires will be formatted in Qualtrics using a tablet or laptop so data will be recorded electronically and immediately backed up. A pilot study of two homes to practice administering the Qualtrics exposure questionnaire will be conducted to provide training opportunities to study staff and identify any technical difficulties with the electronic format.

c. Recruitment and Consent Forms and Protocols

UCB will develop recruitment and consent forms and protocols adapted from prior CERCH environmental health studies that have focused on English and Spanish speaking communities. Recruitment materials for this project will include flyers and letters. The flyer will be posted on bulletin boards and sent as attachments to emails distributed to subscribers of listservs associated with CERCH and other stakeholders identified through project activities. Consent forms will be developed following UCB Committee for the Protection of Human Subjects (CPHS) guidelines.

d. Translate Study Instruments into Spanish

All study instruments (recruitment materials, consent forms, and questionnaires) will be translated into Spanish.

e. Obtain Human Subjects Approval

Human subjects approval will be obtained for all study activities. The UCB CPHS will be the prime Institutional Review Board (IRB), and UCM and CDPH will rely on UCB. Preparation of documents for human subjects approval (consent forms, recruitment materials, questionnaires, inspection forms; etc.) will begin immediately upon contract execution. Participating households will include at least one adult (parent) and dependent child.

Task 5: Recruitment of Study Participants

The targeted enrollment for this study will be not less than ~~90~~ **64** households, with **12 in** ~~half in each of the~~ Stockton and **52 in** Fresno ~~regions~~. From these ~~90~~ **64** households, a subset of ~~30~~ **8** will be selected to have a second study visit for a total of ~~120~~ **72** study visits. Recruitment criteria will include families with an adult parent household member (>18 years) with a dependent child (five to ten years) who speak either English or Spanish and residence within the defined study area (for example, the South-Central Fresno AB 617 selected community) and do not plan to move during the study period.

Smokers will be excluded from enrollment. UCB will also selectively recruit participants to achieve balanced enrollment by housing stock (single family versus multi-family) and a subset of homes that are within a maximum radius of a major traffic source. The study team will also attempt to attain geographic balance within each study area (i.e., participants will not be grouped in one section of a given study area). Air pollutant measurements will be conducted indoors and outdoors at each participating household. Personal exposure measurements will be limited to the participating adult parent.

Based on recruitment procedures employed in prior CERCH air quality studies (Appendix I), UCB will identify census tracts within designated study areas, and based on population and demographics, estimate the geographic balance and demographics to best represent the population. Using recruitment methods employed for our successful East Bay Diesel Exposure Project (EBDEP), study staff will work with stakeholders throughout community engagement activities to identify community organizations, churches, schools, childcare centers, and other neighborhood locations where people gather. (See Appendix I for example of EBDEP recruitment script and flyer). UCB will contact directors and managers of these organizations and ask for permission to post flyers, present to groups to explain the study, and set up tables to invite people to participate. As UCB reaches the participation goals for specific census tracts and study location, the focus of recruitment will shift to ensure geographic and demographic representation by sex, ethnicity, income, and housing type. Participants will be offered a $100 stipend as compensation for their time.

Task 6: Conduct Field Sampling and Data Collection for the Full Study.

UCB will conduct an approximately nine-month field sampling campaign that will span both warm and cool seasons. Measurements and data that will be collected and evaluated are listed as follows:

a. Measurements and data that UCB will collect and evaluate for indoor and outdoor sampling (target N= ~~90~~ **64** households, with ~~120 sample sets~~ **136 days of air sampling**) are listed below:

   i. Real time measurements to include:
      1. $PM_{2.5}$: measured using an instrument such as the SENSIT RAMP combined sensor.
      2. Criteria pollutants (O_3, NO_2, and CO): measured using an instrument such as the SENSIT RAMP combined sensor.
      3. BC: measured using the Lawrence Berkeley National Laboratory (LBL) Aerosol Black Carbon Detector (ABCD) (described in Caubel et al. 2019 (https://pubs.acs.org/doi/pdf/10.1021/acs.est.9b00282)).
      4. Noise levels: Measured using an instrument such as the Lutron SL-4013 monitor.

   ii. Laboratory-based measurements using active or passive sampling methods to include:
      1. VOCs: Active samples collected on a sorbent tube and analyzed using U.S. EPA Method TO-17(see Appendix I). Laboratory analysis by the CDPH Environmental Health Laboratory Branch (EHLB).
      2. Formaldehyde (from a subset of homes): Umex 100 passive sampler. Laboratory analyses by an approved laboratory.
      3. **VOCs: Naphthalene active samples collected by sorbent tube and analyzed in the Berkeley Exposure Assessment Laboratory (BEAR Lab) under direction of Dr. Noth, in conjunction with the Office of Environmental Health Hazard Assessment contract # 21-E0016, titled, "Biomonitoring component of the San Joaquin Valley Pollution and Health Environmental Research Study (BiomSPHERE) ".**
      4. **Semivolatile polycyclic aromatic hydrocarbons (PAHs): collected by XAD-coated filters and analyzed in the BEAR lab under direction of Dr. Noth. UCB will provide information on relevant exposures to PAHs following review of the data.**

iii. Personal Sampling (target N=**72** ~~120~~ sample~~s~~ **sets** (~~90~~ **64** adult participants, ~~30~~ **8** with repeat sampling)) to include:
   1. $PM_{2.5}$: measured using an instrument such as the Atmotube Pro combined sensor.
   2. Criteria pollutants O3, NO_2, CO): measured using an instrument, such as Atmotube Pro combined sensor.
   3. Noise: measured using an instrument such as the Lutron SL-4013 monitor.
   4. GPS Logger.
   5. **Total Volatile Organic Carbons: measured using a photoionization detector, such as Atmotube Pro**

iv. Home inspection: to assess building characteristics, types of appliances location, etc.

v. Participant questionnaire: to collect information about the adult parent and index child on demographics, exposure related behaviors, occupation, health information, etc.

vi. GIS Coordinates of the home to link residential location to:
   1. Daily ambient air quality information
   2. Meteorological information
   3. Land use

vii. Special Studies to include:
   5. One week-duration, indoor-outdoor co-located University of North Carolina passive PM samples(https://rjlg.com/products/unc-passive-aerosol-sampler/) at a subset of households (**up to** N=~~32~~ **64** samples ~~households collected during two seasons~~).

   6. Laboratory Analysis: Scanning electron microscopy/energy dispersive x-ray spectroscopy (SEM/EDS) and $PM_{2.5}$, PM_{10}, $PM_{10\text{-}2.5}$, particle type, and PM source analyses, including low atomicnumber particles (primarily sourced from carbon and NH4, NO3; crustal (primarily sourcedfrom soils) and metals.

Sampling will be conducted over approximately nine months, including a “warm season” period (~~June-~~**March-October**) and “cool season” period (~~December-March~~ **November - February**). This timeframe will ensure data collection over key California meteorological periods that impact air quality, including summer and fall seasons with high air temperatures, O_3 exposure risk, and intensive agricultural activity, and late fall/winter periods that often include temperature inversions that trap pollutants in low elevation regions where most California residents reside. Based on the timeline and sample collection over warm and cold seasons, UCB expects to conduct monitoring over nine months (~~summer 2021-winter 2022~~ **Spring - Winter 2023**), which would require **~5-10 households (or** ~~15-20~~ **10-20** participants**)** a month. ~~UCB does not anticipate problems reaching our target of 90 participants (for 120 visits).~~

b. Consent for Household-Level Data and Sample Collection

Study staff will conduct sampling with each household over two to three days. Following recruitment and obtaining a verbal consent to set up a morning in-home visit, study staff will set up an appointment to provide a detailed explanation of all study activities, obtain consent, and begin data and sample collection. The questionnaire will be administered after the consent, followed by the home inspection. Sampling equipment will be set up both inside and outside the home for indoor and outdoor 24-hour collection (VOCs, real time measurements, noise, etc., as described in Task 6.a.i-iii. The best placement of the devices inside and outside homes will be determined by study staff, in consultation with the residents.

c. Personal Sampling and Data Collection

After the questionnaire, home inspection, and 24-hour household-level sampling equipment is set up, study staff will make plans for personal data collection with the participating adult parent household member, which will happen on the second day of study activities. Study staff will demonstrate the backpack and data collection equipment, provide detailed explanations and training on the participant's tasks, and provide participants with location recording devices. After asking the participants to demonstrate their familiarity with the backpack and related paper forms (location diary to supplement the location recording device, any problems, etc.). Study staff will leave the backpack with the participant in data collection mode. The following morning, study staff will contact the participant early in the morning to ensure there are no problems and they can safely take the backpack with them. Study staff will return to the household in the afternoon the next day to retrieve the household sampling equipment, the backpack, and any related paper forms.

The tools used to collect air quality and noise measurements are described in Task 6a.i-iii and summarized in Table 1. Many companies are using existing technologies to develop real-time air quality monitors and the market for sensor devices is changing rapidly. In consultation with CARB, UCB has chosen to purchase the Atmotube Pro by ATMO for personal sampling (PM, VOCs) and the RAMP monitor by SENSIT (PM, NO_2, NO, CO, O_3) for the household indoor/outdoor sampling. Additionally, as part of QA/QC protocols, as appropriate, devices will be collated with federal reference or equivalent method equipment at fixed locations to assess comparability with regulator monitoring data.

d. Particle Source Identification Studies

For the particle source identification studies supervised by Dr. Wagner, the following will be determined for each of the 64 samples using SEM/EDS: PM2.5, PM10, PM10-2.5 size distributions, dominant PM particle types based on chemistry and size, and PM source analyses, including low atomic number particles (primarily sourced from combustion, bioaerosols, and NH4NO3; crustal particles (primarily sourced from soils and fugitive dusts), and metals (see Task 6a. viii "Special Studies"). Computer- controlled SEM/EDS is used to acquire data rapidly. Measurements for thousands of particles per sampleare automatically converted into conventional PM2.5 concentrations, as well as value-added PM10, elemental chemistry, particle shape, and size distributions, at a rate of approximately one hour per sample. These rich data sets are not otherwise available from conventional low cost sensors and can be used to determine the major air pollution sources (e.g., traffic, shipping, agriculture, regional transport) foreach sample.

Table 1 summarizes the planned data and sample collection for the research (~~90~~ 64 households with ~~120~~ **72** total sample sets **representing 136 days of sampling**).

Table I.	Questionnaire \ Home Inspection	Active VOC Samples[1]	Real-time Measurements				Passive Formaldehyde Measurement[4]	UNC Passive samples[5]	Noise[6]
			Criteria Pollutants[2]	Particulate Matter[2]	**Total VOCs[2]**	Black Carbon[3]			
Household-level data collection (indoor/ outdoor)	X	X	X	X	**X[7]**	X	X	X	X
Personal data collection	X		X	X	**X**		~~X~~		X

[1]U.S. EPA Method TO-17 **and BEAR lab methods**. See text; [2]SENSIT RAMP and Atmotube Pro; [3]Caubel et al. 2019; [4] Collected from a random subset of ~~50~~ **30** homes; [5]**up to 64 samples** ~~N=32 households~~; [6]Lutron SL-4013 monitor; [7] **from a subset of homes** ~~NIOXVERO®~~.

Task 7: Data Management and Data Analysis

a. Real Time Sample, Questionnaire, and Home Inspection Data,

Questionnaire and home inspection data will be recorded electronically into Qualtrics-formatted study instruments. Thus, these data will be recorded in real-time and automatically backed up. Questionnaire, home inspection, and real-time data will be uploaded regularly and stored on CERCH servers. Data management will include range checks to identity unusual outliers or problems with any information that may need resolution.

b. Receive Laboratory Data and Conduct QA Reviews

The laboratory analysis will be conducted at the CDPH under the supervision of Kazukiyo Kumagai, the chief of the IAQ Program, Center of Healthy Communities Environmental Health Laboratory. Measurements of formaldehyde collected by the Umex passive sampler will be completed by an approved laboratory utilizing high-performance liquid chromatography (HPLC). Laboratory results generated during the study (VOCs and formaldehyde) will be checked for range, calibration, detection frequency, recovery, precision, proper labeling and flags, etc. and stored on CERCH servers (see QAPP, as specified in Task 3).

c. Development of Integrated Datasets

The UCB Data Manager will develop integrated data sets of questionnaire, home inspection, real-time, laboratory, and ambient and meteorology data. As data are generated, theUCB Data Manager will develop templates for final data sets that integrate all study data based on the HSN. Final data sets will integrate all information with documentation (e.g., variable nameand description, etc.) to support current and future data analyses.

d. Data Analysis

This study will collect several dozen information streams, including multiple measurements of noise, VOCs, and particles (particulate matter and black carbon) indoors and outdoors at homes; personal exposure measurements for many of the same parameters collected from the adult parent participant; household characteristics such as cooking events, gas stove use, stove fan use, ventilation, air conditioner use, cleaning and products used, etc; personal information such as occupation; as well as multiple regulatory and other environmental monitoring data (ambient air quality measurements, traffic metrics by buffers, railroad routes, output from the United States Department of Transportation (U.S. DOT) national noise maps, and local meteorology). Data management and statistical analyses will be complex, and include descriptive analyses and model building. The broad scope of the data will require both a priori hypothesis testing and exploratory analyses.

Data analysis methods will include:

- *Determinants of Exposure to Air Pollution:* The study team will conduct analyses of study-wide data including preparation of descriptive statistics, ratios of indoor and outdoor measurements, and statistical modeling to identify determinants of indoor, outdoor, and personal exposures to air pollutants. As part of this analysis, UCB and UCM will identify sources of exposure and other determinants that affect pollutant levels and exposure (e.g., traffic, household behaviors). For household-level analyses, key dependent variables will be laboratory and real-time measurements of air quality. Statistical analyses will be conducted by the project investigators, and graduate students, who will be supervised by senior scientific investigators.

Key independent variables will be nearby traffic metrics, land use, and household characteristics including building type (single-family or multi-family welling), age, size, heating/cooling system, and resident behaviors. Dependent variables will consist of air pollution metrics including laboratory and real-time measurements. Typical analyses will include calculation of descriptive statistics for air pollutant and noise exposures and variables used to predict exposure and indoor/outdoor ratios. UCB will conduct bivariate analyses using the Spearman correlation coefficient for continuous predictors and analysis of variance (ANOVA) for categorical predictor variables to identify potential explanatory variables with p-value<0.2 for inclusion in separate multivariable regression models for noise and each pollutant. Air pollution levels are often log normally distributed therefore, UCB will natural log-transform the values to normalize the distributions for regression models. UCB will use manual forward selection to derive final multivariable linear regression models to determine which exposure sources or housing characteristics are significantly associated (p<0.1) with each pollutant. UCB will also use backwards elimination as an alternative method to identify significant predictor variables. UCB will estimate the percentage change associated with eachexposure source by exponentiating the regression coefficients, subtracting one and multiplyingby 100. UCB will evaluate outliers and rerun models excluding extreme values, i.e., with a Student's t-test score >3 (https://en.wikipedia.org/wiki/Student%27s_t-test). UCB will also consider use of causal inference models to quantify the potential impact of altering specific predictors on resident exposures.

Statistical analyses focusing on personal exposures, primarily real-time air quality measurements (with the exception of formaldehyde), will follow similar procedures described for household-level exposures, except UCB will incorporate information about time and location spent away from home and additional potential exposure risk factors, including traffic metrics near work sites, time and roads used for transportation, transport methods (car, bus, etc.), and occupation (e.g., road work would lead to high traffic-related exposures). Additional analyses focusing on real-time measurements will evaluate temporal trends and key events that predict changes in exposure, such as cooking, cleaning, and work-related activities. Location information will be attained from participants' home and work addresses using Google maps and ArcGIS.

- *Determinants of Exposure to Noise*: UCB will compute descriptive statistics for noise measurements, examine temporal trends, and compare personal and indoor and outdoor exposures. Statistical analyses focusing on noise (as the dependent variable) will follow similar procedures described in Task 7d. Determinants of exposure to air pollution above forreal-time personal measurements of air quality. UCB will also compare noise measurementsto noise levels predicted by the U.S. DOT National Noise Map

  (https://www.transportation.gov/highlights/national-transportation-noise-map). If feasible, UCB will attempt to collect noise measurements over longer time periods at select households proximate to study offices (e.g., UCB) to increase understanding of variability in noise exposure. Dr. Tracy Thatcher will provide consultation on data processing and analysis of noisedata.

- *Assessing Cumulative Exposures*: UCB will conduct exploratory analyses examining possible clustering of environmental exposures to develop measures of cumulative exposure. UCB will first rank households by exposures and determine the proportion of households with higher or lower exposures. UCB will summarize this descriptive information and then apply Multiple Factor Analysis and other cluster analysis techniques that have been used to integrate information on air quality, noise, and other environmental metrics to develop indices of environmental exposures (Lalloué et al. 2015). A priori, UCB expects households near freeways, industrial facilities, and other exposures sources to have both poorer air quality and higher noise levels.

- *Health Outcome Analyses*: UCB will also examine associations between exposure metrics (as independent variables) and reported health status (dependent variables). The primary analysis will focus on respiratory outcomes and in the adult parent and index child. UCB will also evaluate associations between noise exposure and sleep habits, stress, and child behaviors. Statistical analyses will generally follow procedures described in Task 7d. Determinants of exposure to air pollution above, and initially focus on individual exposure variables. UCB will also evaluate indices of cumulativeenvironmental exposure, described in Task 7d. Determinants of exposure to air pollution above, as predictor variables. The study team will also explore the application of cluster analyses using Bayesian profile regression (BPR) or other techniques that CERCH researchers have previously employed to evaluate exposure to complex mixtures and health outcomes (Coker et al. 2017).

- *Particle Source Identification:* Dr. Wagner will supervise data analyses from the special study focusing on particle sources. These measurements will be compared statistically in terms of indoor/outdoor matched pairs, and variability within and between the two SJV regions, as well as the two seasons. Ten additional QA samples (blanksand replicates) also will be analyzed. In addition, a subset of ten samples of interest ("hotspots" and background comparison samples) will be analyzed in more detail to provide additional quantitative and qualitative information for particle source attributions at these locations. These methods have been used successfully to identify significant local and regional PM sources in California, including agricultural burns (Wagner et al, 2012), windblown dust (Wagner and Casuccio, 2014),nitrate aerosols (Wagner et al, 2019), and wildfires (Castillo et al, 2019). These types of unique regional sources are not adequately characterized by simple $PM_{2.5}$ measurements, as different types of particle exposures have been reported to produce different impacts on human health (Grahame et al, 2009; Steiner etal, 2016). In addition, source identifications can inform priorities in regional air pollution reduction policies, e.g., vehicle or shipping emission controls, dust suppression, inter-regionalpollution transport, local source regulation, or wildfire suppression.

A priori analyses will determine:

1. Exposure Outcomes:

   - The association of household behaviors (i.e., cooking events, cleaning practices) with indoor particulate matter and VOC levels;
   - The association of nearby traffic density and volume with outdoor and indoor PM levels;
   - Whether diesel exhaust exposures, assessed by BC levels, are lower freeways and other transportation corridors with less truck traffic;
   - The association of nearby traffic density and volume with outdoor and indoor benzene, toluene, ethylbenzene, xylene VOC levels; and
   - The association of nearby traffic density and volume with outdoor and indoor noise levels.

2. Health Outcomes:

   - The association of indoor PM and VOC exposures (evaluated separately) with reported respiratory health status;
   - The association of noise exposures with reported family stress, sleep habits, and, for children, behavioral challenges; and
   - The association of cumulative environmental quality indicators (chemical, PM, noise) with respiratory or behavioral outcomes.

These analyses will be conducted in the context of a multi-factorial analysis, which will assess different building types within different settings. Air exchange rates are an important factor affecting indoor air quality and are likely to modify relationships between exposure determinants and measured pollutant levels for analyses focusing on indoor pollutants.

Task 8: Health Risk Characterization

a. *Non-Cancer Risk Estimation:* UCB will compare resident exposures to health-based benchmarks for environmental concentrations or internal dose, when available. Specifically, concentrations of measured air pollutants will be compared with established regulatory or public health guidelines when available, including OEHHA reference exposure levels, national ambient air quality standards, U.S. EPA reference concentrations, minimal risk levels published by the Agency for Toxics Substances and Disease Registry (https://www.atsdr.cdc.gov/mrls/index.html),

b. National Institute of Occupational Safety and Health (NIOSH) Pocket Guide Recommendations (https://www.cdc.gov/niosh/npg/default.html), and European Union standards. If standards or guidelines for air concentrations are not available, but benchmarksfor internal dose are published, UCB will estimate internal dose from inhalation using exposure factors defined by U.S. EPA (https://www.epa.gov/expobox/about-exposure-factors-handbook) and compare the exposures to health-based reference doses.

c. *Cancer Risk Estimation*: Among the compounds measured, UCB will determine which VOCs have been identified as carcinogens under California's Proposition 65 and have published "Safe Harbor Levels," i.e, no significant risk levels (NSRLs), which are defined by OEHHA as the daily dose posing a one in 100,000 (10-5) excess risk of cancer over a life-time (OEHHA, 2001; 2013). UCB will estimate participants' daily doses assuming the measurement is representative of exposure over one year. If the ratio of air pollutant dose estimate (µg/day) compared with the NSRL (µg/day) is greater than one, the dose estimate will exceed the 10^{-5} threshold. UCB will also estimate the unit life-time cancer risk for all carcinogens based on cancer potency and estimated lifetime average daily dose.

d. *Exposure to Noise*: UCB will compare the distribution of measured noise levels (e.g, average, median, 75^{th}%, 90^{th}%, and maximum) to existing U.S. EPA and United States Occupational Safety and Health Administration standards. As noted in ~~Task 6.a.iii~~ **Task 7.d**, UCB will compare noise measurements to predicted exposures based on the U.S. DOT National Noise Map. Finally, UCB will evaluate the feasibility of including noise exposure as a metric in future versions of CES. Currently, CES does not consider ambient noise to rank environmental exposures. Dr. Tracy Thatcher will consult on risk assessment of noise exposures.

Task 9: Interim, Draft, and Final Report

UCB will submit an interim report twelve months before the end of the project period which will include summaries of available questionnaire, home inspection, and real-time and laboratory monitoring data, results of preliminary statistical analysis, and evaluation of project challenges and accomplishments in relation to the study goals.

Six (6) months prior to the end of the contract, UCB will submit a draft final report (DFR) which will include a written summary of the literature reviews described in Task 1. The DFR shall be submitted in accordance with the Final Report Format and reviewed by CARB staff. CARB's comments will be sent to UCB and after receiving the reviewer's comments, UCB shall modify and resubmit the modified draft final report to the CARB contract manager. The modified DFR will be subject to formal review by the Research Screening Committee (RSC). Once accepted by the RSC, UCB will revise the modified DFR addressing the RSC comments and will submit the revised final report to CARB. If CARB has additional comments on the report, UCB will be notified so appropriate changes can be made; otherwise, CARB will accept the revised final report as the final.

Task 10: Disseminate Findings and Prepare Manuscripts for Publication

UCB will disseminate the study findings at the following levels:

Returning Results to Study Participants: Following guidelines for community-based research, UCB will return individual results to study participants, when requested. Participants will have the opportunity to opt-in to receive study results during the consent process. At the end of the study, information on air concentrations will be provided to participants, along with information on potential health risks and strategies to minimize exposures. Return-result procedures will follow best practices that have been informed by the California Biomonitoring Program, the Silent Spring Institute, and CERCH experience and will be conducted underapproval by the UCB CPHS.

Returning Results to the Larger Community: Returning results to the larger community is an essential component of Task 2 and reflects UCB's commitment to basic principles of community-based research.

UCB will take several steps to disseminate study findings, including in-person and online meetings and webinars with stakeholders, e-newsletters to stakeholders and other subscribers of the study listserv, posting to the study website, and availability to discuss the study findings and implications. Study investigators will also be available to brief CARB, California Environmental Protection Agency management, local and legislative policymakers, and the general public about the study findings.

Dissemination to the Scientific Community: UCB will prepare manuscripts for publication describing the study findings in key environmental health journals, such as Indoor Air, Environmental Science and Technology, or Environmental Health Perspectives. When feasible, UCB will also present findings at scientific meetings and to local offices of state agencies, including CARB, CDPH, OEHHA, and Department of Toxics and Substances Control.

Novelty

This study has several strengths and will produce new information on cumulative environmental exposures to California residents residing in disadvantaged communities. Novel dimensions of the study include:

- Real time and time-integrated measurements of many key indoor and outdoor air pollutants that impact the health of California residents in disadvantaged communities;
- The opportunity to compare diesel exhaust exposure near freeways with heavy truck use to freeways with less truck traffic;
- The first study in California to measure indoor and outdoor noise levels concurrent with air quality. Noise is a key determinant of health and often linked to TRAP because traffic is a major source of both pollutants;
- Comparison of noise measurements to noise levels predicted by the U.S. DOT National Noise Map will allow assessment of this new U.S. DOT resource as an environmental quality metric for future versions of CES;

- Development of cumulative exposure metrics characterizing exposures to mixtures of air pollutants and noise;
- The opportunity to examine associations between individual and cumulative environmental exposures metrics with reported respiratory and other health outcomes; and
- This study will also provide CARB with data to inform policies for decarbonization. Exposure from a variety of sources will be assessed, including consumer products, cooking, and appliances such as gas burning stoves.

Facilities

CERCH, UCB: Facilities at CERCH include 2,000 square feet of office space, a networked computer system, offices and cubicles for senior staff and students, phones, and photocopying and printing and scanning equipment. There is also space to store and stage sampling equipment and supplies, and freezers and refrigerators for storing cold packs and sampling supplies if needed. The CERCH server is linked to the University of California (UC) data storage system and protected by firewalls and other technologies. All data stored on the CERCH servers are backed up daily on campus, and in Southern California, so information canbe retrieved in the event of a disaster of other breach, and complies with strict human subject standards for participant protection.

UCM: Resources at UCM include office space and workspace for the PI, Graduate Student Researcher (GSR), and space for storing study supplies and sampling equipment and staging fieldwork. UCM is also networked to the larger UC computer system, allowing instantaneous sharing of data and other information for transfer and back up.

CDPH EHLB: The EHLB maintains extensive laboratory facilities for air quality studies including: Thermal Desorption-Gas Chromatography/Mass Spectroscopy (TD-GC/MS): Markes TD-100, Agilent 7890B, Agilent 5977MSD; Thermal Desorption-Gas Chromatography w/ dual Detector, Flame Ionization Detector (FID) & Flame Photometric Detector (FPD): Perkin Elmer Turbo Matrix; Agilent Technologies 6890N; Gas Chromatography Mass Spectroscopy with liquid injection autosampler; Agilent 7890B/5977MSD; Liquid Chromatography Mass Spectroscopy (LC-MS): Agilent 1280 Series, Agilent 6420 Triple Quad; High Performance Liquid Chromatography w/ Diode Array Detection (HPLC/DAD): Agilent Technologies 1200; Aerosol physics laboratory for test particle generation and sampler evaluation; X-ray spectroscopy (XRF and XRD) laboratory for elemental composition analysis (Pb) and mineral identification (crystalline silica); High Performance liquid chromatography (HPLC) laboratory for liquid phase organic (aldehydes, polycyclic aromatic hydrocarbons); Ion Chromatography (IC) laboratory for inorganic analytes (hexavalent chromium, sulfates, nitrates, nitrites); Gas chromatography/mass spectrometry (GC/MS) laboratories for positive identification and quantification of unknown organic compounds; Air sampler shop for development, testing, and fabrication; Mobile laboratory for the assessment of toxic releases in the field; Environmental chamber for chemical exposure assessment; Optical microscopy laboratory for conducting phase contrast (PCM) and polarized light microscopy (PLM) with digital image capture; Scanning and transmission electron microscopy laboratories (SEM/EDS and TEM/EDS) for imaging individual toxic particles, coupled with identification of elements by energy dispersive x-ray spectroscopy and crystal phases by electron diffraction; Molecular vibrational spectroscopy laboratories [Fourier transform infrared (FTIR) and Raman micro-spectroscopy (RMS)] to image and identify individual toxic particles.

Project Schedule

Task 1: Complete Literature Reviews
Task 2: Identify Vulnerable Communities for Exposure Studies and Develop Outreach Plan
Task 3: Develop Sampling and Project Protocols
Task 4: Develop Study Instruments and Obtain Human Subjects Approval
Task 5: Recruitment of Study Participants
Task 6: Conduct Field Sampling and Data Collection for the Full Study
Task 7: Data Management and Data Analysis
Task 8: Health Risk Characterization
Task 9: Interim, Draft, and Final Report
Task 10: Disseminate Findings and Prepare Manuscripts for Publication

	Year 1												Year 2											
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p = Quarterly progress report

d = Deliver draft final report (to be submitted 6 months prior to contract expiration)f = Deliver final report

i = Interim Report

m = Meeting with CARB staff

Meetings

A. Initial kick-off meeting. Before work on the contract begins, the Principal Investigator and key personnel will meet with the CARB Contract Project Manager and other staff to discuss the overall plan, details of performing the tasks, the project schedule, items related to personnel or changes in personnel, and any issues that may need to be resolved before work can begin.

B. Progress review meetings. The Principal Investigator and appropriate members of his or her staff willmeet with CARB's Contract Project Manager at quarterly intervals to discuss the progress of the project. This meeting may be conducted by phone.

C. Technical Seminar. UCB will present the results of the project to CARB staff and a possible webcast at a seminar at CARB facilities in Sacramento or El Monte.

Project Management Plan

Dr. Elizabeth Noth will be the UCB PI of this project and will work closely with Dr. Bradman to provide overall direction and oversight of all aspects of the project, including community engagement; development of study protocols to assess exposures to noise and air pollutants; execution of the planned research, including development of study tools and instruments, human subject approval, recruitment and consent, tracking, sampling and analytical procedures; interfacing with laboratories; data management and analyses, and overall quality assurance and control. Dr. Noth will work closely with Drs. Bradman and Castorina, the GSRs, and collaborators to manage the project and ensure appropriate organizational structure and lines of communication among Co-Investigators. Drs. Noth and Bradman will also ensure completion of progress reports to the funding agency, track spending, and participate in writing interim and final project reports and publications.

Dr. Asa Bradman, will be the UCM Co-PI of this project and will provide direction and oversight with Dr. Noth including community engagement; development of study protocols to assess exposures to noise and air pollutants; execution of the planned research, including development of study tools and instruments, human subject approval, recruitment and consent, tracking, sampling and analytical procedures; interfacing with laboratories; data management and analyses, and overall QA and control. Dr. Bradman will work closely with Drs. Noth and Castorina, the GSRs, and collaborators to manage the project and ensure appropriate organizational structure and lines of communication among Co-Investigators. Drs. Bradman and Noth will also ensure completion of progress reports to the funding agency, track spending, and participate in writing interim and final project reports and publications.

Dr. Rosemary Castorina, UCB, will help manage the overall project with Drs. Noth and Bradman. Dr. Castorina will supervise and work closely with the GSRs and the field coordinator to develop sampling protocols, consent forms, and recruitment protocols and obtain human subjects' approval. As the project progresses, Dr. Castorina will help coordinate logistics to ensure supplies are available for field teams and work with Dr. Gunier to ensure real time and laboratory data are properly stored and secured on the CERCH server. Dr. Castorina will also participate in data analysis and preparation of manuscripts and draft and final reports.

Dr. Chelsea Preble, UCB, recently completed her PhD in civil engineering under the supervision of Dr. Tom Kirchstetter. Dr. Preble helped develop and evaluate their BC monitor and worked closely with Drs. Bradman and Castorina on the East Bay Diesel Exposure Project. Dr. Preble will help develop protocols to measure BC and also help coordinate and train field sampling teams who will be collecting samples and data from participants. Dr. Preble will also participate in field sampling visits as available, data analysis and preparation of manuscripts and draft and final reports, particularly sections focusing on diesel exhaust exposure.

Dr. Thomas Kirchstetter is a Senior Scientist and Scientific Division Director, Energy Analysis and Environmental Impacts Division, Lawrence Berkeley National Laboratory and adjunct professor of civil engineering at UCB. Dr. Kirchstetter developed and validated a low cost BC aethelometer with Dr. Preble. Dr. Kirchstetter is an expert on particle measurements and exposure assessment and will provide advice on sampling methods, data analysis, and interpretation of study results.

Field work: Little Manila Rising (LMR), a non-profit community group addressing air quality and providing community asthma prevention services in Stockton, will conduct field work in the Stockton region. LMR staff will coordinate closely with UCM and UCB staff and scientists to ensure data and sample collection procedures comply with IRB and institutional requirements. **Originally, LMR was to conduct 52 visits, but lost a key staff member in August 2023. As a result, LMR will conduct 12 sampling visits to Stockton households.**

Field work: The Central California Asthma Collaborative (CCAC) a non-profit community group addressing air quality and providing community asthma prevention services in Fresno, will conduct field work in the Fresno region. CCAC staff will coordinate closely with UC Merced and UC Berkeley staff and scientists to ensure data and sample collection procedures comply with IRB and institutional requirements.

Dr. Robert Gunier, UCB, is an expert statistician and has extensive experience using GIS to analyze spatial data, including ambient air quality data and meteorological data. Dr. Gunier will advise and consult on statistical and GIS analysis of study data. Dr. Gunier will also oversee downloading and use of ambient air quality and meteorology data. Dr. Gunier will supervise the CERCH data management team, including Kyna Long, the CERCH data manager.

Kyna Long, UCB, will assist with the development of Qualtrics study instruments; compile and track data collection progress; integrate questionnaire data with real-time air monitoring data and laboratory results; and prepare final data analysis sets.

***TBD, Staff Research Analyst*, UCB, will aid in the analysis of collected environmental and survey data, develop and produce the draft and final reports, and participate in manuscript preparation. The Staff Research Analyst will be employed at UCB and be supervised by Drs. Noth, Bradman, and Castorina.**

Dr. Ricardo Cisneros, UCM has extensive experience assessing exposures related to wild fires and has conducted research on air pollution in the SJV. Dr. Cisneros will work with Dr. Bradman to oversee a GSR from UCM who will help conduct field work in the Central Valley. Dr. Cisneros and the UCM GSR will work closely with Drs. Bradman and Noth and the UCB team to coordinate and conduct study activities (outreach, recruitment, and sampling) in the SJV study locations.

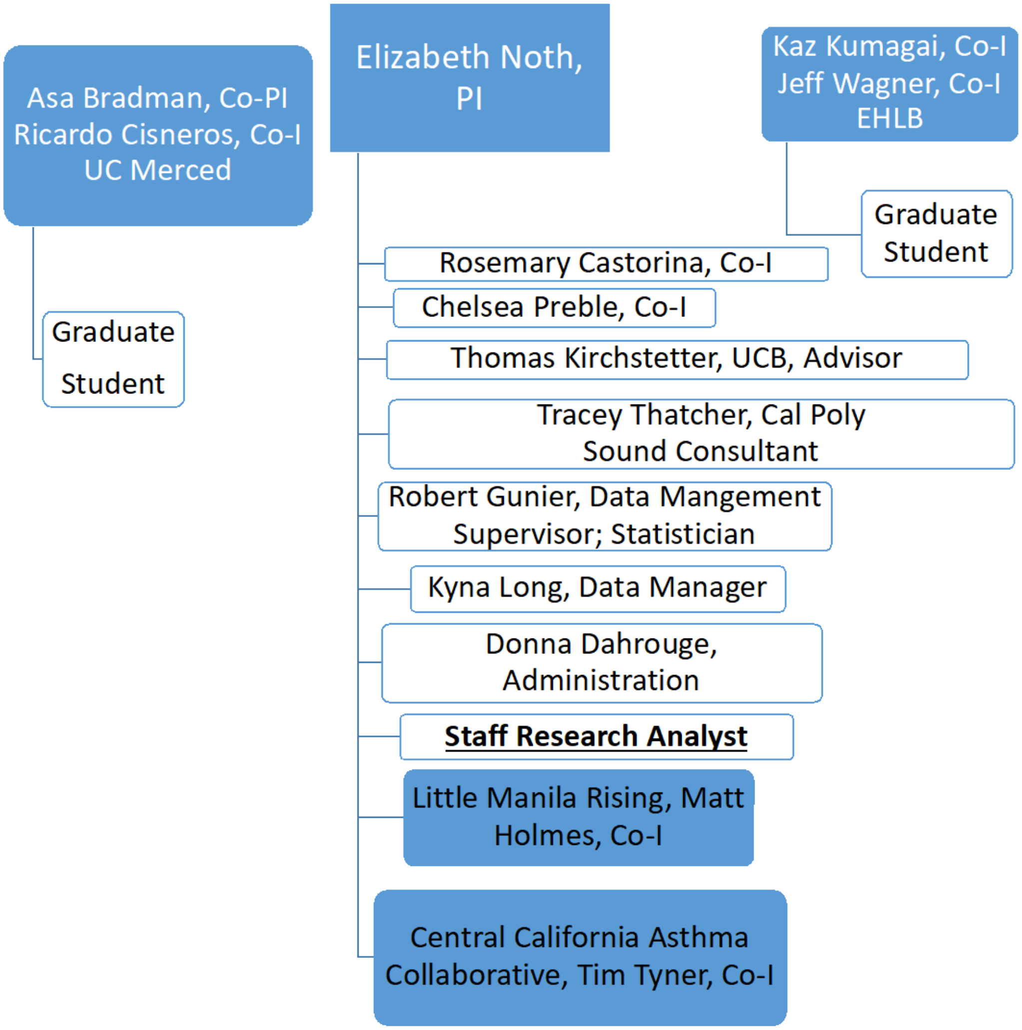
Dr. Kazukiyo Kumagai, Chief, IAQ Section in CDPH EHLB. Dr. Kumagai will supervise chemists and the GSR working in the EHLB laboratory to measure VOCs in field samples according to **the** U.S. EPA Method TO-17.

Dr. Jeff Wagner is a senior research scientist with the Outdoor Air Quality Section in EHLB. Dr. Wagner will supervise scanning electron microscopy/energy dispersive x-ray spectroscopy (SEM/EDS) analyses examining the morphology and chemistry of particles collected under the particle source identification study activities described in the scope of work, including assistance by GSR students. Dr. Wagner will also participate in data analysis and preparation of manuscripts and draft and final reports for the sections focusing on the special PM studies.

Dr. Tracy Thatcher is a professor of environmental engineering with a specialization in air quality and noise control at the California Polytechnic State University. Dr. Thatcher also has prior experience initiating programs to help local organizations solve noise problems. For the current project, Dr. Thatcher will advise investigators on protocol development and use of noise monitoring devices and subsequent data processing to create analysis data sets. Dr. Thatcher will also advise on data analysis utilizing noise information and will participate in the preparation of reports and journal articles.

Confidential Health Data and Personal Information

CARB will not be provided access to and will not receive any confidential health data or other confidential personal information under this contract. Further, CARB will have no ownership of confidential health data or other confidential personal information used in connection with this contract. The entities conducting the research in this contract will follow all applicable regulations regarding access to and the use of confidential data, including the Health Insurance Portability and Accountability Act (HIPAA) and requirements related to the (IRB) process. CARB will not be a listed entity with authorized access to confidentialinformation pursuant to the IRB process for this contract.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EHLB
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Tracey Thatcher, Cal Poly
Sound Consultant
Robert Gunier, Data Mangement Supervisor; Statistician
Kyna Long, Data Manager
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APPENDIX I – Supplemental Material

EPA TO-17 Volatile Organic Compounds

Method TO-17 is used to analyze samples for volatile organic compounds collected on multi-bed sorbent tubes, which are thermally desorbed and cryo-focused on the capillary column and then analyzed by GC/MS. The range of compounds analyzed by the method depends on the selection of the sorbent cartridge. EAS follows the method recommendation that the calibration and QC criteria for Method TO-17 follow the TO-15method.

The modifications done by EAS include the target list. The method recommends using the Method TO-15 QC criteria. EAS uses the modified TO-15 QC criteria listed in Table13.9a.

Table 13.9a
TO-17 Sorbent Cartridge Selection Guide

Tube Name	Compounds	Packing	Desorption Temperature
Tenax TA	BTEX Diesel Range Organic	Tenax TA	300C
Carbotrap 300	General VOC	Carbopak C Carbopak B Carboseive SIII	325C
VOC	General VOC	Tenax TA Carboxen 1000 Carboseive SIII	325C

TO-17 tubes can also be sampled passively using special adapters. The tubes are desorbed and analyzed in the same manner as the normal TO-17, and the TO-17 QC criteria is used.

Table 13.9b
TO-17 Recommended Sampling Times

Final Volume	Flow Rate	Time
500 ml	100 ml/min	5 min
480 ml	1 ml/min	8 hours
720 ml	0.5 ml/min	24 hours

Table 13.9c
TO-17 Summary of QC Criteria for Method TO-17

Parameter	EAS TO-15 Modified	TO-17 Method
BFB Tune	Daily (24 hour) 12 hours if Required	Daily (24 hour)
Tuning Criteria with BFB	TO-15 Tune Criteria	TO-15 Tune Criteria
Initial Calibration	Five points minimum See Table 13.9b 90%compounds meet criteria	Same as TO-15. Either liquid standards or gas phase standards can be used.
Calibration Check Sample (CCS)	After Initial Calibration Same Percent D as Initial Calibration	Same as TO-15
Continuing Calibration Verification (CCV)	Daily (24 hours) See Table 13.9b 90%compounds meet criteria	
Internal Standard (IS)	Pentafluorobenzene 1,4-Difluorobenzene RT < 0.5 min daily std. Response 60% to 140% 20 ppbv	Introduce gas phase internal standard onto sorbent tube (optional)
Surrogate	Toluene-d8 70-130% recovery	
Tube Blank	<RL for Tubes from the same media. From client media if supplied	Once tubes are analyzed they can be considered clean and can be reused Artifact peaks should be identified in final report.
Laboratory Control Spike	1 per Daily Batch 70-130% for LCS list See Table 13.7b	Same as TO-15
Duplicate Lab Control Dup Duplicate Pairs	Duplicate Pair with each 20 samples <30% for LCS spike list See Table 13.7b	The precision is tested by using six standard tubes and repeated every 10 series of samples

The laboratory control spike (LCS) compounds are indicated in bold in Table 13.9d. The MDL for ppbV is based on a sample volume of 5L. This is the maximum volume that should be used.

Table 13.9d

TO-17 Method TO-17 Compound List and QC Criteria

Component	**MDL ug**	**MDL ppbV**	**ICAL/CCV %D**	**LCS %R**	**Precision %D**
Freon 12	0.5	0.02	<30%	70-130	<30%
Chloromethane	0.2	0.02	<30%	70-130	<30%
Freon 114	0.7	0.02	<30%	70-130	<30%
Vinyl chloride	0.3	0.02	<30%	**70-130**	**<30%**
Bromomethane	0.4	0.02	<30%	70-130	<30%
Chloroethane	0.3	0.02	<30%	70-130	<30%
Trichlorofluoromethane	0.6	0.02	<30%	70-130	<30%
1,1-Dichloroethene	0.4	0.02	<30%	**70-130**	**<30%**
Dichloromethane	0.3	0.02	<30%	70-130	<30%
Freon 113	0.8	0.02	<30%	70-130	<30%
1,1-Dichloroethane	0.4	0.02	<30%	70-130	<30%
c-1,2-Dichloroethene	0.4	0.02	<30%	70-130	<30%
Chloroform	0.5	0.02	<30%	**70-130**	**<30%**
1,2-Dichloroethane	0.4	0.02	<30%	**70-130**	**<30%**
1,1,1-Trichloroethane	0.5	0.02	<30%	**70-130**	**<30%**
Benzene	0.3	0.02	<30%	**70-130**	**<30%**
Carbon Tetrachloride	0.6	0.02	<30%	**70-130**	**<30%**
1,2-Dichloropropane	0.5	0.02	<30%	70-130	<30%
Trichloroethene	0.5	0.02	<30%	**70-130**	**<30%**
c-1,3-Dichloropropene	0.5	0.02	<30%	70-130	<30%
t-1,3-Dichloropropene	0.5	0.02	<30%	70-130	<30%
1,1,2-Trichloroethane	0.5	0.02	<30%	70-130	<30%
Toluene	0.4	0.02	<30%	**70-130**	**<30%**
1,2-Dibromoethane	0.8	0.02	<30%	70-130	<30%
Tetrachloroethene	0.3	0.01	<30%	**70-130**	**<30%**
Chlorobenzene	0.5	0.02	<30%	**70-130**	**<30%**
Ethylbenzene	0.4	0.02	<30%	**70-130**	**<30%**
M,p-Xylenes	0.4	0.02	<30%	**70-130**	**<30%**
Styrene	0.4	0.02	<30%	70-130	<30%
o-Xylene	0.4	0.02	<30%	**70-130**	**<30%**
1,1,2,2-Tetrachloroethane	0.3	0.01	<30%	70-130	<30%
1,3,5-Trimethylbenzene	0.5	0.02	<30%	**70-130**	**<30%**
1,2,4-Trimethylbenzene	0.5	0.02	<30%	70-130	<30%
1,3-Dichlorobenzene	0.3	0.01	<30%	70-130	<30%
1,4-Dichlorobenzene	0.3	0.01	<30%	70-130	<30%
1,2-Dichlorobenzene	0.3	0.01	<30%	70-130	<30%
1,2,4-Trichlorobenzene	0.2	0.01	<30%	70-130	<30%
Hexachlorobutadiene	0.3	0.01	<50%	50-150	<50%

Component	MDL ug	MDL ppbV	ICAL/CCV %D	LCS %R	Precision %D
TO-15 Compounds					
1,3-Butadiene	0.2	0.02	<40%	60-140	<40%
2-Butanone	0.3	0.02	<40%	60-140	<40%
Acetone	0.2	0.02	<40%	60-140	<40%
Carbon Disulfide	0.3	0.02	<40%	60-140	<40%
Bromoform	0.3	0.00	<40%	60-140	<40%
4-Methyl-2-pentanone	0.2	0.01	<40%	60-140	<40%
2-Hexanone	0.2	0.01	<40%	60-140	<40%
Bromodichloromethane	0.3	0.01	<40%	60-140	<40%
Dibromochloromethane	0.4	0.01	<40%	60-140	<40%
Vinyl acetate	0.4	0.02	<40%	60-140	<40%
t-1,2-Dichloroethene	0.2	0.01	<40%	60-140	<40%
Benzylchloride	0.3	0.01	<50%	50-150	<50%
4-Ethyltoluene	0.2	0.01	<40%	60-140	<40%
Methyl t-butyl ether	0.2	0.01	<40%	60-140	<40%
Cyclohexane	0.2	0.01	<40%	60-140	<40%
1,4-Dioxane	0.7	0.04	<40%	60-140	<40%
Tetrahydrofuran	0.3	0.02	<40%	60-140	<40%
Hexane	0.2	0.01	<40%	60-140	<40%
Heptane	0.2	0.01	<40%	60-140	<40%
2,2,4-Trimethylpentane	0.2	0.01	<40%	60-140	<40%
3-Chloroprene	0.3	0.02	<40%	60-140	<40%
Ethyl-Acetate	0.4	0.02	<40%	60-140	<40%
2-Propanol	0.2	0.02	<40%	60-140	<40%
TO-15 8260 Compounds					
n-Proplylbenzene	0.2	0.01	<40%	60-140	<40%
Isopropylbenzene	0.2	0.01	<40%	60-140	<40%
2,2-Dichloropropane	0.5	0.02	<40%	60-140	<40%
1,1,1,2-Tetrachloroethane	0.3	0.01	<40%	60-140	<40%
Bromochloromethane	0.3	0.01	<40%	60-140	<40%
Octane	0.2	0.01	<40%	60-140	<40%
Nonane	0.3	0.01	<40%	60-140	<40%
Decane	0.3	0.01	<40%	60-140	<40%
1,1-Dichloropropene	0.2	0.01	<40%	60-140	<40%
1,2,3 Trichloropropane	0.3	0.01	<40%	60-140	<40%
1,3-Dichloropropane	0.2	0.01	<40%	60-140	<40%
Dibromomethane	0.4	0.01	<40%	60-140	<40%
Methyl methacrylate	0.2	0.01	<40%	60-140	<40%
Di-isopropyl ether	0.2	0.01	<40%	60-140	<40%
Isobutyl Alcohol	0.3	0.02	<40%	60-140	<40%
Ethanol	0.6	1.4	<40%	60-140	<40%

Component	MDL ug	MDL ppbV	ICAL/CCV %D	LCS %R	Precision %D
n-Butylbenzene	0.3	0.01	<40%	60-140	<40%
sec-Butylbenzene	0.3	0.01	<40%	60-140	<40%
tert-butylbenzene	0.3	0.01	<40%	60-140	<40%
i-Butylbenzene	0.3	0.01	<40%	60-140	<40%
p-Isopropyltoluene	0.3	0.01	<40%	60-140	<40%
t-Butanol	0.2	0.01	<40%	60-140	<40%
2-Chlorotoluene	0.3	0.01	<40%	60-140	<40%
4-Chlorotoluene	0.3	0.01	<40%	60-140	<40%
Methyl Acrylate	0.4	0.9	<40%	60-140	<40%
Ethyl tert butyl Ether	0.4	0.02	<40%	60-140	<40%
1,2,3-Trichlorobenzene	0.4	0.01	<40%	60-140	<40%

Table 13.9e
Method TO-17 Special Compound List and QC Criteria

The Special List has compounds that EAS has a 5 point initial calibration and QC, but are not regularly reported. We will include these compounds if requested, please call to get the QC criteria for these compounds.

Component	TO-17 MDL ug
Naphthalene	0.1
t-1,4-Dichloro-2-butene	0.3
1,2-Dibromo-3-chloropropane	0.5
Methanol	0.4
Acrylonitrile	0.2
Acetonitrile	0.3
Acrolein	0.2
Methacrylonitrile	0.3
Ethyl methacrylate	0.2
Methyl iodide	0.3
Propionitrile	0.2
Tetraethyl lead	0.3

Received: 18 April 2016 | Accepted: 11 September 2016
DOI: 10.1111/ina.12340

ORIGINAL ARTICLE

WILEY

VOC exposures in California early childhood education environments

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Funding information
California Air Resource Board (CARB), Grant/Award Number: 08-305; Office of Environmental Health Hazard Assessment (OEHHA)

Abstract

Little information exists about exposures to volatile organic compounds (VOCs) in early childhood education (ECE) environments. We measured 38 VOCs in single-day air samples collected in 2010-2011 from 34 ECE facilities serving California children and evaluated potential health risks. We also examined unknown peaks in the GC/MS chromatographs for indoor samples and identified 119 of these compounds using mass spectral libraries. VOCs found in cleaning and personal care products had the highest indoor concentrations (d-limonene and decamethylcyclopentasiloxane [D5] medians: 33.1 and 51.4 μg/m³, respectively). If reflective of long-term averages, child exposures to benzene, chloroform, ethylbenzene, and naphthalene exceeded age-adjusted "safe harbor levels" based on California's Proposition 65 guidelines (10^{-5} lifetime cancer risk) in 71%, 38%, 56%, and 97% of facilities, respectively. For VOCs without health benchmarks, we used information from toxicological databases and quantitative structure–activity relationship models to assess potential health concerns and identified 12 VOCs that warrant additional evaluation, including a number of terpenes and fragrance compounds. While VOC levels in ECE facilities resemble those in school and home environments, mitigation strategies are warranted to reduce exposures. More research is needed to identify sources and health risks of many VOCs and to support outreach to improve air quality in ECE facilities.

KEYWORDS
childcare, children, exposure, QSAR, risk characterization, VOCs, volatile organic compounds

1 | INTRODUCTION

Many infants and young children spend as much as 10 hours per day, 5 days per week, in early childhood education (ECE) facilities, which includes childcare facilities and preschools. Nationally, about 61% (13 million) of all U.S. children under 5 years of age are enrolled in childcare.[1] ECE facilities are varied and include family childcare providers, private centers, and programs run by schools and government agencies. These facilities are located in a variety of building types including houses, schools, commercial buildings, and portable classrooms. Studies of early life exposures have primarily focused on homes or classrooms, but few studies have examined exposures in ECE facilities.[2,3]

Recent studies indicate that ECE environments may contain environmental contaminants hazardous to children's health, including volatile organic compounds (VOCs).[4,5] VOCs are ubiquitous in indoor environments, with sources including building materialsand furnishings, consumer products (cleaning and art supplies), personal care products, and outdoor infiltration from traffic and in- dustrial emissions.[6] Exposures to benzene, toluene, ethylbenzene, and xylenes (collectively, BTEX), a subset of VOCs commonly found in vehicular exhaust, can cause neurologic, developmental, and

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respiratory health effects.[7] Glycol ethers (e.g., 2-butoxyethanol) are frequently used as solvents in household products such as paints and have been associated with increased risk of asthma, rhi- nitis, and eczema.[8] Terpenes (e.g., d-limonene), frequently used in cleaning products, may react with ozone to produce hazardous secondary pollutants such as formaldehyde and ultrafine particles.[9–11] Compared to adults, children are more vulnerable to the adverse effects of environmental contaminants because they are less developed immunologically, physiologically, and neurologically than adults.[12] They also breathe more air per kg of body weight compared with adults and are thus more highly exposed when con- taminants are present.

Several international studies have examined hazardous VOC levels in childcare facilities including benzene, toluene, ethylbenzene, and xylenes.[13–15] Only one study has reported VOC levels in U.S. facilities.[4] As part of a broader study of environmental contaminants in 40 California ECE facilities, we measured indoor and outdoor air concentrations of VOCs.[16] In this study, we report indoor and outdoor levels of 38 VOCs, including 15 compounds with predominantly mobile sources and 23 with non-mobile sources, and evaluate potential determinants of exposure. In addition to the targeted VOCs, we also detected numerous peaks in the gas chromatography/mass spectrometry (GC/MS) chromatographs indicating the presence of many other VOCs in these environments. We used automated deconvolution information software (AMDIS) and National Instituteof Standards and Technology spectral libraries[17] to identify 119 nontargeted VOCs and then estimated concentrations using a tol- uene model. For all compounds, we compared exposure levels to health-based reference values when available, and, for a subset of compounds identified as carcinogens, we applied new methods developed by the California Office of Environmental Health Hazard Assessment (OEHHA) to evaluate potential cancer risk among children.[18] Finally, for VOCs without established health benchmarks, we conducted a hazard assessment using information from toxicological databases and quantitative structure–activity relationship (QSAR) models to identify and prioritize chemicals that warrant additional exposure and health evaluation.

Practical Implications

- This study reports on 157 VOCs in U.S. early childhood education (ECE) environments. Our findings suggest that potentially harmful VOC exposures are occurring in ECE environments. Estimated exposures to four chemicals known to the State of California to cause cancer exceeded California's Proposition 65 guidelines for lifetime cancer risk in >35% ECE facilities, and an additional 12 chemicals show the potential for adverse impacts and warrant further study. More research is needed to fully assess the potential health risks to young children and adult staff and identify the major sources of VOCs in ECE centers. However, current knowledge indicates that care- ful selection of cleaning and personal care products usedin day care environments can help reduce exposures to some VOCs of concern; thus, outreach to childcare providers on how to reduce exposures to indoor VOCs is warranted.

2 | MATERIALS AND METHODS

2.1 | Study population, questionnaires, and study visits

The procedures for participant recruitment, ECE site inspections, and sample collection have been described previously.[18] Briefly, we enrolled 40 ECE facilities located in two northern California counties [Monterey (n=20) and Alameda (n=20)]. Questionnaire and inspection forms were administered to assess environmental quality in the facilities. Information obtained included building type (home, school, or office and if portable or manufactured), ECE type (home vs. center), building materials, renovations (within the last five years), new flooring (within the last year), air freshener and cleaning product use, ventilation, and the presence of composite wood products (CWPs). Site visits occurred from May 2010 to May 2011. All study protocols were approved by the University of California, Berkeley Committee for the Protection of Human Subjects, and informed written consent was obtained from each ECE facility program director or senior administrator.

2.2 | Building and environmental parameters

We used Q-TRAK™ IAQ Monitors (model 8554, TSI Inc.) to measure real-time indoor carbon dioxide (CO_2), relative humidity (RH), and temperature at 60-second intervals in all facilities. TSI calibrated the monitors in the spring of 2010. To address concerns by the ECE facility directors about perfluorocarbon tracer (PFT) gases, as previously described,[18] we used the continuous CO_2 measurements to estimate air exchange rates (AERs).[19,20] Specifically, we recorded minute-by-minute occupancy to estimate CO_2 emissions and recorded changes in the room that might impact AER (whether windows, interior doors, and/or exterior doors were open or closed). Most occupants were either preschool children (age <5) or adults (age >18), so we assumed that the two age groups had per person CO_2 emission rates of 0.0029 L/s and 0.0052 L/s, respectively.[21] The second AER estimation method used a tracer decay test conducted midday when children were out of the room using a bulk release of medical grade CO_2 (Praxair, Part Number CD M-10 United States Pharmacopeia grade).[19,20] (Note we tested the CO_2 gas canisters to confirm no VOC contaminants were present.) The dynamic mass balance was solved for AER to minimize the sum of the squared errors between modeled and measured CO_2 concentrations for each period when conditions in the room were consistent. See Supporting Information (SI) for more detailed information describing the air exchange rate calculations.

2.3 | VOC air sampling

Indoor air samples were collected in the main childcare room dur- ing a single day at each facility.[16] VOC samplers were deployed at the height of a child's breathing zone (~1 m) and were protected by a "kiddie-corral" made of untreated wood. The air sampling system used a rotary vane pump to provide vacuum for multiple sampling lines used during monitoring. The pump was placed in a stainless steel box lined with sound-insulating foil-faced fiberglass; the exhaust system included a muffler to reduce noise and a HEPA and carbon filter to eliminate possible emissions by the pump. Air was pulled at approximately 0.015 liters per minute (LPM) and regulated by inline taper flowmeters, providing a total sample volume of ~7 L. This sample volume was selected as a balance between sample volume (not too large) and sample rate (not too slow) to cover the full-day sampling events. The sample flow rate of 0.015 L/min is approximately two orders of magnitude higher than diffusive uptake on the tubes, so any errors due to uncertainty in sampling rate are expected to be insignificant.

Outdoor air samples were collected from a random subset of ECE facilities (n=20) using SKC AirChek 2000 pumps. Flow rates for both the inline flowmeters and AirChek pumps were calibrated using a Gilibrator® airflow calibrator. Outdoor air samplers were deployed after indoor air samplers were set up, which resulted in a shorter sample collection time for outdoor than indoor samples (429 minutes versus 473 minutes, respectively).

Initial VOC samplers used glass sorbent tubes containing Tenax-TA® backed with Carbosieve™. However, alcohols released by hand sanitizers produced large interferent peaks in chromatograms, rendering samples from six facilities unusable. To resolve these problems, final protocols used separate Tenax-TA® and custom-packed multisorbent Carbopack (containing 2/3 by volume of Carbopack B backed up with 1/3 by volume of Carbopack X) sorbent glass tubes (P/N 012347-005-00; Gerstel or equivalent) to sample VOCs. The Tenax-TA® and Carbopack tubes were operated in parallel when used together. In one facility without alcohol interference, VOC levels were collected on the original method using Tenax-TA® backed Carbosieve. In summary, we report valid indoor VOC measurements for a total of 34 ECE facilities, including 20 with outdoor measurements.

2.4 | Laboratory analyses

The samples were analyzed at Lawrence Berkeley National Laboratory (LBNL) following U.S. EPA Method TO-17.[22] Multipoint calibrations were prepared from standards to quantify 38 target analytes. All standards and analytes were referenced to an internal standard (~120 ng) of 1-bromo-4-fluorobenzene. See SI for more details. All compounds over the method detection limit (MDL) (<1 to several ng) were evaluated using the NIST spectral library followed by comparison with reference standards. On a mass/volume basis, the MDLs ranged from 0.03 to 1.80 μg/m³ (See SI Table S2 for MDL values). VOC levels below the MDL were imputed to MDL/√2.[23] Decamethylcyclopentasiloxane (D5), d-limonene, and octamethylcyclotetrasiloxane (D4) masses exceeded the highest calibration standard in 15 (44%), 11 (32%), and two (6%) of the ECE facilities, respectively. The analytical methods did not allow for reanalysis of these samples because the entire sample was consumed during the analyses. For these samples, the high mass calibration was used to calculate air concentration (using the sample-specific volume, which averaged ~7 L).

For three duplicate VOC samples, the mean relative percent difference (RPD) was 15.2±4.8%, showing good precision overall. Seventeen travel blanks were analyzed for possible contamination. Of the 38 analytes measured, only two had median blank masses above the method detection limit: hexamethylcyclotrisiloxane (D3) (4.1 ng) and benzaldehyde (1.5 ng). Three Tenax travel spikes were used to quantify recovery. All concentrations were blank-corrected. For all 38 analytes, average recovery for the travel spikes was 96.0% (SD=8.0). See SI for additional QA/QC results. Note, when duplicate samples were collected, the average was used for final analyses.

2.5 | Identification and quantification of non-targeted VOCs

For 32 facilities, we identified unknown peaks on the chromatograms from indoor air samples by conducting a mass spectral library search with the National Institute of Science and Technology (NIST) NIST08 database.[17] This approach utilizes automated deconvolution information software (AMDIS), which improves resolution of complex chromatograms with large numbers of unresolved or partially resolved peaks. For especially complex chromatograms, we used a dominant and/or unique fragment ion chromatogram in the mass spectra, referred to here as the extracted ion chromatogram (EIC). The chemical name and retention time for each peak were recorded if the match quality was >80% as determined by the Chemstation software. This approach resulted in the identification of 151 chemicals, including overlap with the previously reported *a priori* target analytes (where standard calibration curves were used). As additional verification, we ran pure standards for 14 selected chemicals identified with the spectral libraries diluted to levels comparable to our estimated concentrations and compared the retention times. The retention times matched almost perfectly (R^2=0.998), confirming the accuracy of our prior identification based on the spectral libraries. We also assessed probability-based matching (PBM) based on the pure standards and measurements in two of the ECE facilities.[24] Seven had a PBM score above 90% and all were above 70% (Range 72%-96%), affirming the accuracy of the VOC identification. See SI for more information.

We applied a modified toluene equivalent mass calibration to compute semiquantitative estimates of the mass of each VOC identified with the spectral libraries. Toluene equivalent mass has long been used in reporting total volatile organic compounds (TVOC) for unidentified chemicals and is optimal for total ion chromatographs (TIC) with well-resolved peaks.[25] We report values for each VOC if the peaks were >5 ng toluene equivalent in the chromatographs. In total, 119 additional VOC analytes were identified and quantified. To assess the quality of the estimated values, we compared levels of the 38 VOCs quantified *a priori* with the standard calibration curve versus estimated values from the toluene equivalent mode. The R^2 of the regression was

0.75, indicating reasonable estimation, with a tendency to underestimate true values with the toluene model (see SI Figure S2).

Overall, these results indicate that we correctly identified the non-targeted VOCs and the estimated values are a good indicator of the likely concentrations.

2.6 | Data analysis

We first computed descriptive statistics for target and non-targeted analytes. For simplicity, we classified the targeted VOCs into two groups: (i) compounds with both indoor and mobile sources ("mixed and mobile sources" [MMS]) (n=15) and (ii) compounds with primarily indoor sources ("household sources" [HS]) (n=23) (Table 1). The MMS VOCs (e.g., toluene) derive predominately from automotive exhaust and petroleum-based products such as paints and adhesives.[26] The HS VOCs (e.g., d-limonene and 2-ethyl-1-hexanol) derive predominately from household products such as cleaning products, air fresheners, fragrances, or solvents.[27,28] To verify these source groupings, we also examined Spearman correlation matrices to assess the relationships between VOCs within each group.

Potential determinants of targeted VOCs with detection frequencies >60% were examined in bivariate analyses. For both MMS and HS VOCs, we examined bivariate associations with license type (center/home-based) and building type (portable/non-portable). For MMS VOCs, we examined bivariate associations with season (summer/winter), attached garages (present/absent), the use of glue (cement, epoxy, or superglue), and permanent markers. For HS VOCs, we examined bivariate associations with reported use of air fresheners, "low-toxicity" cleaning products, and frequency of reported mopping. For MMS VOCs and specific non-fragrance HS VOCs, we also examined associations with the following building characteristics: carpet (present/absent), composite wood products (present/absent), vinyl floors (present/absent), occurrence of renovations within the last five years (yes/no), and installation of new floor coverings within the last year (yes/no). For these analyses, we used the nonparametric Wilcoxon rank-sum test. Due to the small sample size, multivariable statistical modeling was not appropriate.

We computed indoor-to-outdoor (I/O) air concentration ratios of targeted VOCs for each facility with paired measurements (n=20) and used the Wilcoxon signed-rank test to compare the levels. We evaluated Spearman rho correlations between the VOC levels and AER (h^{-1}), RH (%), and temperature (°C). For MMS VOCs, we also evaluated correlations with length-adjusted traffic volumes (∑LATV) within a one-kilometer (km) radius of the facility.[29]

All analyses were performed with STATA statistical software Version 13.0 (StataCorp, College Station, TX).

2.7 | Health risk characterization

2.7.1 | Non-cancer risk estimation

Among the 157 compounds evaluated, 10 targeted and six non-targeted VOCs had OEHHA reference exposure levels (RELs) and/or U.S. EPA reference concentrations (RfCs).[30,31] We compared indoor VOCs concentrations to these inhalation benchmarks. An additional six compounds had EPA oral reference doses (RfDs). However, because of differences in risk across exposure routes, we did not compare estimated inhalation exposures to the oral RfDs.

2.7.2 | Cancer risk estimation

Among the 157 compounds evaluated, four (benzene, chloroform, ethylbenzene, and naphthalene) have been identified as carcinogens under California's Proposition 65 and have "Safe Harbor Levels," called no significant risk levels (NSRLs),[32] defined by OEHHA as the daily dose posing a one in 100 000 (10^{-5}) excess risk of cancer over a lifetime.[33] We computed child-specific NSRLs for these VOCs based on standard child body weights and respiration and adjusted for OEHHA age-specific sensitivity factors (ASF) of 10 for children <2 years of age and 3 for children between the ages of 2 and 6 years.[18,33–35] Age-adjusted NSRLs were computed for four age groups: birth to <1 year; 1 to <2 years; 2 to <3 years; and 3 to <6 years. An age-adjusted NSRL is the estimated daily intake which contributes 1/70th (assuming a 70-year lifetime) of the target lifetime cancer risk in that particular year of life. We then estimated children's daily dose assuming the measurement was representative of exposure over one year, that a child spends 5 days per week and 48 weeks per year in childcare, and 100% absorption of the inhaled VOCs.[34] If the ratio of a child's VOC dose estimate (μg/day) to the age-adjusted NSRL (μg/day) is greater than 1, the dose estimate exceeded the 10^{-5} threshold. See SI equations S1-S2 and Table S6 for more information.

2.8 | Hazard Assessment for compounds without non-occupational health-based exposure benchmarks

For compounds that lacked non-occupational health-based exposure benchmarks (REL, RfC, or RfD) and had detection frequencies >60%, we reviewed information from online databases which aggregate information on chemical hazards from a broader set of authoritative lists, GoodGuide's ScoreCard and the Healthy Building Network's Pharos Project.[36,37] We also applied QSAR models (Virtual models for property Evaluation of chemicals within a Global Architecture [VEGA]) to predict potential toxicity for mutagenicity, carcinogenicity, developmental toxicity, and skin sensitization for all compounds with good reliability scores[38,39] (See SI Hazard Assessment for further details). VEGA utilizes multiple models for some health endpoints and may yield contradictory predictions. When VEGA models produced contradictory predictions, we conservatively used the positive prediction for the health endpoint.

We classified the compounds into potential hazard groups based on findings from VEGA, ScoreCard, and Pharos, including potential carcinogen or mutagen (Group 1), developmental toxicants (Group 2), reproductive toxicants (Group 3), endocrine disrupting chemicals (Group 4), neurotoxicants (Group 5), immunotoxicants/sensitizers (Group 6), specific organ or acute toxicants (Group 7), irritants (Group

TABLE 1 Distributions of indoor air concentrations for 38 targeted VOCs (μg/m³) (n=34 ECE facilities)[a]

Analyte	>MDL (%)	Geometric mean (95th CI)	Arithmetic mean (SD)	25th %	Median	75th %	95th %	Max
Mixed and mobile sources								
Benzene	71	0.8 (0.7, 0.9)	0.9 (0.5)	<MDL	0.9	1.0	2.0	2.6
Butylbenzene	18	<MDL	<MDL	<MDL	<MDL	<MDL	0.1	0.2
n-Decane[b]	91	0.6 (0.4, 0.8)	0.8 (0.9)	0.4	0.6	1.0	3.0	4.5
n-Dodecane	91	0.8 (0.6, 1.1)	1.1 (1.1)	0.4	0.7	1.6	2.8	5.0
Ethylbenzene	100	0.5 (0.4, 0.7)	0.7 (0.6)	0.3	0.6	1.0	2.0	2.0
n-Heptane	100	1.5 (1.0, 2.3)	3.0 (4.1)	0.5	1.5	3.5	10.9	19.8
n-Hexadecane	100	0.9 (0.7, 1.1)	1.0 (0.7)	0.6	0.8	1.2	2.4	4.1
n-Hexane	59	0.7 (0.5, 0.9)	0.9 (0.9)	<MDL	0.6	1.0	2.9	3.6
n-Octane	100	0.7 (0.5, 0.9)	0.8 (0.8)	0.5	0.6	1.1	1.8	4.3
n-Tetradecane	100	2.1 (1.5, 2.8)	3.1 (3.3)	1.1	1.9	4.0	7.7	17.3
Toluene	100	3.3 (2.5, 4.2)	4.1 (3.0)	1.7	3.1	5.5	11.2	12.4
1,2,3-Trimethylbenzene	65	0.1 (0.1, 0.2)	0.2 (0.2)	<MDL	0.1	0.3	0.7	1.0
1,2,4-Trimethylbenzene	97	0.5 (0.4, 0.7)	0.7 (0.6)	0.3	0.5	0.9	2.3	2.7
n-Undecane	85	0.6 (0.4, 0.8)	0.9 (1.0)	0.3	0.6	0.9	3.3	4.6
Xylenes	100	2.3 (1.7, 3.1)	3.2 (2.7)	1.0	2.5	4.8	9.2	9.4
Household sources								
Fragrances								
Benzaldehyde	100	2.7 (2.3, 3.2)	3.0 (1.7)	2.0	2.4	3.8	5.7	9.4
Butanal	100	0.7 (0.6, 0.9)	0.8 (0.4)	0.5	0.7	0.9	1.6	2.0
3-Carene	82	0.2 (0.1, 0.4)	0.5 (0.7)	0.1	0.2	0.6	1.8	3.0
Decanal[f]	94	2.5 (1.6, 3.9)	4.3 (4.7)	1.6	2.6	4.7	18.2	22.0
Heptanal	97	0.9 (0.7, 1.2)	1.1 (0.5)	0.8	1.0	1.3	2.1	2.7
Hexanal[f]	100	6.3 (5.0, 8.0)	7.7 (5.4)	3.9	5.7	10.0	20.9	22.5
d-Limonene	100	23.1 (15.1, 35.2)	37.3 (28.1)	9.1	33.1	>68.7[c]	>74.9[c]	>81.5[c]
Nonanal	100	8.5 (7.4, 9.7)	9.1 (3.5)	6.5	8.5	10.3	15.6	16.0
Octanal[f]	100	2.2 (1.9, 2.5)	2.3 (1.0)	1.7	2.1	2.5	5.3	5.7
α-Pinene	100	3.7 (2.6, 5.3)	6.4 (10.0)	1.7	3.6	6.4	19.9	57.7
α-Terpineol[g]	85	0.5 (0.3, 1.0)	1.8 (4.2)	0.3	0.4	1.9	6.4	24.1
γ-Terpinene[f]	62	0.2 (0.1, 0.3)	0.7 (1.4)	<MDL	0.3	0.4	4.8	7.1
Other household sources								
2-Butoxyethanol	100	4.7 (3.2, 7.1)	10.9 (19.4)	1.8	2.9	8.6	>64.0[c]	>92.4[c]
Carbon tetrachloride	3	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	2.1
Chloroform	38	0.6 (0.4, 0.8)	1.3 (2.6)	<MDL	<MDL	0.8	7.7	12.6
Decamethylcyclopentasiloxane (D5)	100	34.2 (24.6, 47.6)	46.4 (28.2)	17.4	51.4	>70.8[c]	>83.6[c]	>88.2[c]
2-Ethyl-1-hexanol	100	1.7 (1.4, 2.0)	1.9 (1.0)	1.1	1.6	2.8	3.9	3.9
Hexamethylcyclotrisiloxane (D3)	50	2.3 (1.8, 3.0)	3.0 (2.3)	<MDL	1.5	4.6	8.0	9.3
Methylene chloride	3	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.5
Octamethylcyclotetrasiloxane (D4)[b]	91	1.4 (0.8, 2.6)	7.4 (18.1)	0.5	0.9	2.9	>70.9[c]	>78.5[c]
Tetrachloroethylene[b]	52	0.1 (0.1, 0.2)	0.4 (1.3)	<MDL	0.1	0.2	1.0	7.8
Texanol[d]	100	5.0 (3.6, 7.1)	8.7 (12.0)	2.4	4.6	8.6	32.7	60.7
TXIB[e]	100	4.6 (3.4, 6.3)	7.7 (13.8)	2.3	4.7	7.9	14.1	82.8

[a]If indoor concentrations <MDL, values were inputted as MDL/√2.
[b]All VOCs were analyzed in 34 samples, except for decane, D4, and tetrachloroethylene (n=33 samples).
[c]Denotes when the highest calibration range was used as analyte mass to calculate sample concentration. Values underestimate the true air concentrations.
[d]Texanol: 2,2,4-trimethyl-1,3-pentanediol monoisobutyrate.
[e]TXIB: 2,2,4-trimethyl-1,3-pentanediol diisobutyrate.
[f]U.S. EPA SCP "yellow triangle" rating: The chemical has met Safer Choice Criteria for its functional ingredient class, but has some hazard profile issues.
[g]U.S. EPA SCP "green half-circle" rating: The chemical is expected to be of low concern based on experimental and modeled data.[40]

8), persistent or bioaccumulative chemicals (Group 9), and no information (Group 10). To quantify the breadth of hazard data, we allotted a binary score to each group according to the presence or absence (score=1 or 0) of positive toxicity data. We summed the scores for each chemical, creating a cumulative "hazard score." We selected a hazard score of >3 to prioritize compounds for further review. We then evaluated chemical-specific information when available, including peer-reviewed literature, summaries in the U.S. National Institute of Occupational (NIOSH) NIOSH Pocket Guide to Chemical Hazards (http://www.cdc.gov/niosh/npg/),[41] Material Safety Data Sheets (MSDS), classification by the U.S. EPA Safer Choice Program (SCP), and independent reviews for final consideration of compounds warranting further study. For example, we excluded propylene glycol because it has been independently reviewed as a food additive.[42]

3 | RESULTS

3.1 | ECE facility characteristics

Detailed ECE facility and child characteristics for this study have been published previously.[18] The programs served 1764 children, with an average of 44 children per facility. Average outdoor and indoor air temperature (mean) ranged from 11.0-31.7°C (19.0) to 16.0-24.6°C (21.1), respectively. Average outdoor and indoor RH (mean) ranged from 21.6%-74.7% (49.4) to 34.5%-62.6% (49.3), respectively. See SI Tables S7-S9 for further information. The ECE facilities had an average AER of 1.7±1.3 h^{-1} with a range of 0.3-5.6 h^{-1} (see SI Table S10). Due to the moderate climate in California, natural ventilation (i.e., open windows) was often used, with 91% of the facilities opening windows or doors for ventilation, especially in the afternoons, which are often breezy. The AERs measured in this study were higher than rates reported in new California homes (median=1.31 versus 0.26 h^{-1}, respectively).[43] This difference is not surprising given our measurements were taken during the day with highly variable occupancy, versus measurements in homes which included time periods at night when occupancy is constant and windows and doors are often closed during sleep.

3.2 | Targeted VOC levels in air

3.2.1 | MMS VOCs

For the 15 MMS VOCs, the median indoor concentration ranged from 0.1 $\mu g/m^3$ for 1,2,3-trimethylbenzene to 3.1 $\mu g/m^3$ for toluene (Table 1). Seven compounds were detected in 100% of indoor samples—including toluene, ethylbenzene, and xylenes. Benzene was detected in 70.6% of samples. Many of the MMS VOCs were moderately to strongly correlated with each other (rho>0.35-0.99; SI Table S11).

For example, benzene was significantly correlated with all the MMS VOCs (r=.42-0.84, P<.05). The MMS VOCs were detected more frequently indoors than outdoors (Tables 1 and 2 and SI Table S12), and 86% had significantly higher levels indoors than outdoors, with the mean I/O ratios ranging from ~1 for benzene and butylbenzene to

TABLE 2 Outdoor VOC concentrations ($\mu g/m^3$) and indoor-to-outdoor (I/O) ratios[a]

	Outdoor (n=20)		I/O ratios
Analyte	>MDL (%)	Median	Mean
Mixed and mobile sources			
Benzene	75	0.6	~1
Butylbenzene	0	<MDL	~1
n-Decane	30	<MDL	>1-10*
n-Dodecane	0	<MDL	>1-10*
Ethylbenzene	65	0.1	>1-10*
n-Heptane	85	0.4	>1-10*
n-Hexadecane	5	<MDL	>10-50*
n-Octane	60	0.1	>1-10*
n-Tetradecane	10	<MDL	>50-100*
Toluene	100	0.9	>1-10*
1,2,3-Trimethylbenzene	25	<MDL	>1-10*
1,2,4-Trimethylbenzene	60	0.1	>1-10*
n-Undecane	5	<MDL	>1-10*
Xylenes	100	0.6	>1-10*
Household sources			
Fragrances			
Benzaldehyde	100	2.3	~1
Butanal	25	<MDL	>10-50*
3-Carene	0	<MDL	>10-50*
Decanal	55	0.1	>10-50*
Heptanal	15	<MDL	>10-50*
Hexanal	80	0.2	>10-50*
d-Limonene	5	<MDL	>1000*
Nonanal	95	0.2	>10-50*
Octanal	55	0.1	>10-50*
α-Pinene	45	<MDL	>50-100*
α-Terpineol	0	<MDL	>10-50*
γ-Terpinene	0	<MDL	>10-50*
Other household sources[b]			
2-Butoxyethanol	20	<MDL	>50-100*
Chloroform	0	<MDL	>1-10*
Decamethylcyclopentasiloxane (D5)	95	0.3	>100*
2-Ethyl-1-hexanol	5	<MDL	>10-50*
Hexamethylcyclotrisiloxane (D3)	25	<MDL	~1
Octamethylcyclotetrasiloxane (D4)	35	<MDL	>50-100*
Tetrachloroethylene	30	<MDL	>1-10*
Texanol	10	<MDL	>100*
TXIB	10	<MDL	>100*

*$P < .05$ from Wilcoxon matched-pairs signed-ranks test comparing indoor and outdoor VOC concentrations.
[a]If VOC concentrations were <MDL, values were imputed as MDL/√2 and used for analyses.
[b]I/O ratios were not calculated for carbon tetrachloride and methylene chloride due to their very low detection frequencies indoors (3%) and outdoors (0%).

>50 for n-tetradecane (Table 2), underscoring that several of these compounds also have indoor sources.

3.2.2 | HS VOCs

For the 23 HS VOCs, the median indoor concentrations ranged from 0.1 for tetrachloroethylene to 51.4 µg/m³ for D5 (Table 1). The fragrance VOCs were frequently detected indoors with nine (of twelve) compounds detected in >90% of ECE facilities. D-limonene was detected in all facilities and had a median (range) of 33.1 µg/m^3 (0.8-81.5 µg/m^3). D5, which is predominantly found in personal care products,[44] had the highest median concentration (51.4 µg/m³, range: 2.6-88.2 µg/m^3). D4 also had a high detection frequency (90.9%) with a median concentration (range) of 0.9 µg/m^3 (0.1-78.5 µg/m^3). Many of the indoor HS VOC concentrations (SI Table S13) were also moderately correlated (rho>0.36), albeit less strongly than the MMS VOCs. HS VOCs were detected more frequently indoors than outdoors (n=19) (Tables 1 and 2). The mean I/O ratios for HS VOCs ranged from ~1 (benzaldehyde and D3) to >1000 (d-limonene) and were higher than the MMS ratios, indicating that indoor sources were dominant for these compounds; 91% of the 23 HS VOCs had significantly higher levels indoors than outdoors (Table 2).

3.3 | Determinants of targeted VOCs

3.3.1 | MMS VOCs

Several indoor MMS VOC air concentrations (including ben-zene; n-heptane, n-hexadecane, n-tetradecane, toluene, and 1,2,4-trimethylbenzene) were inversely and significantly associated with AER (Spearman rho=−0.38 to −0.67, *P*<.05, see SI Table S14).Three MMS VOCs, benzene, n-heptane, and n-hexadecane, were positively correlated with proximity to traffic (ΣLATV) (Spearman rho=0.38-0.44, *P*<.05). Five MMS VOCs were significantly lower(*P*<.05) in centers compared to home-based facilities (ethylbenzene,n-octane, toluene, 1,2,4-trimethylbenzene, and xylenes). The presence/absence of attached garages in home-based facilities was not significantly associated with these compounds (*P*<.05) and does not explain the difference by license type. Reported glue use was significantly associated with indoor levels of xylenes (*P*<.05; Table S15).

3.3.2 | HS VOCs

Butanal, hexanal, α-pinene, 2-ethyl-1-hexanol, and D4 were significantly and inversely associated with AER (Spearman rho=−0.42 to −0.62, *P*<.05, See SI Table S16), indicating indoor sources of these chemicals. Indoor concentrations of hexanal, decanal, and D5 were significantly and positively correlated with reported air freshener use (*P*<.05; SI Table S17). Aliphatic aldehydes (hexanal, decanal) can be found as oxidation products of fatty acid ozonolysis,[45,46] and as secondary pollutants from constituents of fragrances and cleaning products.[47] D5 can be found in personal care products.[44] Levels of HS VOCs, including siloxanes, were similar in facilities that reported use/purchase of low-toxicity cleaners compared with those using traditional cleaners. However, D5 concentrations were significantly higher in facilities with higher mopping frequency, suggesting VOC emissions from the floor cleaners. Building type, vinyl flooring, carpet, and license type were not significantly associated with any HS VOCs.

3.4 | Non-targeted VOC levels in air

Estimated levels of all 119 non-targeted VOC analytes are presented by chemical class in the SI (Table S18). For the 31 alkane compounds, median concentrations ranged from <MDL to 0.29 µg/m^3 for methyl-cyclohexane. For the 31 oxygenated hydrocarbon compounds, median concentrations ranged from <MDL to 7.36 µg/m^3 for propylene glycol. For the 34 aromatic compounds, median concentrations ranged from <MDL to 1.13 µg/m^3 for phenol. Naphthalene, a possible carcinogen, was detected in 96.9% of samples with a median concentration of 0.34 µg/m^3. Siloxane median concentrations ranged from <MDL to 1.89 µg/m^3 for dodecamethyl-cyclohexasiloxane (D6). For the 15 terpenes, median concentrations ranged from <MDL to 1.66 µg/m^3 for 2,6-dimethyl-7-octen-2-ol.

3.5 | Health risk characterization

3.5.1 | Non-cancer risk evaluation

Of the 10 targeted VOCs and six non-targeted VOCs with RELs or RfCs, none of the risk ratios exceeded one and were often much lower (see SI Tables S19 and S20).

3.5.2 | Cancer risk evaluation

Table 3 presents the 50th and 95th percentile inhalation dose estimates compared to the age-adjusted NSRL values by age group. The 50th and 95th percentile dose estimates for benzene exceeded the age-specific NSRL in all four age groups assessed (ratio range: 1.8-17.4). The 95th percentile dose estimates for chloroform exceeded the age-specific NSRL in all four age groups assessed (ratio range=5.2-22.5). The 95th percentile dose estimates for ethylbenzene exceeded the age-adjusted NSRL in the three youngest age groups (ratio range=1.2-4.2). The 50th percentile dose estimates for ethylbenzene exceeded the age-adjusted NSRL in the two youngest age groups (ratio range=1.2-1.3). Among the non-targeted VOCs, only naphthalene is listed as a carcinogen by OEHHA.[32] Naphthalene NSRL ratios exceeded the age-specific NSRL in all age groups assessed (range: 1.6-22.4) (Table 3). If reflective of long-term averages, child dose estimates exceeded age-adjusted NSRL benchmarks for benzene, chloroform, ethylbenzene, and naphthalene in 71%, 38%, 56%, and 97% of facilities, with all facilities having exposures to at least one compound exceeding the respective NSRL.

3.6 | Hazard assessment and prioritization for future study

Of the targeted VOCs without non-occupational health-based exposure benchmarks, two were excluded from detailed review due

TABLE 3 Inhalation VOC dose estimates compared to $NSRL_{child\ (age\ group)}$

Analyte	Age group	Dose estimates (μg/day) median	Dose estimates (μg/day) 95th %	$NSRL_{child}$ (μg/day)	Ratio median	Ratio 95th %
Targeted						
Benzene	Birth to <1 year	1.0	2.3	0.1	7.4	17.4
	1 to <2 years	1.5	3.6	0.2	7.1	16.8
	2 to <3 years	1.8	4.2	0.9	2.1	4.9
	3 to <6 years	2.0	4.8	1.2	1.8	4.2
Chloroform	Birth to <1 year	NC	8.7	0.4	NC	22.5
	1 to <2 years	NC	13.6	0.7	NC	20.9
	2 to <3 years	NC	16.2	2.6	NC	6.1
	3 to <6 years	NC	18.5	3.5	NC	5.2
Ethylbenzene	Birth to <1 year	0.7	2.2	0.5	1.3	4.2
	1 to <2 years	1.1	3.5	0.9	1.2	3.9
	2 to <3 years	1.3	4.1	3.5	0.4	1.2
	3 to <6 years	1.4	4.7	4.8	0.3	1.0
Non-targeted						
Naphthalene[a]	Birth to <1 year	0.38	1.3	0.06	6.9	22.4
	1 to <2 years	0.60	2.0	0.09	6.4	20.9
	2 to <3 years	0.83	2.7	0.38	2.2	7.2
	3 to <6 years	0.82	2.7	0.51	1.6	5.2

NC, not calculated.
NSRLs are available for carbon tetrachloride and methylene chloride, but are not included here due to low detection frequencies (>MDL=3%).
[a]To measure naphthalene, we applied a modified toluene equivalent mass calibration to compute semiquantitative estimates of its mass (see "*Identification and quantification of non-targeted VOCs*" above.)

to lower detection frequency (<60%). Twenty-four of the remain- ing 25 compounds had positive toxicological information cited by PHAROS, ScoreCard, or QSAR predictions (see SI Tables S21 and S22). The 24 VOCs were distributed into respective hazard groups (groups 1-9) as follows: 8% (n=2) for carcinogenicity or mutagenicity, 29% (n=7) for developmental toxicity, 4% (n=1) for reproductive toxicity, 4% (n=1) for endocrine activity, 25% (n=6) for neurotoxicity, 58% (n=14) for immunotoxicity or sensitization, 71% (n=17) for specific organ or acute toxicity, 63% (n=15) for irritation, and 25% (n=6) for persistence or bioaccumulation (see SI Tables S21 and S23). Each hazard group is not mutually exclusive. We identified seven compounds with hazard scores >3 for ad-ditional evaluation (Table 4): d-limonene, α-pinene, α-terpineol, 1,2,4-trimethylbenzene, D4, n-heptane, and heptanal. The persis- tent and bioaccumulative nature of cyclosiloxanes (D4 and D5)raises health concerns, especially given adverse reproductive ef- fects reported in animals.[48] These compounds are also listed as pri- ority chemicals for biomonitoring by the California Biomonitoring Program.[49] Thus, we recommend additional evaluation of D5 be- cause of health concerns raised by OEHHA, and the high detection frequency and levels measured (Table 1).[50]

Applying the same methods to the 119 non-targeted VOCs with no non-occupational health-based exposure benchmarks (SI Tables S24 and S25), we identified four additional compounds with hazard scores >3 for further evaluation: butyl ester acetic acid; camphor; n-pentane; 3-phenyl-2-propenal (see Table 4 and SI Table S26 for detailed hazard information).

In total, 12 compounds were identified for further review by the hazard analysis. Four of these—d-limonene, α-pinene, α-terpineol, and camphor—are terpenes. These products have natural sources, but are often concentrated in cleaning and other scented products. Levels of d-limonene were among the highest VOCs measured in the childcare facilities, and several information sources suggest health concerns about this compound (Table 4).[51] The U.S. EPA Safer Choice Program (SCP) has classified limonene and pinene with yellow triangles, indicating they have "hazard profile" concerns.[40] Camphor is used in air fresheners and other consumer products and in concentrated forms as an insect repellant and pesticide; it is a known hazard that has been associated with child poisoning.[52] Terpenes can also react with ozone to form formaldehyde,[53] a known carcinogen, and ultrafine particles.[10] Given the high formaldehyde levels previously reported in these facilities,[18] additional research on the relative contributions of terpenes and other formaldehyde sources in day care centers is needed to assess overall exposure and health risks and determine whether these compounds are significantly contributing to formaldehyde exposure.

The remaining eight compounds identified for further review include the following: acetic acid, butyl ester; D4; D5; n-heptane; heptanal; n-pentane; 3-phenyl-2-propenal; and 1,2,4-trimethylbenzene. European agencies have set occupational exposure standardsfor 1,2,4-trimethylbenzene and n-heptane based on adverse

TABLE 4 Summary of potential health concerns for VOCs warranting additional evaluation[a]

Analyte	PHAROS[b]	ScoreCard[c]	VEGA[d]	Hazard score
Mixed and Mobile Sources				
n-Heptane	Developmental Toxicant, Irritant, Neurotoxicant, Respiratory Toxicant, Acute Toxicant	Neurotoxicity	Non-mutagen	5
n-Pentane	Acute Toxicant, Developmental Toxicant, Neurotoxicant, Persistent, Respiratory Toxicant, Specific Organ Toxicant	Neurotoxicity	Non-mutagen	5
Household Sources				
Fragrances				
Acetic acid, butyl ester	Acute Toxicant, Developmental Toxicant, Neurotoxicant, Persistent, Specific Organ Toxicant	Gastrointestinal or Liver Toxicity, Neurotoxicity, Respiratory Toxicity, Skin or Sense Organ Toxicity	Non-mutagen, Sensitizer	6
Heptanal	Irritant, Acute Toxicant	Neurotoxicity	[Non-mutagen], Skin Sensitizer	4
d-Limonene	Developmental Toxicant, PBT, Skin Sensitizer, Suspected Asthmagen, Irritant (eye, skin), Acute Toxicant	Gastrointestinal or Liver Toxicity, Immunotoxicity, Kidney Toxicity, Neurotoxicity, Respiratory Toxicity, Skin or Sense Organ Toxicity	[Non-mutagen], [Skin Sensitizer]	6
α-Pinene	Bioaccumulative, Irritant, Acute Toxicant	Neurotoxicity, Respiratory Toxicity, Skin or Sense Organ Toxicity	[Non-mutagen], Developmental Toxicant, Skin Sensitizer	6
2-Propenal, 3-phenyl-	Acute Toxicant, Developmental Toxicant, Reproductive Toxicant, Skin Sensitizer	Immunotoxicity, Neurotoxicity, Skin or Sense Organ Toxicity	[Non-mutagen], Non-carcinogen, [Sensitizer]	5
α-Terpineol[e]	Irritant, Acute Toxicant	Data lacking	[Non-mutagen], Developmental Toxicant, Skin Sensitizer	4
1,2,4-Trimethylbenzene	Developmental Toxicant, Irritant (eye, skin, lungs), Acute Toxicant (inhalation)	Cardiovascular or Blood Toxicity, Neurotoxicity, Respiratory Toxicity	[Non-mutagen], [Carcinogen], Sensitizer	6
Other household products				
Camphor	Acute Toxicant, Reproductive Toxicant, Specific Organ Toxicant	Gastrointestinal or Liver Toxicity, Neurotoxicity, Respiratory Toxicity, Skin or Sense Organ Toxicity	Sensitizer, [Developmental Toxicant]	5
Decamethylcyclopentasiloxane (D5)	PBT	Data lacking	Data lacking	1
Octamethylcyclotetrasiloxane (D4)	PBT (high priority), Reproductive Toxicant, EDC, Acute Toxicant	Gastrointestinal or Liver Toxicity	Data lacking	4

Persistent bioaccumulative toxicant (PBT); endocrine disrupting compound (EDC).
[a]Compounds with a hazard score >3, except for D5, which was prioritized due to potential health concerns raised by California OEHHA[50] and high concentration measurements.
[b]Acute toxicant is listed as "Toxic to Mammals" in PHAROS.
[c]Suspected effects.
[d]Brackets indicate experimental data.
[e]U.S. EPA SCP "green half-circle" rating: The chemical is expected to be of low concern based on experimental and modeled data.[40]

developmental effects, and they both affect the respiratory and central nervous systems.[54] Heptanal is one of several fragrance-related compounds we measured and is identified as a respiratory irritant in occupational settings with high exposures.[28] Butyl ester acetic acid (SI Table S26; CAS #123-86-4) has natural sources and is used in air fresheners, cleaners, as a synthetic flavoring in foods, and in floor sealants and finishes.[36] Although the hazard score for this compound was relatively high (6), aggregated information summarized in PHAROS and

ScoreCard generally indicates only moderate hazards, and the median estimated levels were <1 μg/m^3. However, its use in air fresheners and cleaners suggests the potential for widespread exposure as mixtures of fragrance-related compounds. Fragrances have been associated with reductions in lung function and other respiratory symptoms.[55] Thus, additional research on low-level exposure and chronic toxicities for these fragrance-related compounds is needed.

There are three compounds with hazard scores >3 that we did not prioritize in our assessment (dipropylene glycol monomethyl ether and 2-methylpropyl ester acetic acid, acetate 2-pentanol). 2-Methylpropyl ester acetic acid (SI Table S26; CAS #110-19-0) is a solvent used in a variety of coatings and also as a flavoring agent.[36] Although the hazard score from our analysis was >3, aggregated information summarized in PHAROS and ScoreCard indicates only moderate hazards, and the U.S. EPA SCP classified this compound as a "green half-circle", indicating low concern but missing data. Similarly, aggregated information for dipropylene glycol monomethyl ether (DGME) (SI Table S26; CAS #34590-94-8), a solvent used in coatings and flooring, suggests some moderate hazards and contradicts the classification as a "green circle", or of low concern, by the U.S. EPA SCP. According to a 2001 review by the United Nations Environment Program (UNEP), one DGME isomer is a reproductive toxicant, but adverse effects were noted at exposures in animals at 1818 mg/m^3 to 2424 mg/m^3, with no observed adverse effect levels (NOAELs) from >303 mg/m^3 to 1212 mg/m^3.[56] Applying uncertainty factors to these NOAELs would result in health-based exposure thresholds significantly higher than the levels we measured. Thus, we did not prioritize this compound for further research.

Levels of acetate 2-pentanol (CAS #626-38-0) were very low (<1 μg/m^3), and this substance is listed as a food ingredient by the U.S. Food and Drug Administration. At very high exposures, effects on skin, the respiratory system, and central nervous system are noted, but at many orders of magnitude above the levels we estimated (median=0.06 μg/m^3 versus a NIOSH REL of 650 mg/m^3). Thus, we also did not prioritize this compound for further research.

In summary, this initial screening identified 12 VOCs without non-occupational health-based exposure benchmarks in these ECE facilities that warrant additional exposure and hazard assessment. Recommendations for follow-up of these and other measured VOCs are discussed below.

4 | DISCUSSION

This is the first study to report on a wide array of VOCs in U.S. early childhood and education environments. Among the chemicals with established non-cancer health-based inhalation benchmarks, there were no concentrations that exceeded acceptable thresholds. However, if reflective of long-term averages, child dose estimates exceeded age-adjusted NSRL benchmarks for benzene, chloroform, ethylbenzene, and naphthalene in 71%, 38%, 56%, and 97% of facilities, respectively. All facilities had exposures to at least one compound exceeding the respective NSRL. It is likely that our risk characterization underestimates total risk to the children as they are likely exposed to these chemicals in other indoor and outdoor environments.[43,57]

A strength of this study was the successful application of AMDIS software combined with NIST mass spectral libraries to identify numerous chemicals not previously measured in ECE facilities or other indoor environments. Among all the compounds we initially tar- geted or subsequently identified, the vast majority did not have non-occupational health-based exposure benchmarks relevant to young children. However, based on the application of QSAR models and extensive review of aggregated health information for all VOCs measured, we identified 12 compounds that warrant additional research on exposure and health risks (acetic acid, butyl ester, camphor, D4, D5, n-heptane, heptanal, d-limonene, n-pentane, 3-phenyl-2-propenal, α-pinene, α-terpineol, 1,2,4-trimethylbenzene). These include commonly used terpenes and fragrance-related compounds, which have been associated with respiratory or other health problems.[28,51–53,55] Future studies examining VOC exposures in ECE facilities should target these compounds, as well as other compounds where exposures exceeded exposure benchmarks based on carcinogenicity (benzene, chloroform, ethylbenzene, and naphthalene).

Consistent with other studies, overall, indoor levels were higher than outdoor levels, indicating that indoor sources predominated. For compounds with both indoor and outdoor sources (e.g., BTEX compounds), the I/O ratios were relatively low and several were associated with nearby traffic density, indicating that outdoor sources contributed to indoor contamination in some cases. We also observed a significant positive association between xylenes and reported use of cement glue, epoxy, or superglue, consistent with xylene's use in adhesives.[24] For household source VOCs (with primarily indoor sources), we observed significant positive associations between D5, hexanal, and decanal with air fresheners, and D5 with mopping frequency, consistent with their use as fragrances and solvents in consumer products.[58]

In general, the VOC levels in the childcare facilities were within the range of measurements in other child indoor environments.[43] For example, average indoor air concentrations of BTEX compounds ranged from 0.7 to 4.1 μg/m^3 compared to mean levels in California classrooms that ranged from 0.41 to 6.32 μg/m^3.[59] Overall, median indoor air levels of benzene, 2-butoxyethanol, chloroform, naphthalene, and xylenes were similar to or slightly higher in the ECE facilities compared to those measured in new California homes.[43] In contrast, levels of d-limonene (median=33 μg/m^3) were higher than concentrations reported in new California homes (median=11 μg/m^3),[43] likely due to frequent cleaning in childcare facilities.[60] The D5 levels we observed (mean=46 μg/m^3) were also higher than measurements in U.S. office buildings (mean=3 μg/m^3).[61] D5 is frequently used as a solvent for blending fragrance oil and is often present in air fresheners and cleaning fluids.[48,62] The I/O ratios for d-limonene and D5 were extremely high, underscoring the predominance of indoor sources.

Limitations of this study include the sample size and the 8-hour sample collection period. Although it is the largest study to date reporting on a wide variety of VOCs in U.S. ECE facilities, our original sample size of 40 facilities was reduced to 34 for most measurements due to analytical challenges, limiting our statistical power to build multivariable models and draw inferences. Also, the samples were collected during a single day and may not reflect long-term levels. Limitations related to our use of CO_2 as a tracer gas to estimate AERs[19,20] have been described previously.[18] Further, the sources of indoor air contaminants are ubiquitous and difficult to disentangle and thus may not have been fully captured in our questionnaire and inspection data.

The lack of toxicological information for many of the chemicals we measured is another limitation. For example, QSAR programs are constrained by the availability of toxicological data for reference chemicals adequate to making accurate hazard predictions. Insufficient VEGA reliability scores limited our capacity to judge whether some compounds pose health hazards and warrant additional study. Similarly, the databases we used that aggregate toxicological information may not be complete, and may not consider proprietary information or government or other reports that are not published in the peer-reviewed literature.[36,37]

In summary, child exposures for benzene, chloroform, ethylbenzene, and/or naphthalene exceeded California Safe Harbor Levels for cancer in all of the ECE facilities tested. More exposure research is needed on these compounds to clarify the long-term risks to children. While exposures to 16 of the VOC compounds we measured were below non-cancer health benchmarks, more than 70% of the compounds lacked any health-based exposure standards that could be used to characterize potential risks. Based on databases aggregating toxicological information and the application of QSAR modeling methods, we identified 12 chemicals without health benchmarks that warrant additional exposure and health evaluation due to the potential for carcinogenic or neurologic effects and other health effects. Our findings demonstrate that potentially harmful VOC exposures are occurring in ECE environments, and indicate that more research is needed to fully assess the potential health risks to young children and adult staff and identify major sources of VOCs present in ECE centers. As warranted, restrictions on the use of some compounds should be considered as well as outreach to childcare providers on strategies to improve indoor air quality, such as ensuring proper ventilation, to mitigate these exposures. Sufficient information and guidance are already available through a number of programs that allow childcare providers to assure safer environments. For example, childcare providers can select cleaning and personal care products showing the Green Seal logo (which meets one or more of the many Green Seal voluntary product standards),[63] and products that contain only chemicals registered through the European Union's Registration, Evaluation, Authorisation, and Restriction (REACH) Program.[64]

ACKNOWLEDGEMENTS

This research was supported by the California Air Resource Board (CARB), Agreement Number 08-305. This work does not necessarily reflect the opinion or official policy of the CARB. This study is derived in part from a full project report available from CARB. We thank J. Williams of the California Air Resources Board for reviewing the manuscript and providing input on study methods. We also thank M. Sandy of the Office of Environmental Health Hazard Assessment (OEHHA) for reviewing risk evaluation methods and approaches to incorporate age-specific sensitivity factors when evaluating OEHHA NSRLs. Finally, we also thank the ECE programs that participated in this study.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

SAMPLE ONLY

Participant # _____

East Bay Diesel Exposure Project

Questionnaire Form

P1.	Date of interview:	— — /__ __ /__ __ MO DAY YR
P2.	Time interview began	__ __ : __ __ AM / PM
P3.	Study interviewer:	________________________ ___ ___ **[CODE]**

PRIOR TO STARTING THE QUESTIONNAIRE:

Thank you for participating in this important study about how people in the East Bay are exposed to diesel exhaust. With your permission, I would like to ask you some questions about you, your child, and your home. For some questions, I will read you all of the possible responses so that you know what all the choices are. If you do not know the answer to a question, please just say you don't know. You can skip any questions that you do not want to answer -- just let me know, and I will move to the next question. All the information you provide will be kept confidential.

Can we continue with this questionnaire now? Yes No

What is the month and year of your birth?

P4.	Parent's age today	__________ __________ Month (mm) Year (yyyy)

What is the month and year of your child's birth?

P5.	Child's age today	__________ __________ Month (mm) Year (yyyy)

SAMPLE ONLY

Participant # _____

A. MEASUREMENTS

First, we would like to take the height and weight of you and your child. As we mentioned in the consent form, knowing how tall you are and how much you weigh can help us understand more about your chemical exposures. Please remove your and your child's shoes and coats.

I.	Name of person(s) taking measurements: A. ________________________________ B. ________________________________		___ ___ **[CODE]** ___ ___ **[CODE]**
II.	A.	Child's weight	_____ .__ lbs
	B.	Child's height	_____ inches
III.	A.	Parent's weight	________ .__ lbs
	B.	Parent's height	_____ inches

SAMPLE ONLY

Participant # _____

B. GENERAL DEMOGRAPHIC INFORMATION

1. What is your gender identity?

Female	1
Male	2
Prefer not to answer…	3
Other	_

Specify____________________ **[CODE LATER]**

2. How do you describe your ethnicity or race? Select one or more.

American Indian/Alaskan Native	1
Asian	2
Black/African American	3
Hispanic/Latino	4
Native Hawaiian/Other Pacific Islander…	5
White	6
Prefer not to identify	7
Other…	_

Specify____________________ **[CODE LATER]**

A. How do you describe your child's ethnicity or race? Select one or more.

American Indian/Alaskan Native	1
Asian	2
Black/African American	3
Hispanic/Latino	4
Native Hawaiian/Other Pacific Islander…	5
White	6
Prefer not to identify	7
Other…	_

Specify____________________ **[CODE LATER]**

3. What is the highest level of education you have completed?

Some elementary school (grades 1-5)…	1
Some middle school (grades 6-8)…	2
Some high school (grades 9-12)…	3
High school diploma or GED	4
Technical/Trade school	5
Some college	6
College degree	7
Graduate degree	8
Prefer not to answer…	10
Other…	_

Specify____________________ **[CODE LATER]**

4. What is the yearly income in your household?

0-$25,000	1
$25,001-$75,000	2
>$75,000	3
Prefer not to answer…	5
DK	9

SAMPLE ONLY

Participant # _____

5. How many people live in your household, including you? _____ people

C. HOUSING CHARACTERISTICS

6. When did you and your child move to this home?

DATE: __ _ / __ __ __ _

MO Year

[CODE 99/9999 FOR DON'T KNOW]

A. *If participant moved to this home within the past six months:* What is the address of your previous home?

Fill in the corresponding section in Appendix 1 (Question #A1).

7. Does your child live at more than one home?

No……………………..(8)…............................	0
Yes	1

A. Does your child live most of the time here at the home we are in now (4 days per week or more)?

No	0
Yes……………………(8)…	1

B. What is the address of the home where your child lives most of the time (4 days per week or more)?

Fill in the corresponding section in Appendix 1 (Question #A2).

8. How many rooms (*not including bathrooms)* are in this home?

One...	1
Two...	2
Three..	3
Four…	4
Five or more...	5

9. What type of stove do you use for cooking?

Gas..	1
Electric	2
Other	_

Specify ____________________

[CODE LATER]

10. How often is the stove used?

Participant # ____

Never…	0
Less than once per week	1
Once per week	2
2 to 3 times per week	3
4 to 5 times per week	4
Daily	5
DK…	9

SAMPLE ONLY

Participant # _____

	A. Does your stove have a fan?	No…………………(11)	0
		Yes..	1
		DK……………………………………………	9
	B. How often is your stove fan used when you prepare food?	Never……………………………………..	0
		Sometimes..……………….………………	1
		Often…………………………………………	2
		Always………………………………………	3
		DK…………….…………………………..	9
11.	Do you have a grill or smoker for cooking?	No …………………(12)………………..…	0
		Yes …………………………………………	1
		DK……………………………………………	9
	A. Is the grill or smoker electric?	No……………………………………......	0
		Yes…………………(12)…………….......	1
		DK……………………………………………	9
	B. Is the grill or smoker used indoors, outdoors, or both?	Indoors………………………………………	1
		Outdoors …………(12)…………………	2
		Both …………………………………………	3
		DK……………………………………………	9
	C. How often is the grill or smoker used indoors for cooking?	Less than once per week…………………	1
		Once per week…………………………….	2
		2 to 3 times per week………………………	3
		4 to 5 times per week………………………	4
		Daily…………………………………………	5
		DK……………………………………………	9
	D. Was the grill or smoker used indoors in the past week?	No……………………………………......	0
		Yes…………………………………….......	1
		DK……………………………………………	9
12.	Does your home have an attached garage?	No…………………(13)…………….........	0
		Yes…………………………………….......	1
	A. Does anyone park their car(s) in your attached garage?	No…………………(13)…………….........	0
		Yes…………………………………….......	1
		DK……………………………………………	9
	B. Is diesel or biodiesel fuel used in the car(s) parked in the attached garage?	No…………………(13)…………….......	0
		Yes…………………………………….......	1
		DK…………………………………………...	9
	C. Which fuel does the car (or cars) use: diesel or biodiesel?	Diesel………………………………………..	1
		Biodiesel……………………………………	2
		DK……………………………………………	9

Participant # _____

13. Are candles, votives, incense, or sage ever burned in your home?

No……………………(14) 0
Yes.. 1
DK… 9

A. How often are candles, votives, incense, or sage used?

Less than once per week 1
Once per week.. 2
2 to 3 times per week..................................... 3
4 to 5 times per week..................................... 4
Daily... 5
DK… 9

B. Have you burned candles, votives, incense, or sage in the past week?

No 0
Yes.. 1

D. DAILY ACTIVITIES

Now I will ask some questions about you (*the child's parent or guardian*) and your daily activities. Please answer the following questions for the current season [*specify months*].

14. Does your personal car or truck run on diesel or biodiesel fuel?

No………………(15) 0
Yes..1

A. Which fuel does it use: diesel or biodiesel?

Diesel 1
Biodiesel 2
DK… 9

15. What is your primary job?

___________________________ ___________
Specify [CODE LATER] **SIC CODE**

16. What is the address of your primary job?

Fill in the corresponding section in the Appendix 1 (Question #A3).

17. Do you have any other jobs?

No……………(19)…...0
Yes..1

___________________________ __ __ __ __
Specify [CODE LATER] **SIC CODE**

___________________________ __ __ __ __
Specify [CODE LATER] **SIC CODE**

18. What is/are the address(es) of your other job(s)?

Fill in the corresponding section in the Appendix 1 (Question #A4).

19. How many hours do you work on

average per week (Monday through

Sunday)?

Hours _____

SAMPLE ONLY

Participant # _____

20.	Do you drive a diesel- or biodiesel-powered vehicle at work?	No……………….(21)……………………......	0
		Yes…………………………………….........	1
		DK……………………………………………	9
	A. What kind of vehicle?	______________________ **Specify [CODE LATER]**	
	B. Which fuel does the vehicle use: diesel or biodiesel?	Diesel………………………………………..	1
		Biodiesel……………………………………..	2
		DK……………………………………………	9
	C. Do you drive this vehicle indoors?	No…………………………………….......	0
		Yes…………………………………….........	1
		DK……………………………………………	9
21.	Do you operate any diesel- or biodiesel powered equipment at work?	No……………….(22)………………………	0
		Yes…………………………………………..	1
		DK……………………………………………	9
	A. What kind of equipment?	______________________ **Specify [CODE LATER]**	
	B. Which fuel does the equipment use: diesel or biodiesel?	Diesel………………………………………..	1
		Biodiesel……………………………………..	2
		DK……………………………………………	9
	C. Do you operate this equipment indoors?	No…………………………………….......	0
		Yes…………………………………….........	1
		DK……………………………………………	9
22.	Are diesel- or biodiesel-powered vehicles or equipment used at your workplace?	No…………………(35)……………………	1
		Yes…………………………………………..	2
		DK……………………………………………	9
23.	Are generators used at your workplace?	No…………………(24)……………….…...	0
		Yes…………………………………….........	1
		DK……………………………………………	9
	A. What type of fuel is used in the generator: biodiesel or diesel?	Diesel………………………………………..	1
		Biodiesel……………………………………..	2
		DK……………………………………………	9
	B. Where is the generator located or used: indoors, outdoors or both?	Indoors………………………………………	1
		Outdoors……………………………………..	2
		Both…………………………………………..	3
		DK…………………………………………….	9

SAMPLE ONLY

Participant # _____

24.	Are tractors used at your workplace?	No…………………(25)………………….....	0
		Yes……………………………………..........	1
		DK……………………………………………	9
	A. What type of fuel is used in the tractor: biodiesel or diesel?	Diesel………………………………………..	1
		Biodiesel……………………………………..	2
		DK……………………………………………	9
	B. Where is the tractor used: indoors, outdoors or both?	Indoors………………………………………	1
		Outdoors……………………………………..	2
		Both…………………………………………..	3
		DK…………………………………………….	9
25.	Are bulldozers used at your workplace?	No…………………(26)………………….....	0
		Yes……………………………………..........	1
		DK……………………………………………	9
	A. What type of fuel is used in the bulldozer: biodiesel or diesel?	Diesel………………………………………..	1
		Biodiesel……………………………………..	2
		DK……………………………………………	9
	B. Where is the bulldozer used: indoors, outdoors or both?	Indoors………………………………………	1
		Outdoors……………………………………..	2
		Both…………………………………………..	3
		DK…………………………………………….	9
26.	Are forklifts used at your workplace?	No………………(27)……………………....	0
		Yes……………………………………..........	1
		DK……………………………………………	9
	A. What type of fuel is used in the forklift: biodiesel or diesel?	Diesel………………………………………..	1
		Biodiesel……………………………………..	2
		DK……………………………………………	9
	B. Where is the forklift used: indoors, outdoors or both?	Indoors………………………………………	1
		Outdoors……………………………………..	2
		Both…………………………………………..	3
		DK…………………………………………….	9
27.	Are bucket lifts used at your workplace?	No……………………(28)………………....	0
		Yes……………………………………..........	1
		DK……………………………………………	9
	A. What type of fuel is used in the bucket lift: biodiesel or diesel?	Diesel………………………………………..	1
		Biodiesel……………………………………..	2
		DK……………………………………………	9
	B. Where is the bucket lift used: indoors, outdoors or both?	Indoors………………………………………	1
		Outdoors……………………………………..	2
		Both…………………………………………..	3
		DK…………………………………………….	9

SAMPLE ONLY

Participant # _____

28.	Is road construction equipment, like motor graders or road rollers, used in or around your workplace?	No…………………(29)………………...... Yes……………………………………....... DK……………………………………………	0 1 9
	A. What type of fuel is used in the road construction equipment: biodiesel or diesel?	Diesel……………………………………….. Biodiesel…………………………………….. DK……………………………………………	1 2 9
	B. Where is the road construction equipment used: indoors, outdoors or both?	Indoors………………………………………. Outdoors…………………………………….. Both………………………………………….. DK…………………………………………….	1 2 3 9
29.	Are large, 18-wheel trucks used in or around your workplace?	No……………………(30)………………..... Yes……………………………………....... DK……………………………………………	0 1 9
	A. What type of fuel is used in the 18-wheel truck: biodiesel or diesel?	Diesel……………………………………….. Biodiesel…………………………………….. DK……………………………………………	1 2 9
	B. Where is the 18-wheel truck used: indoors, outdoors or both?	Indoors………………………………………. Outdoors…………………………………….. Both………………………………………….. DK…………………………………………….	1 2 3 9
30.	Are delivery trucks used in or around your workplace?	No……………………(31)………………..... Yes……………………………………....... DK……………………………………………	0 1 9
	A. What type of fuel is used in the delivery truck: biodiesel or diesel?	Diesel……………………………………….. Biodiesel…………………………………….. DK……………………………………………	1 2 9
	B. Where is the delivery truck used: indoors, outdoors or both?	Indoors………………………………………. Outdoors…………………………………….. Both………………………………………….. DK…………………………………………….	1 2 3 9
31.	Are there any other trucks used in or around your workplace (besides delivery or 18-wheelers)?	No……………………(32)………………..... Yes……………………………………....... DK……………………………………………	0 1 9
	A. What type of fuel is used in the truck: biodiesel or diesel?	Diesel……………………………………….. Biodiesel…………………………………….. DK……………………………………………	1 2 9

SAMPLE ONLY

Participant # _____

	B. Where is the truck used: indoors, outdoors or both?	Indoors…………	1
		Outdoors…………	2
		Both…………	3
		DK…………	9
32.	Are any buses used in or around your workplace?	No…………(33)…………	0
		Yes…………	1
		DK…………	9
	A. What type of fuel is used in the bus: biodiesel or diesel?	Diesel…………	1
		Biodiesel…………	2
		DK…………	9
	B. Where is the bus used: indoors, outdoors or both?	Indoors…………	1
		Outdoors…………	2
		Both…………	3
		DK…………	9
33.	Are any cars used in or around your workplace?	No…………(34)…………	0
		Yes…………	1
		DK…………	9
	A. What type of fuel is used in the car: biodiesel or diesel?	Diesel…………	1
		Biodiesel…………	2
		Both…………	3
		DK…………	9
	B. Where is the car used: indoors, outdoors or both?	Indoors…………	1
		Outdoors…………	2
		Both…………	3
		DK…………	9
34.	Is there any other diesel- or biodiesel-powered equipment that is used in or around your workplace we did not ask you about here?	No…………	0
		Yes…………	1
		Specify ____________________ **[CODE LATER]**	
		DK…………	9

SAMPLE ONLY

Participant # _____

E. SMOKING

35. Do you smoke cigarettes?

No………………(36)......................................0
Yes..1

A. On average, how many cigarettes per day do you smoke? Include all smoking, even when you are not around your child.

_______ CIGARETTES PER DAY

[CODE 988 IF < 1 CIG A DAY]
[CODE 999 IF DON'T KNOW]

36. Do you smoke pipes, cigars, or other tobacco products?

No………………(37)…..............................0
Yes..1

A. On average, how often do you smoke pipes, cigars, or other tobacco products?

Less than once per week 1
Once per week..2
2 to 3 times per week..3
4 to 5 times per week..4
Daily...5
DK…..9

37. In the past week, how many people (including yourself **[*IF S/HE IS A SMOKER*]**) have regularly smoked cigarettes, cigars, pipes, or other tobacco products inside your home?

_____ MEMBERS

[00=NONE]
[99=DON'T KNOW]

38. In the past week, how many hours per day, on average, has your child been around someone (including yourself **[*IF S/HE IS A SMOKER*]**) who is smoking indoors? Please include time at home, away from home, and in the car.

_____ HRS/DY

[00=NONE]
[98=< 1 HOUR]
[95 = YES TO AROUND SMOKE BUT DK HRS/DY]
[99=DON'T KNOW]

F. BUILDING SYSTEMS

39. Does your home have any portable gas-burning appliances, such as a small propane or kerosene heater?

No……………(40)… 0
Yes.. 1
DK….. 9

A. How often are portable gas-burning appliances used to heat your home in the current season [*specify months*]?

SAMPLE ONLY

Never……….(40) 0
Less than once per week.................................1
Once per week……………………….…….. 2
2 to 3 times per week 3
4 to 5 times per week……………..…….. 4
Daily 5
DK...9

SAMPLE ONLY

Participant # _____

B.	Were any portable gas-burning appliances used to heat your home in the past week?	No....0 Yes....1 DK....9
40.	Does your home have a fireplace?	No……(41)....0 Yes....1
A.	What fuel does the fireplace use?	Wood....1 Gas....2 DK....9
B.	How often is the fireplace used?	Never……(41)…… 0 Less than once per week....1 Once per week…… 2 2 to 3 times per week....3 4 to 5 times per week…… 4 Daily....5 DK....9
C.	Was your fireplace used in the past week?	No....0 Yes....1 DK....9
41.	Does your home have a wood- or pellet-burning stove for heating?	No……(42)……0 Yes....1 DK....9
A.	How often is the wood- or pellet-burning stove used?	Never……(42)....0 Less than once per week....1 Once per week....2 2 to 3 times per week....3 4 to 5 times per week....4 Daily....5 DK....9
B.	Was your wood- or pellet-burning stove used in the past week?	No....0 Yes....1 DK....9
42.	What type of heating system does your home have?	Gas....1 Electric....2 Other .... _ Specify____________________ [**CODE LATER**] DK....9

inspected and maintained by a professional?

43. How often is your heating system

SAMPLE ONLY

Never 0
Less than once per year 1
At least once per year 2
DK 9

SAMPLE ONLY

Participant # _____

44. Does your furnace have a filter?
- No……………………(45)…..........................0
- Yes...1
- DK… 9

A. How frequently is the furnace filter changed?
- Never 0
- Less than once per year 1
- Once per year..2
- Once every three months 3
- Monthly 4
- DK… 9

B. On what date was the furnace filter last changed? Please give your best estimate of the month and year.

DATE: __ _ / __ __ __ _

MO Year

[CODE 99/9999 FOR DO NOT KNOW]

45. Are portable air-cleaning or filtering appliances ever used in your home when your child is present? **[SEE CARD 1]**
- No……………………………………......... 0
- Yes…………………………………......... 1
- DK…………………………………………… 9

46. Does your home have air conditioning?
- No……………………(47)……………...... 0
- Yes………………………………………........ 1

A. What kind?
- Central air………………………………….. 1
- Portable unit……………………………….. 2
- Other………………………………………… 3
- DK…………………………………………… 9

47. Do you ever open your windows to the outside?
- No……………………………………......... 0
- Yes…………………………………......... 1

48. Not including when you cook or bathe, do the windows in your home "fog up" during cold weather?
- No……………………………………......... 0
- Yes…………………………………......... 1
- DK 9

49. Do you have a gas water heater inside your home?
- No……………………(50)………………… 0
- Yes………………………………………….. 1
- DK…………………………………………… 9

A. Where is it located?

____

Specify [CODE LATER]

50. Do you have a gas clothes dryer inside your home?
- No……………………(51)…..........................0
- Yes...1
- DK… 9

SAMPLE ONLY

Participant # _____

A. Where is it located?

____

Specify [CODE LATER]

51. Does this home have any carpet or rugs?

No……………………(54)…......................0
Yes...1
DK..9

A. How often are any of your carpets or rugs vacuumed?

Never… 0
Less than once per week...............................1
Once per week...2
2 to 3 times per week...................................3
4 to 5 times per week...................................4
Daily...5
DK..9

52. How often are any of the carpets or rugs in your home deeply cleaned by yourself or a professional? By this I mean steam cleaned, shampooed, sent out to a cleaner, or other wet cleaning method.

Never………………(54)................................0
Less than once per year................................1
Once per year...2
Once every three months...............................3
Monthly..4
DK..9

53. When were any of your carpets or rugs last deeply cleaned by yourself or a professional?

DATE: __ _ / __ __ __ _

MO Year

[CODE 99/9999 FOR DO NOT KNOW]

54. How often are any of the uncarpeted floors in your home swept or vacuumed?

Never… 0
Less than once per week...............................1
Once per week...2
2 to 3 times per week...................................3
4 to 5 times per week...................................4
Daily...5
DK..9

55. How often are any of the uncarpeted floors in your home cleaned with a damp/wet mop or cloth?

Never… 0
Less than once per week...............................1
Once per week...2
2 to 3 times per week...................................3
4 to 5 times per week...................................4
Daily...5
DK..9

SAMPLE ONLY

Participant # _____

G. HEALTH AND THE ENVIRONMENT

56. Are there any specific chemicals or environmental health hazards that you are concerned about?

57. Do you have anything that you would like to tell me or add to this questionnaire?

58. Thank you for taking the time to complete this questionnaire. We can now move to the home walk-through. Do you have any questions for me?

SAMPLE ONLY

Participant # _____

Card 1. Portable Air Cleaning or Filtering Appliances

SAMPLE ONLY

TEAR-OFF SHEET

Participant # _____

Appendix 1

A1. What is the address of your previous home (last six months)?

Address line 1:

Address line 2:

City:

State:

ZIP Code:

Country:

If more than one address in the last six months:

Address line 1:

Address line 2:

City:

State:

ZIP Code:

Country:

A2. What is the address of the home where your child lives most of the time (4 days per week or more)?

Address line 1:

Address line 2:

City:

State:

ZIP Code:

SAMPLE ONLY

Participant # _____

A3. What is the address of your primary job?

Address line 1:

Address line 2:

City:

State:

ZIP Code:

A4. What are the addresses of any additional jobs?

Address line 1:

Address line 2:

City:

State:

ZIP Code:

Address line 1:

Address line 2:

City:

State:

ZIP Code:

SAMPLE ONLY

Participant # _____

East Bay Diesel Exposure Project

Follow-up Questionnaire Form

P1.	Date of Interview	_______ /_______/________ MO DAY YR
P2.	Time interview began	_____:_____ AM / PM
P3.	Study interviewer	____________________________ ___ ___ **[CODE]**

The following questions are about your and your child's activities <u>since your last interview on [Sunday, Monday or Tuesday, (*insert DATE*)].</u>

First, I will ask you some questions about your **home**. In the past three days…

1. Have you used the heating system in your home?
   - No…………………………………………… 0
   - Yes…………………………………………… 1
   - DK …………………………………………… 9

2. Have you used a gas cooking stove to heat your home?
   - No…………………………………………… 0
   - Yes…………………………………………… 1
   - Do not have…………………………………… 2
   - DK …………………………………………… 9

3. Have you used a fireplace to heat your home?
   - No…………………………………………… 0
   - Yes…………………………………………… 1
   - Do not have…………………………………… 2
   - DK …………………………………………… 9

4. Have you used any portable gas-burning appliances to heat your home?
   - No…………………………………………… 0
   - Yes…………………………………………… 1
   - Do not have…………………………………… 2
   - DK …………………………………………… 9

5. Have you used a wood- or pellet-burning stove to heat your home?
   - No…………………………………………… 0
   - Yes…………………………………………… 1
   - Do not have…………………………………… 2
   - DK …………………………………………… 9

6. Have you burned candles, votives, incense, or sage in your home?
   - No…………………………………………… 0
   - Yes…………………………………………… 1
   - DK …………………………………………… 9

Participant # _____

7.	Have you used a gas stove for cooking?	No…………………………………………............. Yes…………………………………………............. Do not have……………………………………... DK ……………………………………………….	0 1 2 9
8.	Have you used a non-electric grill or smoker <u>indoors</u> for cooking?	No…………………………………………............. Yes…………………………………………............. Do not have……………………………………... DK ……………………………………………….	0 1 2 9
9.	Have you used a non-electric grill or smoker <u>outdoors</u> for cooking?	No…………………………………………............. Yes…………………………………………............. Do not have……………………………………... DK ……………………………………………….	0 1 2 9

Now I will ask you some questions about **your child's** activities.

10.	Does your child usually attend daycare, preschool, or school? Daycare includes time spent at a relative's or friend's home.	No……………………(11)……………............. Yes…………………………………………............. DK ……………………………………………….	0 1 9
	A. Did your child attend daycare, preschool, or school <u>in the past three days?</u>	No……………..………(10d)……………............. Yes…………………………………………............. DK ……………………………………………….	1 2 9
	B. How many days did your child attend daycare, preschool, or school?	1 day………………………………………………… 2 days……………………………………………… 3 days………………………………………………. DK ……………………………………………….	1 2 3 9
	C. On average, how many hours per day (in the past three days)?	Less than 1 hour………………………………… 1-2 hours……………………………………………. >2-5 hours………………………………………. >5-8 hours………………………………………. >8-10 hours……………………………………... >10-13 hours…………………………………… More than 13 hours……………………………. DK ……………………………………………….	1 2 3 4 5 6 7 9
	D. What is the address of the daycare, preschool, or school that your child usually attends?	**Fill in the corresponding section in Appendix 3 (Question #A1).**	

SAMPLE ONLY

Participant # _____

The following questions concern your child and his/ her activities **over the past three days.**

11.	On average, how many hours did your child spend outside on each <u>weekday</u>?	Less than ½ hour	1
		½ hour to 1 hour	2
		>1-2 hours	3
		>2-3 hours	4
		>3-4 hours	5
		>4-5 hours	6
		More than 5 hours	7
		DK	9
12.	How many hours did your child spend outside on Sunday? **(NOT APPLICABLE IF FIRST APPOINTMENT MONDAY OR TUESDAY.)**	Less than ½ hour	1
		½ hour to 1 hour	2
		>1-2 hours	3
		>2-3 hours	4
		>3-4 hours	5
		>4-5 hours	6
		More than 5 hours	7
		NOT APPLICABLE	8
		DK	9
13.	How much total time did your child spend in a diesel- or biodiesel-powered car, bus, truck, or van over the past three days?	None	0
		Less than 1 hour	1
		>1-2 hours	2
		>2-5 hours	3
		>5-8 hours	4
		>8-10 hours	5
		>10-13 hours	6
		More than 13 hours	7
		DK	9
14.	Did your child eat any grilled or broiled food, like meat (beef/chicken/other), fish, or vegetables?	No	0
		Yes	1
		DK	9
15.	Did your child eat any BBQ?	No	0
		Yes	1
		DK	9

Now I will ask some questions about **you** (*the parent or guardian)* and your activities **over the past three days**.

16.	On average, how many hours did **you** spend outside on each <u>weekday</u>?	Less than ½ hour	1
		½ hour to 1 hour	2
		>1-2 hours	3
		>2-3 hours	4
		>3-4 hours	5
		>4-5 hours	6
		More than 5 hours	7
		DK	9

SAMPLE ONLY

Participant # _____

17.	How many hours did **you** spend outside on Sunday? **(NOT APPLICABLE IF FIRST APPOINTMENT MONDAY OR TUESDAY.)**	Less than ½ hour	1
		½ hour to 1 hour	2
		>1-2 hours	3
		>2-3 hours	4
		>3-4 hours	5
		>4-5 hours	6
		More than 5 hours	7
		NOT APPLICABLE	8
		DK	9
18.	How much total time did you spend in a diesel- or biodiesel-powered car, bus, truck, or van over the past three days?	None	0
		Less than 1 hour	1
		>1-2 hours	2
		>2-5 hours	3
		>5-8 hours	4
		>8-10 hours	5
		>10-13 hours	6
		More than 13 hours	7
		DK	9
19.	Did you work?	No……(20)……	0
		Yes	1
	A. How many days?	1 day	1
		2 days	2
		3 days	3
	B. On average, how many hours per day?	Less than 1 hour	1
		>1-2 hours	2
		>2-5 hours	3
		>5-8 hours	4
		>8-10 hours	5
		>10-13 hours	6
		More than 13 hours	7
		DK	9
	C. Were you working with or near any diesel- or biodiesel-powered equipment?	No……(20)……	0
		Yes	1
		DK	9
	D. Is this equipment or vehicle powered by diesel, biodiesel or both?	Diesel	1
		Biodiesel	2
		Both	3
		DK	9
20.	Did you or anyone else smoke cigarettes, cigars, pipes, or other tobacco products inside your home?	No	0
		Yes	1
		DK	9

SAMPLE ONLY

Participant # _____

21.	Did you eat any grilled or broiled food, like meat (beef/chicken/other), fish, or vegetables?	No……………………………………………	0
		Yes……………………………………………	1
		DK ……………………………………………	9
22.	Did you eat any BBQ?	No……………………………………………	0
		Yes……………………………………………	1
		DK ……………………………………………	9

Lastly, I have some questions about your time-activity diary.

23.	How complete is the information you provided on your time-activity diary?	Complete……………………………………	1
		Mostly complete………………………………	2
		Somewhat complete…………………………	3
		Not complete…………………………………	4
		DK ……………………………………………	9
24.	How complete is the information you provided on your child's time-activity diary?	Complete……………………………………	1
		Mostly complete………………………………	2
		Somewhat complete…………………………	3
		Not complete…………………………………	4
		DK ……………………………………………	9

25. Do you have anything that you would like to tell me or add to this questionnaire?

26. Thank you for taking the time to complete this questionnaire. Do you have any questions for me?

SAMPLE ONLY

TEAR-OFF SHEET

Participant # _____

Appendix 3

A1. What is the address of your child's daycare, preschool, or school? Daycare includes time spent at a relative's or friend's home.

Address line 1:	
Address line 2:	
City:	
State:	
ZIP Code:	

SAMPLE ONLY

Participant # _____

East Bay Diesel Exposure Project

Home Walk-Through Form

P1.	Date of interview:	_____ /_____/_____ MO DAY YR
P2.	Time interview began	_____ :_____ AM / PM
P3.	Study interviewer:	___________________________ ___ ___ **[CODE]**
P4.	Record GPS coordinates of the home	**Fill in the corresponding section in Appendix 2 (Question #A1).**

EQUIPMENT NEEDED TO COMPLETE HOME WALK-THROUGH:	
• FLASHLIGHT	• CLIPBOARD
• PEN	• GPS

DIRECTIONS: *ALL SPOKEN QUESTIONS AND INSTRUCTIONS ARE IN ITALICIZED PRINT*.
ALWAYS ASK PERMISSION BEFORE ENTERING A ROOM.

Thank you for participating in the East Bay Diesel Exposure Project. I would like to walk through your home in order to collect information about your indoor and outdoor environments.

May I do the home walk-through now? ***Yes*** ***No***

SAMPLE ONLY

Participant # _____

BUILDING CHARACTERISTICS

1. Which of the following best describes the residence?

Detached home……………………..…(2)…..................	1
Duplex (two apartments)…	2
Building with three or more apartments	3
Garage converted to residence..…….(2)…	4
Trailer or mobile home…..……………(2)…................	5
Other_______________________ Specify [CODE LATER]	__

A. Which story is the home on?

1st..	1
2nd	2
3rd	3
4th..	4
5th..	5
Other_______________________ Specify [CODE LATER]	__
DK…	9

2. *What type of heating system does your home have? Select all that apply.*

   Can you please show me your furnace?

None……………………(5)……………………….	0
Central forced air	1
Wall mounted heaters	2
Baseboard heaters…………………………………	3
Radiant floor heating	4
Portable (such as space heaters)	5
Floor mounted heaters...	6
Other_______________________ Specify [CODE LATER]	__

3. *What type of furnace filter?*

None	0
Pleated filter (not HEPA)..	1
High efficiency particulate filter (HEPA)	2
Filter with activated carbon..	3
Other _________________________ Specify [CODE LATER]	__
DK………………………………………………………..	9

4. *Does your furnace have a working fan?*

No………………………………………....................	0
Yes………………………………………...................	1
DK………………………………………………………..	9

5. *Does your home have a stove fan?*

No………………………(8)..……………....................	0
Yes………………………………………...................	1
DK………………………………………………………...	9

6. *Does your stove fan vent to the outside?*

No………………………………………....................	0
Yes………………………………………...................	1
DK………………………………………………………..	9

SAMPLE ONLY

Participant # _____

7.	Is there heavy grease/dirt on the stove fan vent?	No…………………………………………………..	0
		Yes………………………………………………..	1
		DK…………………………………………………	9
8.	*Do you use a portable air cleaner?*	No……………………(9)……………………..	0
		Yes………………………………………………..	1
		DK…………………………………………………	9

If it's here today, can you please show it to me?

A.	What type is it?	Pleated filter (not HEPA)…………………………….	1
		High efficiency particulate filter (HEPA)……………	2
		Filter with activated carbon…………………………	3
		Electrostatic precipitator……………………………..	4
		Ionizer…………………………………………………	5
		Other ______________________________ **Specify [CODE LATER]**	_
		DK…………………………………………………	9

9.	*Do you have a vacuum cleaner?*	No..………………………(12)……………………..	0
		Yes..………………………………………………..	1
		DK…………………………………………………	9

If it's here today, can you please show it to me?

10.	*Does the vacuum have a HEPA filter?*	No…………………………………………………..	0
		Yes…..……………………………………………..	1
		DK…………………………………………………	9
11.	*Is the vacuum cleaner bagless?*	No ………………………………………………….	0
		Yes………………………………………………..	1
		DK…………………………………………………	9

12. *Thank you for your time and for letting me walk through your home. Now I will take your vacuum bag so we can analyze the dust inside of it. Do you have any questions for me?*

    [If the vacuum cleaner is not available, try to schedule a time to come back and pick up the vacuum bag on another day.]

SAMPLE ONLY

Participant # _____

13. ADDITIONAL OBSERVATIONS:

SAMPLE ONLY

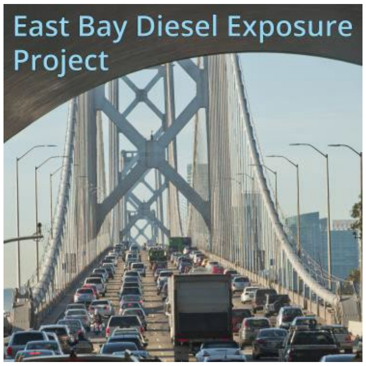
TEAR-OFF SHEET

Participant # _____

Appendix 2
GPS Coordinates of Participant's Residence

A1. Latitude and Longitude

Latitude	__ __ °	__ __'	__ __"	N
Longitude	__ __ __ °	__ __'	__ __"	W



SAMPLE ONLY

Want to learn about diesel exhaust in your neighborhood?

Join the East Bay Diesel Exposure Project with UC Berkeley and Biomonitoring California!

- Learn about how much you and your child come into contact with diesel exhaust.
- Help us understand how diesel exhaust affects your communities.
- Be part of the effort to find ways to reduce exposure to diesel exhaust.

You can participate if:

- You are 18 years or older
- You have a potty-trained child up to 10 years old
- You live in the East Bay

What does participation involve?

Participants will be asked about their home and activities, and will provide urine samples (self and child) that will be tested for chemicals in diesel exhaust. We will also collect house dust samples and air samples for a few days.

Why should I participate?

This project will help you understand how much you and other people in your community are exposed to diesel exhaust. One important goal of the project is to help find ways to reduce your and your child's exposures to diesel exhaust.

To thank you for your participation, we will give you $80 in gift cards to a local store.

Do I have to participate?

No, your participation is voluntary.

How do I find out more?

For more information, please contact:

Duyen Kauffman at Duyen.Kauffman@oehha.ca.gov; cell phone: (510) 301-0638

Rosemary Castorina at rcastori@berkeley.edu; cell phone: (510) 220-4332

Asa Bradman at abradman@berkeley.edu; phone: (510) 643-3023

SAMPLE ONLY

RECRUITMENT SCRIPT

Participant # _______

East Bay Diesel Exposure Project

Hello, my name is [INSERT NAME], and I am a [INSERT POSITION] working with Dr. Asa Bradman at the UC Berkeley Center for Environmental Research and Children's Health and Biomonitoring California. We would like to invite you to participate in a project about diesel exhaust, and how children and their families may be exposed to it in their homes or neighborhoods. Can I provide you with a brief description of the project and what your participation would involve?

_______ **No.** Okay, thank you for your time. If you change your mind, please feel free to contact me at the Center for Environmental Research and Children's Health. Again, my name is [INSERT NAME]. If you would like more information, you can call Dr. Asa Bradman, Project Director, at (510) 643-3023, or Duyen Kauffman, Health Educator at the California Office of Environmental Health Hazard Assessment, at (510) 301-0638 (cell phone).

________**Yes.** Thanks! I'd like to tell you more about our project now. If you have questions at any time, please ask me.

We are studying diesel exhaust and how adults and children may be exposed to it at home or in their neighborhoods. Our goal is to identify ways for people to reduce their exposures to diesel exhaust. To help do this, we would like to visit your home and ask questions about your home environment and daily activities. We would also like to collect urine samples from you and your child, and air and dust samples from your home to measure levels of diesel exhaust chemicals. If you decide to participate today, we will schedule four appointments with you at your home. The first appointment will be on a Sunday, Monday, or Tuesday, and will take about 2 hours. At that appointment, we will explain more about the project and answer any questions you may have. If you decide to continue, we will ask you to sign a consent form. Then we will ask questions about your home, like if you have a gas stove or an attached garage. We will also look at your home and the area around your home for sources of diesel exhaust, such as traffic.

We will then collect a vacuum bag or dust from your vacuum. If you don't have a vacuum cleaner we will collect some sweepings from your floor. If we do not collect the dust sample at this first appointment, we will collect it at a later appointment.

Before we come to your home, we will ask you not to change your vacuum bag or sweep right before our visit. We will also ask you to complete two activity diaries that describe your and your child's activities for the next 3 days. In addition, we will ask you and your child to carry small devices (about the size of a thumb) for 3 days that will collect information about your locations. We will use this information to look at how close you and your child come to freeways, railways, or other sources of diesel exhaust. We will also set up an air sampler at your home.

We will schedule a second appointment for 3 days after the first appointment. The second appointment will take 1 hour or less. We will collect urine samples from you and your child at that time. We will also pick up the air sampler and location devices at the second appointment.

SAMPLE ONLY

We will schedule two other appointments up to 4 months later to repeat the questionnaire and sample collection. We will provide everything that is needed to collect the samples. There is no risk associated with collecting any of the samples. All the information collected, including the levels of chemicals, if found, will be kept confidential.

At these appointments, you only have to answer questions that you would like to answer. Your participation in this project is voluntary. You can refuse to participate or stop participating in the project at any time.

We will take all steps possible to keep all information about you and your home private and confidential. No information that identifies you or your home will be released to people outside the project without your written permission.

By participating in this project, you can help your community learn more about exposure to diesel exhaust. To thank you for your time and effort, we will give you a $20.00 gift card to a local store at the end of the winter sampling period, and gift cards to a local store worth $60.00 at the end of the spring/summer sampling period (for a total of $80.00) after we have collected your urine, dust, and air samples. In addition, individual urine results, called "biomonitoring" results, for you and your child will be provided to you at your request, and project staff will be available to explain your results. Your home air and dust results will also be sent to you at your request. In addition, we will provide you with information about possible ways to reduce chemical exposures in your home.

Do you have any questions?

Are you interested in participating?

_______ **No.** Okay, thank you for your time. If you change your mind, please feel free to contact us at the Center for Environmental Research and Children's Health. Again, my name is [Insert Name]. If you would like more information, you can call Dr. Asa Bradman, Project Director, at (510) 643-3023, or Duyen Kauffman, Health Educator at the California Office of Environmental Health Hazard Assessment, at (510) 301-0638 (cell phone).

________**Needs More Information.** If you would like more information about the project, I can send it to you by email or to your mailing address. I just need your email or mailing address.
Email or mailing address:____

I will send you the information today. Please let me know if you have any other questions. Thank you.

________**Yes.** That's great – thank you! I am going to send you a copy of what I just read to you for your records. Do I have your permission to collect your name, phone number, and address, and schedule a visit to your home?

_______ **No.** I'm sorry, but without this information, you cannot join the project. Are there any other questions I can answer for you?

_______ **No.** Okay, thank you for your time. If you change your mind, please feel free to contact us at the Center for Environmental Health and Children's Research. Again, my name is [Insert Name]. If you would like more information, you can call Dr. Asa Bradman, Project Director, at (510) 643-3023, or Duyen Kauffman, Health Educator at

SAMPLE ONLY

the California Office of Environmental Health Hazard Assessment, at (510) 301-0638 (cell phone).

________**Yes** [NOTE NAME, ADDRESS, AND PHONE NUMBER OF ADULT PARTICIPANT ON NEXT PAGE]

SAMPLE ONLY

Contact Information for Adult Participant

Name	Phone (cell/home/other)
Street Address	

City	State	Zip Code
Email Address		

What is a convenient date and time for our staff to meet you at your home for the first appointment? Please remember that it has to be a Sunday, Monday, or Tuesday. [NOTE DATE AND TIME BELOW]

Appointment

Date: ______________ Time: ______________ AM/PM

Thank you very much. I have one final question: would you be interested in providing additional urine samples for us to measure these diesel exhaust chemicals over several days? Your additional samples would give us valuable information about using urine samples to measure diesel exposure, and could show you how your chemical levels change from one day to the next. If you agree, you would need to collect one sample per day from yourself and your child for 4 days in a row, beginning on the first day we come to your home, and store them in a mini fridge that we will lend to you. We will also ask you to repeat this 4-day sample collection when we come back to see you in up to 4 months. Are you interested in providing additional urine samples?

________ **No**. Okay, thank you. We will see you at our scheduled appointment to start the project.

________**Yes**. That's great – thank you so much! When we come to your home, we will go over the instructions on how to collect and store your urine samples until we pick them up at the second appointment. To thank you for your additional time and effort, we will give you a $20.00 gift card to a local store at the end of the winter sampling period, and gift cards to a local store worth $80.00 at the end of the spring/summer sampling period (for a total of $100.00) after we have collected your urine, dust, and air samples.

Thank you for your time today, and we look forward to seeing you on [DATE AND TIME OF APPOINTMENT]. I will mail you a reminder card with the date and time of this appointment on it, along with a copy of what we have gone over today.

If you have any questions, you can call the Project Director, Dr. Asa Bradman, at (510) 643-3023, or Duyen Kauffman, Health Educator at the California Office of Environmental Health Assessment, at (510) 301-0638 (cell).

If you have any questions about your rights or treatment as a participant in this research project, please contact the University of California at Berkeley's Committee for the Protection of Human Subjects at (510) 642-7461, or email subjects@berkeley.edu. You can also contact the State of California Committee for the Protection of Human Subjects at (916) 326-3660, or email cphs-mail@oshpd.ca.gov.

EXHIBIT A1

SCHEDULE OF DELIVERABLES

Unless otherwise directed by the State, the University Principal Investigator shall submit all deliverables to State Contract Project Manager, identified in Exhibit A3, Authorized Representatives.

Deliverable	Description	Due Date
Initial Meeting	Principal Investigator and key personnel will meet with CARB Contract Project Manager and other staff to discuss the overall plan, details of performing the tasks, project schedule, items related to personnel or changes in personnel, and any issues that may need to be resolved before work can begin.	Month 1
Progress Reports & Meetings	Quarterly progress reports and meetings throughout the agreement term, to coincide with work completed in quarterly invoices.	Quarterly
Interim Report	The interim report will include summaries of available questionnaire, home inspection, and real-time and laboratory monitoring data, results of preliminary statistical analysis, and evaluation of project challenges and accomplishments in relation to completion of the study goals.	Month ~~24~~ **36**
Draft Final Report	Draft version of the Final Report detailing the purpose and scope of the work undertaken, the work performed, and the results obtained and conclusions.	Six (6) months prior to agreement end date.
Data	Data produced in the performance of this Agreement by the Principal investigator or the University's project personnel will be provided to CARB in conformance with IRB approvals.	Two (2) weeks prior to agreement end date.
Technical Seminar	Presentation of the results of the project to CARB staff and a possible webcast at a seminar at CARB facilities in Sacramento or El Monte.	On or before agreement end date.
The following Deliverables are subject to paragraph 19. Copyrights, paragraph B of Exhibit C		
Final Report	Written record of the project and its results.	Two (2) weeks prior to agreement end date.

1. Reports and Data Compilations

A. With respect to each invoice period University shall submit, to the CARB Contract Project Manager, one (1) electronic copy of the progress report. When emailing the progress report, the "subject line" should state the contract number and the billing period. Each progress report will begin with the following disclaimer:

> *The statements and conclusions in this report are those of the University and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.*

B. Each progress report will also include:

1. A brief narrative account of project tasks completed or partially completed since the last progress report;

2. A brief discussion of problems encountered during the reporting period and how they were or are proposed to be resolved;

3. A brief discussion of work planned, by project task, before the next progress report; and

4. A graph or table showing allocation of the budget and amount used to date.

5. A graph or table showing percent of work completion for each task.

C. If the project is behind schedule, the progress report must contain an explanation of reasons and how the University plans to resume the schedule.

D. Three (3) months prior to Agreement expiration date, University will deliver to CARB five (5) bound copies of a draft final report. The reports may be stapled or spiral bound, depending on size. The draft final report will conform to Exhibit A1, Section 2 – Research Final Report Format.

E. Within forty-five (45) days of receipt of CARB's comments, University will deliver to CARB's Contract Project Manager two (2) copies of the final report incorporating all reasonable alterations and additions. Within two (2) weeks of receipt of the revised report, CARB will verify that all CARB comments have been addressed. Upon acceptance of the amended final report approved by CARB in accordance to Exhibit A1, Section 2 – Research Final Report Format, University will within two (2) weeks, deliver to CARB two (2) camera ready UNBOUND originals of a final report incorporating all final alterations and additions.

F. Together with the final report, University will deliver a copy of the report on CD, using any common word processing software (please specify the software used) and a set of all data compilations as specified in Exhibit A1 – Schedule of Deliverables.

G. University's obligation under this Agreement shall be deemed discharged only upon submittal to CARB of an acceptable final report in accordance to Exhibit A1, Section 2 – Research Final Report Format, report CD, all required data compilations, and any other project deliverables.

2. Research Final Report Format

The research contract Final Report (Report) is as important to the contract as the research itself. The Report is a record of the project and its results, and is used in several ways. Therefore, the Report must be well organized and contain certain specific information. The CARB's Research Screening Committee (RSC) reviews all draft final reports, paying special attention to the Abstract and Executive Summary. If the RSC finds that the Report does not fulfill the requirements stated in this Exhibit, the document will not be approved for release, and final payment for the work completed may be withheld. This Exhibit outlines the requirements that must be met when producing the Report.

Note: In partial fulfillment of the Final Report requirements, the Contractor shall submit a copy of the Report on a CD in PDF format and in a word-processing format, preferably in Word – Version 6.0 or later. This is in addition to the submission of any paper copies required. The CD shall be clearly labeled with the contract title, CARB contract number, the words "Final Report", and the date the report was submitted.

Legibility. Each page of the approved Final Report must be legible and camera-ready.

Binding. The draft Report, including its appendices, must be either spiral bound or stapled, depending on size. The revised Report and its appendices should be spiral bound, except for two unbound, camera-ready originals.

Cover. Do not supply a cover for the Report. The CARB will provide its standard cover.

One-sided vs. two-sided. To conserve paper, the draft Report, the revised Report, and the unbound camera-ready copies should be printed on both sides of the page.

Watermark. Each page of the draft Report must include a watermark stating “DRAFT.” The revised report should not include any watermarks.

Title. The title of the Report should exactly duplicate the title of the contract unless a change is approved in writing by the contract manager.

Spacing. In order to conserve paper, copying costs, and postage, please use single or one-line (1) spacing.

Page size. All pages should be of standard size (8 ½" x 11") to allow for photo-reproduction.

Large tables or figures. Foldout or photo-reduced tables or figures are not acceptable because they cannot be readily reproduced. Large tables and figures should be presented on consecutive 8 ½" x 11" pages, each page containing one portion of the larger chart.

Color. Printing shall be black on white. However, color images are acceptable where necessary.

Corporate identification. Do not include corporate identification on any page of the Final Report, except the title page.

Unit notation. Measurements in the Reports should be expressed in metric units. However, for the convenience of engineers and other scientists accustomed to using the British system, values may be given in British units as well in parentheses after the value in metric units. The expression of measurements in both systems is especially encouraged for engineering reports.

Section order. The Report should contain the following sections, in the order listed below:

Title page
Disclaimer
Acknowledgment (1)
Acknowledgment (2)
Table of Contents
List of Figures

List of Tables
Abstract
Executive Summary
Body of Report
References
List of inventions reported and copyrighted materials produced
Glossary of Terms, Abbreviations, and Symbols
Appendices

Page numbering. Beginning with the body of the Report, pages shall be numbered consecutively beginning with “1”, including all appendices and attachments. Pages preceding the body of the Report shall be numbered consecutively, in ascending order, with small Roman numerals.

Title page. The title page should include, at a minimum, the contract number, contract title, name of the principal investigator, contractor organization, date, and this statement: "Prepared for the California Air Resources Board and the California Environmental Protection Agency"

Disclaimer. A page dedicated to this statement must follow the Title Page:

The statements and conclusions in this Report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Acknowledgment (1). Only this section should contain acknowledgments of key personnel and organizations who were associated with the project. The last paragraph of the acknowledgments must read as follows:

> This Report was submitted in fulfillment of [CARB contract number and project title] by [contractor organization] under the [partial] sponsorship of the California Air Resources Board. Work was completed as of [date].

Acknowledgment (2). Health reports should include an acknowledgment to the late Dr. Friedman. Reports should include the following paragraph:

> This project is funded under the CARB’s Dr. William F. Friedman Health Research Program. During Dr. Friedman’s tenure on the Board, he played a major role in guiding CARB’s health research program. His commitment to the citizens of California was evident through his personal and professional interest in the Board’s health research, especially in studies related to children’s health. The Board is sincerely grateful for all of Dr. Friedman’s personal and professional contributions to the State of California.

Table of Contents. This should list all the sections, chapters, and appendices, together with their page numbers. Check for completeness and correct reference to pages in the Report.

List of Figures. This list is optional if there are fewer than five illustrations.

List of Tables. This list is optional if there are fewer than five tables.

3. Other Deliverables

Any other deliverables shall be provided in a mutually agreed upon format unless the deliverable format is already specified in Exhibit A.

EXHIBIT A2

KEY PERSONNEL

Last Name, First Name	Institutional Affiliation	Role on Project
Principal Investigator (PI):		
Noth, Elizabeth	UCB	Principal Investigator
Bradman, Asa	UCM	Co-Principal Investigator
Other Key Personnel:		
Castorina, Rosemary	UCB	Co-Investigator
Preble, Chelsea	UCB	Co-Investigator
Gunier, Robert	UCB	Statistical/GIS advising
Cisneros, Ricardo	UCM	Co-Investigator
Kumagi, Kazukiyo	CDPH	Co-Investigator/Laboratory
Wagner, Jeff	CDPH	Co-Investigator/Laboratory
Kirchstetter, Thomas	UCB	Advisor

EXHIBIT A3

AUTHORIZED REPRESENTATIVES & NOTICES

The following individuals are the authorized representatives for the State and the University under this Agreement. Any official Notices issued under the terms of this Agreement shall be addressed to the Authorized Official identified below, unless otherwise identified in the Agreement.

State Agency Contacts Agency Name: **CARB**	**University Contacts** University Name: **UCB**
Contract Project Manager (Technical) Name: Jeffery Williams Address: Research Division 1001 I Street, 5th Floor Sacramento, CA 95814 Telephone: (916) 322 7145 Fax: (916) 322-4357 Email: jeffery.williams@arb.ca.gov	***Principal Investigator (PI)*** Name: Elizabeth Noth, **Associate** ~~Assistant~~ Researcher Address: School of Public Health, University of California, Berkeley 2121 Berkeley Way, #5302 Berkeley, CA 94720-7360 Telephone: (510) 915-4907 Email: bnoth@berkeley.edu Designees to certify invoices under Section 14 ofExhibit C on behalf of PI: 1. **Jessica Luevano, Research Administrator, jessicaluevano@berkeley.edu** ~~Constanza Rodriguez, Tom Jones, Research Administrator, constanzar@berkeley.edu, tjonne_3@berkeley.edu~~
Authorized Official (contract officer) Name: Alice Kindarara, Branch Chief Address: Research Division 1001 I Street, 19th Floor Sacramento, CA 95814 ***Send notices to (if different):*** Name: Renee Carnes Address: Research Division 1001 I Street, 5th Floor Sacramento, CA 95814 Telephone: (916) 445-3366 Fax: (916) 322-4357 Email: renee.carnes@arb.ca.gov	***Authorized Official*** Name: Angela R. Ford, Associate Director Address: Sponsored Projects Office 1608 Fourth Street, Ste. 220, MC 5940 Berkeley, CA 94710 - 1749 Telephone: (510) 642-8117 Fax: (510) 643-7628 Email: spoawards@berkeley.edu ***Send notices to (if different):*** Name: Joyce Chun Diaz, Contract and GrantOfficer Address: Sponsored Projects Officer 1608 Fourth Street. Ste. 220 Berkeley, CA 94710-1749 Telephone: (510) 642-8109 Fax: (510) 642-8236 Email: joycechun@berkeley.edu

Administrative Contact	Administrative Contact
Name: Renee Carnes Address: Research Division 1001 I Street, 5th Floor Sacramento, CA 95814 Telephone: (916) 445-3366 Fax: (916) 322-4357 Email: renee.carnes@arb.ca.gov	Name: Joyce Chun Diaz, Contract and Grant Officer Address: Sponsored Projects Office University of California, Berkeley1608 Fourth Street, Suite 220 Berkeley, CA 94710-1749 Telephone: (510) 642-8109 Fax: (510) 642-8236 Email: joycechun@berkeley.edu
Financial Contact/Accounting	***Authorized Financial Contact/Invoicing***
Name: Accounts Payable Address: P.O. Box 1436 Sacramento, CA 95814 Email: AccountsPayable@arb.ca.gov **Send courtesy copy to Sarah Szepesi:** Fax: (916) 322-4357 Telephone: (916) 327-1256 Email: sarah.szepesi@arb.ca.gov	Name: Elizabeth D. Chavez, Interim Contracts & Grants Accounting Director Address: Contracts & Grants Accounting University of California, Berkeley 2195 Hearst Ave., Rm. 130 Berkeley, CA 94720-1103 Telephone: (510) 643-4246 Fax: (510) 643-7628 Email: CGAawards@berkeley.edu

EXHIBIT A4

USE OF PREEXISTING INTELLECTUAL PROPERTY & DATA

A. State: Preexisting Intellectual Property (IP)/Data to be provided to the University from the State or a third party for use in the performance in the Scope of Work.

☒ None or ☐ List:

B. University: Restrictions in Preexisting IP/Data included in Deliverables identified in Exhibit A1, Deliverables.

☒ None or ☐ List:

C. Anticipated restrictions on use of Project Data.

If the University PI anticipates that any of the Project Data generated during the performance of the Scope of Work will have a restriction on use (such as subject identifying information in a data set), then list all such anticipated restrictions below. If there are no restrictions anticipated in the Project Data, then check "none" in this section.

☐ None or ☒ List:

Owner	Description	Nature of restriction:
UCB	Global Positioning System coordinates of participant homes.	Considered identifying information by IRB. Cannot be shared with CARB.

EXHIBIT A5

RÉSUMÉ / BIOSKETCH

OMB No. 0925-0001 and 0925-0002 (Rev. 09/17 Approved Through 03/31/2020)

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Elizabeth M. Noth

eRA COMMONS USER NAME (credential, e.g., agency login): ELIZABETHNOTH

POSITION TITLE: Assistant Researcher

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
University of California, Berkeley	B.S.	05/1996	Conservation and Resource Studies
Boston University, School of Public Health	M.P.H.	01/2000	Environmental Health
University of California, Berkeley	PhD	05/2009	Environmental Health Sciences

A. Personal Statement

The focus of my research career has been assessing exposure for epidemiologic studies. During my doctoral work I was funded by both the CA Air Resources Board on the Fresno Asthmatic Children's Environment Study (FACES) and the Mickey Leland National Urban Air Toxics Research Center to investigate the spatial distribution of polycyclic aromatic hydrocarbons (PAHs) in urban air and in pine needles of trees in Fresno, California. During this research, I developed spatial air pollution models for 16 individual PAHs in air and 14 individual PAHs in pine needles. During my doctoral work, I also created individual daily exposure estimates for use in epidemiologic studies of childhood asthma. During my postdoctoral work to present, I have been able to expand this work into exposure studies related to birth outcomes, epigenetic changes, and immune function, also in Fresno, CA. During my postdoctoral training my field of study broadened to include occupational exposure assessment because of my concern for the very high concentrations that workers are exposed to from such air pollutants as particulate matter, polycyclic aromatic hydrocarbons, fluorides and more. Recently, I played a lead role in the Exposure Core of the NIEHS/EPA-funded Children's Environmental Health Center, the Children's Health and Air Pollution Study (CHAPS), in Fresno. Currently, I am one of three multiple PIs of the NIEHS-funded R24 Environmental Epidemiology Cohort (EEC) grant to extend follow-up of the CHAPS cohorts.

a. **Noth EM**, Hammond SK, Biging GS, Tager IB. A spatial-temporal regression model to predict daily outdoor residential PAH concentrations in an epidemiologic study in Fresno, CA. Atmospheric Environment 2011**;** 45, (11): 2394-2403; doi:10.1016/j.atmosenv.2011.02.014
b. **Noth EM**, Hammond SK, Biging GS, Tager IB. Mapping and modeling airborne urban phenanthrene distribution using vegetation biomonitoring. Atmospheric Environment 2013; 77: 518-524, doi: http://dx.doi.org/10.1016/j.atmosenv.2013.05.056.

c. **Noth EM**, Lurmann F, Northcross A, Perrino C, Vaughn D, Hammond SK. Spatial and Temporal Distribution of Polycyclic Aromatic Hydrocarbons and Elemental Carbon in Bakersfield, California. *Air Quality, Atmosphere & Health* 9(8): 899-908.
d. **Noth EM,** Lurmann F, Perrino C, Vaughn D, Minor HA, Hammond SK. Decrease in Ambient Polycyclic Aromatic Hydrocarbon Concentrations in California's San Joaquin Valley 2000-2019. Atmospheric Environment *in press*.

B. Positions and Honors

Positions and Employment

1994-1996 Teaching Assistant, Vista Community College, Berkeley, CA
1996-1997 Research Assistant, United States Department of Agriculture, Albany, CA
1997-1998 Research Assistant, Public Health Institute, Emeryville, CA
1998 GIS Consultant, Town of Needham Board of Health, Needham, MA
1999 Intern as Environmental Scientist, Menzie Cura & Associates, Chelmsford, MA
2000 Data Manager, State University of New York, Stony Brook, NY
2000-2009 Graduate Student Researcher in Environmental Health Sciences, University of California, Berkeley, CA
2001-2003 Research Scientist on contract to California Environmental Health Investigations Branch, Impact Assessment, Oakland, CA
2009-2013 Post-doctoral Scholar, Environmental Health Sciences, School of Public Health, University of California, Berkeley
2013-present Assistant Researcher, Environmental Health Sciences, School of Public Health, University of California, Berkeley

Other Experience and Professional Memberships

2008-present Member, International Society of Exposure Assessment

Honors

1998-2000 Boston University School of Public Health, Dean's Scholarship
2001-2002 University of California, Berkeley, Regent's Fellowship
2004-2005 Marian Rennie Benson Fellowship, University of Calfornia Berkeley Public Health Alumni Association.

C. Contributions to Science

1. Traffic-Related Air Pollution and Childhood Asthma: While my doctoral research focused primarily on developing the spatial-temporal concentration model for elemental carbon and polycyclic aromatic hydrocarbons, I also worked on translating those concentrations into exposures for children in the Fresno Asthmatic Children's Environment Study. My main contribution to this was the novel spatial-temporal mixed models using land regression, but I also worked with epidemiologists and other exposure scientists to determine the appropriate time windows for air pollution exposure and various asthma-related short-term health outcomes.

a. **Noth EM**, Hammond SK, Biging GS, Lurmann F, Tager IB. Disentangling spatial and temporal variation in exposure assessment: A case study. Epidemiology 17 (6): S474 Suppl. S, Nov 2006. doi: 10.1097/00001648-200611001-01275
b. **Noth EM**, Hammond SK, Biging GS, Tager IB. Characterizing the spatial distribution of ambient PAHs using vegetation biomonitoring. Epidemiology 19 (6): S330-S331 Suppl. S, Nov 2008.

c. Hammond SK, **Noth EM**, Tager IB, Biging GS, Gale S, Mann JK. Short- and Long-Term Respiratory Effects of Exposure to Traffic PAHs in a Cohort of Children with Asthma. Mickey Leland Urban Air Toxics Research Center: 2010.

d. Gale SL, **Noth EM,** Mann J, Balmes J, Hammond SK, Tager IB. Polycyclic aromatic hydrocarbon exposure and wheeze in a cohort of children with asthma in Fresno, CA. Journal of Exposure Science and Environmental Epidemiology 2012: 22(4):386-92; doi:10.1038/jes.2012.29, PMCID: PMC4219412.

2. Polycyclic aromatic hydrocarbon exposure assessment for birth outcomes, epigenetics, and immune function. In addition to working on estimating relatively short-term exposures for children with asthma, I have also worked with immunologists to estimate annual exposures related to subclinical immunologic outcomes. This work is particularly groundbreaking because there is very little available to evaluate which windows of exposure may be important for immunologic outcomes in children. Similarly, polycyclic aromatic hydrocarbon exposures *in utero* are not fully understood and offer an opportunity to expand our knowledge around preterm birth.

a. Nadeau K, McDonald-Hyman C, **Noth EM**, Pratt B, Hammond SK, Balmes J, Tager IB. Ambient air pollution impairs regulatory T-cell function in asthma. Journal of Allergy and Clinical Immunology 2010; 126: 845-852. doi: 10.1016/j.jaci.2010.08.008.
b. Walker AI, Kohli A, Syed A, Eisen EA, **Noth EM**, Pratt B, Hammond SK, Nadeau K. Exposure to Polycyclic Aromatic Hydrocarbons Is Associated with Higher Levels of Total IgE, Decreased Function of T Regulatory Cells and an Increase of Asthma Occurrence in Children. Journal of Allergy and Clinical Immunology 2013; 131(2): AB54 Suppl. S.
c. Hew K, Walker AI, Kohli A, Garcia M, Syed A, McDonald-Hyman C, **Noth EM**, Mann J, Pratt B, Balmes J, Hammond SK, Eisen E, Nadeau K. Childhood exposure to ambient polycyclic aromatic hydrocarbons is linked to epigenetic modifications and impaired systemic immunity in T cells. Clinical & Experimental Allergy 2015; 45(1):238-48. doi: 10.1111/cea.12377, PMCID: PMC4396982.
d. Padula AM, **Noth EM**, Hammond SK, Lurmann FW, Wang W, Tager IB, Shaw GM. Exposure to Polycyclic Aromatic Hydrocarbons During Pregnancy and Preterm Birth. Environmental Research 2014: 135:221-6. doi: 10.1016/j.envres.2014.09.014, PMCID: PMC4262545.

3. Occupational Exposures and Epidemiology: Cardiac morbidity and mortality has been shown to be associated with high environmental settings, but has not been fully evaluated in an industrial setting when concentrations of particulate matter are often magnitudes higher than those experienced in an environmental setting. My work in estimating exposures of particulate matter in two sizes (total and fine) for aluminum workers has resulted in the ability of epidemiologists to look at the impact of these exposures on worker health. I have also contributed to evaluating the particle size distribution of particulate matter in different jobs within aluminum manufacturing.

a. **Noth EM**, Dixon-Ernst C, Liu S, Cantley L, Tessier-Sherman B, Eisen EA, Cullen MR, Hammond SK. Development of a job-exposure matrix for exposure to total and fine particulate matter in the aluminum industry. Journal of Exposure Science and Environmental Epidemiology 2014; 24(1): 89-99. doi: 10.1038/jes.2013.53, PMCID: PMC4067135
b. **Noth EM**, Liu S, Cullen MR, Eisen EA, Hammond SK. Approaches to developing exposure estimates that reflect temporal trends in total particulate matter in aluminium smelters. Occupational and Environmental Medicine 2014;71 Suppl 1:A14. doi: 10.1136/oemed-2014-102362.43.
c. Liu S, **Noth EM**, Dixon-Ernst C, Eisen EA, Cullen MR, Hammond KH. Particle Size Distribution in Aluminum Manufacturing Facilities. Environment and Pollution 2014: 3(4):79-88, doi: 10.5539/ep.v3n4p79
d. Navarro K, Cisneros R, **Noth EM**, Balmes JR, Hammond SK (2017). "Occupational Exposure to Polycyclic Aromatic Hydrocarbon of Wildland Firefighters at Prescribed and Wildland Fires." *Environmental Science & Technology* 51(11): 6461–6469

Complete List of Published Work in MyBibliography:
http://www.ncbi.nlm.nih.gov/sites/myncbi/elizabeth.noth.1/bibliography/47913915/public/?sort=date&direction=ascending

NAME: Asa Bradman

POSITION TITLE: Associate Researcher, Division of Epidemiology, Adjunct Associate Professor, Environmental Health Sciences

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE	Completion Date	FIELD OF STUDY
University of California, Berkeley	B.Sc.	1984	Cons. and Res. Studies
University of California, Berkeley	M.Sc.	1989	Energy and Resources
University of California, Berkeley	Ph.D.	1997	Environmental Health Sciences

A. Personal Statement

I have conducted research over the last 30 years examining occupational and environmental exposures and health effects in pregnant women and children. My work has focused on pesticides, flame retardants, metals, emerging pollutants such as phthalates, VOCs, indoor and outdoor air quality, and other contaminants. I have published extensively on environmental exposures and health outcomes in children. I co-founded and am the Associate Director for Exposure of the Center for Environmental Research and Children's Health (CERCH) at UC Berkeley, Director of the Center's Exposure Assessment Study, and Co-Director of the CHAMACOS Laboratory Core. I also work to improve environmental quality in California childcare facilities and have conducted extensive indoor and outdoor air quality monitoring for VOCs, SVOCs, and particles in these environments. I work extensively on community outreach and education and interface with other scientists, state and federal agencies, policy makers, and industry. I participate on numerous local and national advisory boards and am past member and Chair the California Biomonitoring Scientific Guidance Panel (appointed by Governors Schwarzenegger (2007) and Brown (2013)). I teach Introduction to Environmental Health for a large undergraduate class and frequently lecture to graduate students courses on a variety of environmental health topics. I also mentor and advise undergraduate, master's, and PhD students. For this project, I will provide overall direction and oversight including community engagement; development of study designs to assess exposures to air pollutants; execution of planned research, including development of study tools and instruments, human subject approval, sampling and analytical procedures, interfacing with laboratories; data management and analyses, and overall quality assurance and control. I will also provide progress reports to the funding agency, track spending, and participate in writing interim and final project reports and publications.

Positions and Honors

1984-1987 Field Scientist: Rocky Mountain Biological Laboratory and Lawrence Berkeley Laboratory; Crested Butte, Colorado and Berkeley, California.

1988-1989 Research Specialist I: Impact Assessment Inc., Contractor to Environmental Health Investigations Branch, California Department of Health Services, Berkeley, California.

1989-1990 Analyst: National Acid Precipitation Assessment Program (NAPAP), Berkeley, California.

993-1994 Graduate Student Fellow: Department of Environment Health Sciences, School ofPublic Health, UC Berkeley.

1994-1994 Research Specialist II: Impact Assessment Inc., contractor to Childhood Lead Poisoning Prevention Branch, California Department of Health Services, Emeryville, California.

1994-1997 Research Scientist II: Childhood Lead Poisoning Prevention Branch, California Department of Health Services, Emeryville, California.

1998-Present Associate Director, Center for Environmental Research and Children's Health (CERCH), School of Public Health, University of California, Berkeley.

2015-Present Associate Adj. Professor, Environmental Health Sciences, School of Public Health, University of California, Berkeley

Other Experience and Professional Memberships

1994 Exposure Assessment Workgroup, California Comparative Risk Project.

2002 NIEHS external rev. committee, UC Davis NIEHS Core Env. Health Science Ctr.

2002-2004 Exposures to Chemical Agents Working Group, National Children's Study

2002-2003 Advisory Board, California Biomonitoring Project, CA Dept of Health Services

2006-2015 Scientific Advisory Council, National Center for Healthy Homes

2012-2014 Biomonitoring Expert Workgroup, US EPA Pesticide Program Dialogue Committee; 21st Century Toxicology/New Integrated Testing Strategies Workgroup.

2007-2017 Scientific Guidance Panel, CA Biomonitoring (apt. Govs. Schwarzenegger and Brown) 2017-Present National Organic Standards Board, US Department of Agriculture

Honors

1992 Fitzgerald Scholarship, Graduate Division, U.C. Berkeley.

1993-1994 Dowdle Award, School of Public Health, University of California, Berkeley.

1996 Switzer Env. Fellowship, 1996-1997, Switzer Foundation, San Francisco, CA

1996 Regents Fellow, Spring 1996, Graduate Division, UC Berkeley

2001 Chancellor Berdahl award for Community/University Partnerships, UC Berkeley.

2006 Switzer Leadership Grant Mentor, 2005-2006, Switzer Foundation, San Francisco, CA 2008 US EPA Children's Environmental Health Excellence Award, with US EPA NERL 2012 IPM Innovators Award, Ca. Department of Pesticide Regulation.

B. Contributions to Science

1. Historically, studies examining environmental exposure to young children have focused on home environments. Yet, many children spend a large portion of their waking hours in child care. I have conducted pioneering research (see EHP feature article: http://ehp.niehs.nih.gov/121-a160/) examining environmental exposures in early child care facilities, including flame retardants, formaldehyde, acetaldehyde, VOCs, and phthalates. Each of these chemicals are of particular interest as they may be associated with adverse developmental health risks, and can be found at levels that exceed health based reference values in some child care settings. This research is supporting nationwide interest in exposure in childcare and the development of policies to reduce chemical exposures. I am currently examining the potential impact of volatile organic compound emissions from art markers in children's indoor air environments.

   a. **Bradman**, A., Castorina, R., Gaspar, F., Nishioka, M., Colón, M., Weathers, W., Egeghy, P.P., Maddalena, R., Williams, J., Jenkins, P.L., McKone, T.E. (2014) Flame retardant exposures in California early childhood education environments. *Chemosphere*: 48(13):7593-601. PMID: 24835158.
   b. **Bradman** A., Gaspar, F., Castorina, R., Williams, J., Hoang, T., Jenkins, P.L., McKone, T.E., Maddalena, R. (2015) Formaldehyde and Acetaldehyde Exposures in California Early Childhood Education Environments. *Indoor Air.* PMID: 26804044.
   c. Gaspar, F.W., Castorina, R., Maddalena, R.L., Nishioka, M.G., McKone, T.E., **Bradman**, A. (2014) Phthalate exposure and risk assessment in California child care facilities. *Environmental Science & Technology*: 48(13):7593-601. PMID: 24870214.

d. Tysman, M., Castorina, R., **Bradman**, A., Hoover, S., Iyer, S., Russell, M., Maddalena, R. (2016) Volatile Organic Compound Emissions from Art Markers used in Preschool, School and Home Environments. *International Journal of Environmental Analytical Chemistry,* 96:13,12471263.
e. Gaspar FW, Maddalena R, Williams J, Castorina R, Wang ZM, Kumagai K, McKone TE, Bradman A. (2017). Ultrafine, fine, and black carbon particle concentrations in California child-care facilities. Indoor Air. 2018 Jan;28(1):102-111. doi: 10.1111/ina.12408. Epub 2017 Sep 11.

2. Pesticide exposure continues to be a focus area for scientists and policymakers, as they understand the potential health risk it presents to sensitive populations, such as pregnant women and children. I have worked extensively to characterize pre- and postnatal exposures to a number of different agents, have determined factors that influence exposure, modeled the cumulative health risks of organophosphate pesticide exposure, and evaluated statistical issues on the use of urinary metabolites as exposure biomarkers for use in health- outcome studies. This work has resulted in a numerous papers published in peer reviewed journals, and has added to the body of knowledge about human exposure to pesticides and health outcomes.

a. **Bradman** A, Kogut K, Eisen EA, Jewell NP, Quirós-Alcalá L, Castorina R, Chevrier J, Holland NT, Barr DB, Kavanagh-Baird G, Eskenazi B. Variability of organophosphorous pesticide metabolite levels
in spot and 24-hr urine samples collected from young children during 1 week. Environ Health Perspect. 2013 Jan;121(1):118-24. doi: 10.1289/ehp.1104808. Epub 2012 Oct 9. PMCID: PMC3553429
b. Eric S Coker, Robert Gunier, **Asa Bradman**, Kim Harley, Katherine Kogut, John Molitor, Brenda Eskenazi. Association between Pesticide Profiles Used on Agricultural Fields near Maternal Residences during Pregnancy and IQ at Age 7 Years. *International Journal of Environmental Research and Public Health* 2017, *14*, 506. PMCID: PMC5451957
c. **Bradman** A, Eskenazi B, Barr DB, Bravo R, Castorina R, Chevrier J, Kogut K, Harnly ME, McKone TE. Organophosphate urinary metabolite levels during pregnancy and after delivery in women living in an agricultural community. Environ Health Perspect. 2005 Dec;113(12):1802-7. PMCID: PMC1314925
d. **Bradman** A, Castorina R, Barr DB, Chevrier J, Harnly ME, Eisen EA, McKone TE, Harley K, Holland N, Eskenazi B. Determinants of organophosphorus pesticide urinary metabolite levels in young children living in an agricultural community. Int J Environ Res Public Health. 2011 Apr;8(4):1061-83. doi: 10.3390/ijerph8041061. Epub 2011 Apr 8. PMCID: PMC3118878

Maternal and child exposure to flame retardants and other endocrine disrupting persistent pollutants is an important public health issue worldwide, and especially in California where unique flammability standards resulted in high chemical flame retardants in furniture. I have lead extensive research examining exposure to flame retardants, including studies on organophosphate flame retardant (OPFR) levels in air and dust in homes and child care, analyzing predictors of polybrominated biphenyl ether (PBDE) flame retardant exposure in pregnant women and young children, and compared CHAMACOS child PBDE levels in serum with children living in communities within Mexico from which the majority of CHAMACOS mothers had originated. These exposure studies have supported health outcome research lead by other Investigators in our group. I have also published pioneering studies examining flame retardant exposures in child care facilities.

e. Castorina, R. **Bradman**, A., Sjödin A., Fenster L., Jones R.S., Harley K., Eisen E.A., Eskenazi B. (2011) Determinants of Serum Polybrominated Diphenyl Ether (PBDE) Levels among Pregnant Women in the CHAMACOS Cohort. *Environmental Science & Technology* 45(15):6553-6560. PMCID: PMC3285470.

f. Eskenazi, B., Fenster, L., Castorina, R., Marks, A., Sjödin, A., Goldman Rosas, L., Holland, N., Garcia
Guerra, A., Lopez Carillo, L., **Bradman**, A. (2011) A Comparison of PBDE serum concentrations in Mexican and Mexican-American children living in California. *Environmental Health Perspectives* 119(10):1442-1448. PMCID: PMC3230428.
g. **Bradman**, A., Castorina, R. Sjödin A., Fenster L., Jones R.S., Harley K.G., Chevrier J., Holland, N.T., Eskenazi B. (2012) Factors Associated with Serum Polybrominated Diphenyl Ether (PBDE) Levels among School-Age Children in the CHAMACOS Cohort. *Environmental Science & Technology* 46(13):7373-7381. PMCID: PMC3406184.
h. **Bradman**, A., Castorina, R., Gaspar, F., Nishioka, M., Colón, M., Weathers, W., Egeghy, P.P., Maddalena, R., Williams, J., Jenkins, P.L., McKone, T.E. (2014) Flame retardant exposures in California early childhood education environments. *Chemosphere*: 48(13):7593-601. PMID: 24835158.

Complete List of Published Work in My Bibliography:
http://www.ncbi.nlm.nih.gov/sites/myncbi/1tCyqnwl_D1QR/bibliography/48569835/public/?sort=date&direction=ascending

NAME: **Rosemary Castorina**

Position Title: Project Scientist, Division of Epidemiology

EDUCATION/ TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
University of California, Santa Cruz	B.A.	1988	Politics
University of California, Berkeley	M.P.H	1998	Environmental Health Sciences
University of California, Berkeley	Ph.D.	2003	Environmental Health Sciences

A. Personal Statement

I am a Project Scientist in the School of Public Health at the University of California, Berkeley. I have been part of the Center for Environmental Research and Children's Health (CERCH) since its inception in 1999, and have worked with PI Dr. Asa Bradman for over 20 years. I have published several first-author, peer-reviewed journal articles on brominated flame retardant exposure in pregnant women, cumulative organophosphate (OP) pesticide dose modeling, current-use pesticide urinary metabolites, and risk extrapolation based upon EPA benchmark doses. My research has also focused on assessing chemical exposures in early childcare facilities, emissions from children's art markers, organophosphate flame retardant (OPFR) levels measured in urine and house dust collected from pregnant women, and evaluating associations between in utero OPFR exposure and cognitive or behavioral performance (attention) in school-age children. Recently, I have examined environmental exposures in California early childcare facilities, including flame retardants, formaldehyde, acetaldehyde, VOCs, and phthalates. I have also coordinated OEHHA-funded research studies examining diesel exhaust exposure among families living in the East Bay, and exposure to synthetic turf fields among soccer players in California. For this project, I will work closely with Dr. Bradman and the Graduate Student Researcher on the development and execution of studies examining community exposures to air pollutants. I will help design the planned studies, develop study instruments and sampling protocols, interface with human subject committees, coordinate field work, work with our data management team, and participate in data analyses and preparing final reports and publications.

B. Positions and Honors

Positions and Employment

1996-1997 Graduate Student Assistant: California Environmental Protection Agency, Office of Environmental Health Hazard Assessment. Berkeley, CA.

1998 Graduate Student Instructor: Division of Environmental Health Sciences, U.C. Berkeley.

2001 Graduate Student Instructor: Division of Environmental Health Sciences, U.C. Berkeley. 2001-2002 Graduate Student Fellow: Division of Environment Health Sciences, School of Public Health, University of California, Berkeley

1998-2003 Graduate Student Researcher: Center for Environmental Research and Children's Health (CERCH), School of Public Health, University of California, Berkeley.
2003-2004 Data Analyst: Seveso Women's Health Study, School of Public Health, University of California, Berkeley.
2003-2011 Staff Research Associate III: Center for Children's Environmental Health Research, School of Public Health, University of California, Berkeley.
2011-present Project Scientist IV: Center for Environmental Research and Children's Health (CERCH), School of Public Health, University of California, Berkeley

Honors:

US Public Health Service Traineeship (1995-96)
UC Toxic Substances Research and Teaching Program Traineeship (1998-00)
UC Public Health Alumni Association Scholarship (2000-01)
UC Berkeley Fellowship for Graduate Study (2001-02)
Patricia H. Woods Scholarship (2002-03)
Editor's Choice Award as *Environmental Science &Technology's* Best Paper of 2009, Runner-up.

C. Contributions to Science

1. Pesticide exposure continues to be a focus area for scientists and policy makers as they work to understand the potential health risks it presents to sensitive populations, such as pregnant women and children. I have worked extensively to characterize pre- and postnatal exposures to a number of different agents, have determined factors that influence exposure, and modeled the cumulative health risks of organophosphate pesticide exposure. This work has resulted in numerous papers published in peer reviewed journals, and has added to the body of knowledge about human exposure to pesticides.

   a. Castorina, R., Bradman, A., Fenster, L., Barr, D.B., Bravo, R., Vedar M., Harnly, M.E., McKone, T.E., Eisen, E.A., Eskenazi, B. (2010) Comparison of Current-Use Pesticide and Other Toxicant Urinary Metabolite Levels among Pregnant Women in the CHAMACOS Cohort and NHANES. *Environmental Health Perspectives* 118(6):856-863. PMCID: PMC2898864
   b. Castorina, R., Bradman, A., McKone, T., Barr D.B., Harnly M.E., Eskenazi B. (2003) Cumulative Organophosphate Pesticide Exposure and Risk Assessment among Pregnant Women Living in an Agricultural Community: A Case Study from the CHAMACOS Cohort. *Environmental Health Perspectives* 111(13): 1640-1648. PMCID: PMC1241687
   c. McKone, T.E., Castorina, R., Harnly, M.E., Kuwabara, Y., Eskenazi, B., Bradman, A. (2007) Merging models and biomonitoring data to characterize sources and pathways of human exposure to organophosphorus pesticides in the Salinas Valley of California. *Environmental Science & Technology* 1:41(9):3233-3240.
   d. Payne-Sturges, D., Cohen, J., Castorina, R., Axelrad, D.A., Woodruff, T.J. (2009) Evaluating Cumulative Organophosphorus Pesticide Body Burden of Children: A National Case Study. *Environmental Science & Technology* 43(20):7924-7930. PMCID: PMC2796428

2. I have conducted extensive research on exposures and health effects due to flame retardants. I have summarized organophosphate flame retardant (OPFR) levels measured in air and dust, analyzed predictors of polybrominated biphenyl ether (PBDE) flame retardant exposure in pregnant women, and examined the association between prenatal OPFR exposure and neurodevelopment in school-aged children.

a. Castorina, R., Bradman, A., Stapleton, H.M., Butt, C., Avery, D., Harley, K.G., Gunier, R.B., Holland, N., Eskenazi, B. (2017) Current-use flame retardants: Maternal exposure and neurodevelopment in children of the CHAMACOS cohort. Chemosphere 189:574-580. PMCID: PMC6353563

b. Flame retardants and their metabolites in the homes and urine of pregnant women residing in California
(the CHAMACOS cohort). Castorina, R., Butt, C., Stapleton, H.M., Avery, D., Harley, K.G., Holland, N.,
Eskenazi, B., Bradman, A. (2017) Chemosphere. 179:159-166. PMCID: PMC5491392

c. Castorina, R., Bradman, A., Sjödin A., Fenster L., Jones R.S., Harley K., Eisen E.A., Eskenazi B. (2011) Determinants of Serum Polybrominated Diphenyl Ether (PBDE) Levels among Pregnant Women PMC3285470

d. Bradman, A., Castorina, R. Sjödin A., Fenster L., Jones R.S., Harley K.G., Chevrier J., Holland, N.T., Eskenazi B. (2012) Factors Associated with Serum Polybrominated Diphenyl Ether (PBDE) Levels among School-Age Children in the CHAMACOS Cohort. *Environmental Science & Technology* 46(13):7373-7381. PMCID: PMC3406184

3. In addition, I have conducted pioneering research examining environmental exposures in early child care facilities, including flame retardants, formaldehyde, acetaldehyde, VOCs, and phthalates. Each of these chemicals are of particular interest as they may be associated with adverse developmental health risks, and can be found at levels that exceed health based reference values in some child care settings. I have also examined the potential impact of volatile organic compound emissions from art markers in children's indoor air environments.

a. Bradman, A., Castorina, R., Gaspar, F., Nishioka, M., Colón, M., Weathers, W., Egeghy, P.P., Maddalena, R., Williams, J., Jenkins, P.L., McKone, T.E. (2014) Flame retardant exposures in California early childhood education environments. *Chemosphere*: 48(13):7593-601.

b. Bradman A., Gaspar, F., Castorina, R., Williams, J., Hoang, T., Jenkins, P.L., McKone, T.E., Maddalena, R. (2017) Formaldehyde and Acetaldehyde Exposures in California Early Childhood Education Environments. *Indoor Air:* 27(1):104-113.

c. Gaspar, F.W., Castorina, R., Maddalena, R.L., Nishioka, M.G., McKone, T.E., Bradman, A. (2014) Phthalate exposure and risk assessment in California child care facilities. *Environmental Science & Technology*: 48(13):7593-601.

d. Gaspar FW, Maddalena R, Williams J, Castorina R, Wang ZM, Kumagai K, McKone TE, Bradman A. (2017). Ultrafine, fine, and black carbon particle concentrations in California child-care facilities. Indoor Air. 2018 Jan;28(1):102-111. doi: 10.1111/ina.12408. Epub 2017 Sep 11.

e. Castorina, R., Tysman, M., Bradman, A., Hoover, S., Iyer, S., Russell, M., Maddalena, R. (2016) Volatile Organic Compound Emissions from Art Markers used in Preschool, School and Home Environments. *International Journal of Environmental Analytical Chemistry:* 96(13): 1247-1263.

Complete List of Published Work in My Bibliography:

http://www.ncbi.nlm.nih.gov/sites/myncbi/1vUnycyKmz858/bibliography/41529971/public/?sort=date&direction=ascending

Biographical Sketch: Thomas W. Kirchstetter

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655 Davis Hall, Berkeley, California 94720 • Phone: 510-908-1237 • Email:
twkirchstetter@berkeley.edu

(a) Professional Preparation

Alexander Hollaender Distinguished Postdoctoral Fellow, LBNL, 1998 –
2000 Ph.D. Environmental Engineering, University of California at
Berkeley, 1998
M.S. Environmental Engineering, University of California at Berkeley, 1994
B.S. Atmospheric Science and Mathematics, State University of New York at Albany, 1991

(b) Current Appointments

Energy Technologies Area, Lawrence Berkeley National Laboratory, Senior Scientist, 2018 – present
Scientific Division Director, Energy Analysis and Environmental Impacts, 2017 – present
Department Head, Sustainable Energy and Environmental Systems, 2015 – present
Group Leader, Sustainable Energy Systems, 2015 – 2017
Staff Scientist, 2000 – 2018

Dept of Civil & Environmental Engineering, University of California Berkeley
Adjunct Professor, 2018 – present
Associate Adjunct Professor, 2011 – 2018
Lecturer, 2005 – 2011

Research interests*:* Air pollution science & technology: pollutant emissions and controls with a focus on the transportation sector; characterization and environmental impacts of carbonaceous aerosols; low-cost sensor development; community air monitoring • Municipal solid waste-to-energy; evaluation of benefits and barriers to commercial scale-up • Mobility: energy impacts of emerging megatrends

Course instruction:
Air Quality Engineering: Air pollution and climate change; sources and controls; atmospheric transport, deposition, and chemical transformations; atmospheric aerosol dynamics and control techniques (Spring 2017 and 2016 - with RA Harley and WW Nazaroff)
Water and Air Quality Laboratory: Contaminant transport and transformation, reactor models, water treatment, and air quality (Fall 2019, 2018, 2017; Spring 2016, 2015, 2014)
Environmental Engineering: Contaminant transport and transformation, reactor models, water treatment, and air quality (Fall 2012; Spring 2011; Spring 2008)
Environmental Engineering and Science: Population growth, energy consumption, air pollution, climate change, and water treatment (Spring 2005)

(c) Selected Professional Service and Synergistic Activities

Member, SMART Mobility Steering Committee, Vehicle Technologies Office, DOE, 2018 – present Editor, Aerosol Science and Technology Journal, 2013 – 2018

Organizer, International Conference on Carbonaceous Particles in the Atmosphere, 2000 – present

Contributor, EPA's Integrated Science Assessment for particulate matter welfare effects – 2016

Editor, Journal of Atmospheric Chemistry and Physics, 2006 – 2013

Member, Distinguished Lecture Series Committee, Lawrence Berkeley National Lab, 2011 – 2013

TW Kirchstetter, Mar 2020

(g) Peer-Reviewed Journal Publications, selected from full list of 79

79. Preble, CV; Harley, RA; Kirchstetter, TW (2019) Control Technology-Driven Changes to In-Use
Heavy-Duty Diesel Truck Emissions of Nitrogenous Species and Related Environmental Impacts, *Environ. Sci. Technol.*, doi:10.1021/acs.est.9b04763

78. Caubel, JJ; Cados, TE; Prevle, CV; Kirchstetter, TW (2019) Distributed Network of 100 Black Carbon Sensors for 100 Days of Air Quality Monitoring in West Oakland, California, *Environ. Sci. Technol.*, doi:10.1021/acs.est.9b00282

77. Sun, T; Liu, L; Flanner, MG; Kirchstetter, TW; Jiao, C; Preble, CV; Chang, WL; Bond, TC (2019) Constraining a Historical Black Carbon Emission Inventory of the United States for 1960-2000, *J. Geophy. Res. Atmos.,* doi:10.1029/2018JD030201

76. Browne, E; Zhang, X; Franklin, J; Ridley, K; Kirchstetter, TW; Wilson, K; Cappa, C; Kroll, J (2019)
Effect of heterogeneous oxidative aging on light absorption by biomass-burning organic aerosol, *Aerosol Sci. Technol.*, 53:6, 663-674, doi:10.1080/02786826.2019.1599321

75. Satchwell, AJ; Scown, CD; Smith, SJ; Amirebrahimi, J; Jin, L; Kirchstetter, TW; Brown, NJ; Preble, CV (2018) Accelerating the Deployment of Anaerobic Digestion to Meet Zero Waste Goals, *Environ. Sci. Technol.*, doi: 10.1021/acs.est.8b04481

74. Preble, CV; Cados, TE; Harley, RA; Kirchstetter, TW (2018) In-use performance and durability of particle filters on heavy-duty diesel trucks, *Environ. Sci. Technol.*, doi: 10.1021/acs.est.8b02977

73. Caubel, JJ; Cados, TE; Kirchstetter, TW (2018) A New Black Carbon Sensor for Dense Air Quality Monitoring Networks, *Senosrs*, *18*, 738

72. Apte, JS; Messier, KP; Gani, S; Brauer, M; Kirchstetter, TW; Lunden, MM; Marshall, JD; Portier,
CJ; Vermeulen, RCH; Hamburg, SP (2017) High-resolution air pollution mapping with Google Street View cars: exploiting big data, *Environ. Sci. Technol.*, doi: 10.1021/acs.est.7b00891

71. Kirchstetter, TW; Preble, CV; Hadley, OL; Bond, TC; Apte, JS (2017) Large reductions in urban black carbon concentrations in the United States between 1965 and 2000, Atmos. Environ., 151, 17-23, doi:10.1016/j.atmosenv 2016.11.001

70. Berdahl P, Chen SS, Destaillats H, Kirchstetter TW, Levinson RM, Zalich MA (2016) Fluorescent cooling of objects exposed to sunlight – The ruby example. Solar Energy Materials & Solar Cells, doi:10.1016/j.solmat.2016.05.058

69. Sleiman, M; Chen, S; Gilbert, HE; Kirchstetter, TW; Berdahl, P, et al (2015) Soiling of building envelope surfaces and its effect on solar reflectance - Part III: Interlaboratory study of an accelerated aging method for roofing materials, SOLMAT, 143, 581-590, doi:10.1016/j.solmat.2015.07.031

68. Preble, CV, Dallmann, TR; Kreisberg, NM; Hering, SV; Harley, RA; Kirchstetter, TW (2015) Effects of particle filters and selective catalytic reduction on heavy-duty diesel drayage truck emissions at the Port of Oakland, *Environ. Sci. Technol*., doi:10.1021/acs.est.5b01117

67. Tang, NW; Apte, JS; Martien, PT; Kirchstetter, TW (2015) Measurement of black carbon emissions from in-use diesel-electric passenger locomotives in California, *Atmos. Environ., 115*, 295-303, doi:10.1016/j.atmosenv.2015.05.001

66. Browne, EC; Franklin, JP; Canagaratna, MR; Massoli, P; Kirchstetter, TW; Worsnop, DR; Wilson, KR; Kroll, JH (2015) Changes to the Chemical Composition of Soot from Heterogeneous Oxidation Reactions, *J. Physical Chem. A, 119,* 1154-1163, doi: 10.1021/jp511507d.

65. Canagaratna, MR; Massoli, P; Browne, EC; Franklin, JP; Wilson, KR; Onasch, TB; Kirchstetter, TW;
Fortner, EC; Kolb, CE; Jayne, JT; Kroll, JH; Worsnop, DR (2015) Chemical Compositions of Black Carbon Particle Cores and Coatings via Soot Particle Aerosol Mass Spectrometry with Photoionization and Electron Ionization, *J. Physical Chem. A, 119,* 4589-4599, doi:10.1021/jp510711u.

Chelsea Preble
Postdoctoral Researcher
Department of Civil and Environmental Engineering | University of California, Berkeley
cvpreble@berkeley.edu | (909) 489-8836

EDUCATION

Ph.D. Civil and Environmental Engineering, May 2017 (GPA 3.8)
University of California, Berkeley
Dissertation: Effects of Advanced After-Treatment Control Technologies on Heavy-Duty Diesel Truck Emissions

M.S. Civil and Environmental Engineering, December 2013 (GPA 3.6)
University of California, Berkeley

B.S. Environmental Sciences, May 2010 (GPA 3.9)
University of California, Berkeley
Senior Thesis: A Comparison of Pollutant Emissions from a Traditional and an Improved Cookstove

RECENT RESEARCH EXPERIENCE

Postdoctoral Researcher, UC Berkeley — June 2017–Present

- Studied the effects of advanced after-treatment control technologies on emissions by onroad heavy-duty diesel trucks at the Caldecott Tunnel
- Created a community network of 100 low-cost black carbon sensors that operated outside of homes and businesses in West Oakland, CA for a period of 100 days
- Characterized greenhouse gas, criteria air pollutant, and odorous pollutant emissions from the dry anaerobic digestion of organic municipal solid waste at a facility in San Jose, CA and from the composting of the resultant material at a facility in Gilroy, CA
- Supporting work to evaluate high-, mid-, and low-cost sensors and develop an automated system to identify high-emitting in-use heavy-duty diesel trucks
- Quantifying in-use black carbon and nitrogen oxide emission rates for ferries and excursion vessels operating in the San Francisco Bay
- Mentoring undergraduate and graduate students working on these studies

Graduate Student Researcher, UC Berkeley — August 2012–May 2017

- Evaluated the particle- and gas-phase emissions by on-road heavy-duty diesel trucks, including field measurements and data collection at the San Francisco Bay Area's Port of Oakland and Caldecott Tunnel

PUBLICATIONS

Preble, CV; Harley, RA; Kirchstetter, TW (2019) Control technology-driven changes to in-use heavy-duty diesel truck emissions of nitrogenous species and related environmental impacts. *Envir. Sci. Tech.*, 53, 14568–14576. DOI: 10.1021/acs.est.9b04763.

Caubel, JJ; Cados, TE; **Preble, CV**; Kirchstetter, TW. (2019) A distributed network of 100 black carbon sensors for 100 days of air quality monitoring in West Oakland, California. *Envir. Sci. Tech.*, 53, 7564–7573. DOI: 10.1021/acs.est.9b00282.

Sun, T; Liu, L; Flanner, MG; Kirchstetter, TW; Jiao, C; **Preble, CV**; Chang, WL; Bond, TC. (2019) Constraining a historical black carbon emission inventory of the United States for 1960– 2000. *J. Geophys. Res.–Atmos.*, 124, 1–22. DOI: 10.1029/2018JD030201.

Satchwell, AJ; Scown, CD; Smith, SJ; Amirebrahimi, J; Jin, L; Kirchstetter, TW; Brown, NJ; **Preble, CV** (2018) Accelerating the deployment of anaerobic digestion to meet zero waste goals. *Envir. Sci. Tech.*, 52, 13663–13669. DOI: 10.1021/acs.est.8b04481.

Preble, CV; Cados, TE; Harley, RA; Kirchstetter, TW (2018) In-use performance and durability of particle filters on heavy-duty diesel trucks. *Envir. Sci. Tech.*, 52, 11913–11921. DOI:
10.1021/acs.est.8b02977.

Kirchstetter, TW; **Preble, CV**; Hadley, OL; Bond, TC; Apte, JS. (2017) Large reductions in urban black carbon concentrations in the United States between 1965 and 2000. *Atmos. Environ.*, 151, 17–23. DOI: 10.1016/j.atmosenv.2016.11.001.

Preble, CV; Dallmann, TR; Kreisberg, NM; Hering, SV; Harley, RA; Kirchstetter, TW. (2015) Effects of particle filters and selective catalytic reduction on heavy-duty diesel drayage truck emissions at the Port of Oakland. *Envir. Sci. Tech.*, 49, 8864–8871. DOI: 10.1021/acs.est.5b01117.

Preble, CV; Hadley, OL; Gadgil, A; Kirchstetter, TW. (2014) Emissions and climate-relevant optical properties of pollutants emitted from a three-stone fire and the Berkeley-Darfur stove tested under laboratory conditions. *Envir. Sci. Tech.*, 48, 6484–6491. DOI: 10.1021/es5002715.

Sleiman, M; Kirchstetter, TW; Berdahl, P; Gilbert, HE; Quelen, S; Marlot, L; **Preble, CV**; Chen, S; Montalbano, A; Rosseler, O; Akbari, H; Levinson, R; Destaillats, H. (2014) Soiling of building envelope surfaces and its effect on solar reflectance - Part II: Development of an accelerated aging method for roofing materials. *Sol. Energ. Mat. Sol. C.*, 122, 271–281. DOI: 10.1016/j.solmat.2013.11.028.

HONORS & AWARDS

- ACS Editors' Choice, Preble et al. (ES&T, 2019) (December 6, 2019)
- 2016–2017 Outstanding Graduate Student Instructor Award, UC Berkeley (May 2017)
- Outstanding Student Paper Award, American Geophysical Union (AGU), 2014 Fall Meeting (December 2014)
- Student Poster Award, American Association of Aerosol Research (AAAR), 32nd Annual Conference (October 2013)
- National Science Foundation (NSF) Fellow (awarded 2012)
- Safety Spot Award, Lawrence Berkeley National Laboratory (June 1, 2012)
- Departmental Citation Award, Environmental Sciences (May 2010)
- Graduated with High Distinction in the College of Natural Resources (May 2010)

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors. Follow this format for each person.

DO NOT EXCEED FIVE PAGES.

NAME: Wagner, Jeff

eRA COMMONS USER NAME (credential, e.g., agency login): n/a

POSITION TITLE: Research Scientist

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
University of Illinois at Urbana-Champaign	BS	05/1993	Engineering Physics (Honors)
University of Illinois at Urbana-Champaign	AB	05/1993	Philosophy (Cum Laude)
University of Illinois at Urbana-Champaign	MS	05/1995	Environmental Engineering in Civil Engineering
University of North Carolina at Chapel Hill	PhD	05/2000	Environmental Sciences and Engineering
CA Dept. of Public Health / University of North Carolina at Chapel Hill (NIOSH Fellowship)	Postdoctoral	02/2001	Airborne Particle Sampling Methods
Lawrence Berkeley National Laboratory / Public Health Institute	Postdoctoral	06/2001	Environmental Tobacco Smoke

A. Personal Statement

I am a subject matter expert on environmental measurements, airborne particle health effects, air sampler and exposure assessment study design, data analysis, and pollutant transport. My applied research includes development of environmental forensic methods to identify sources of toxics in air, water, and soils using electron microscopy, light microscopy, vibrational spectroscopy, and gas/liquid chromatography. I've conducted field investigations of airborne pollutants in residential, occupational, and outdoor environments measured with both low-cost and research grade airborne particle monitors, particle collection devices, filters, vapor-phase samplers and sensors, and other environmental measurements. I've conducted laboratory research investigations of airborne pollutant measurement and control using bench-scale, wind tunnel, and large-scale HVAC / environmental chamber facilities.

B. Positions and Honors

Positions and Employment

- Research Scientist, Environmental Health Laboratory, California Dept. of Public Health, 2001-present
- Acting Chief, Outdoor Air Quality Section, California Dept. of Public Health, 2017-2019

Patents

- Wagner J and Leith D "Passive aerosol sampler and methods", US Patent #6321608, issued November 27, 2001

C. Contributions to Science

1. Airborne particulate matter (PM) measurement and PM source identification.

    A. Freedman, F.R.; English, P.; Wagner, J.; Liu, Y.; Venkatram, A.; Tong, D.Q.; Al-Hamdan, M.Z.; Sorek-Hamer, M.; Chatfield, R.; Rivera, A.; Kinney, P.L. (2020) Spatial Particulate Fields during High Winds in the Imperial Valley, California. Atmosphere, 11, 88, doi:10.3390/atmos11010088.
    B. Wagner J, Wang,Z, Ghosal S (2019) Source Identification on High PM2.5 Days using SEM/EDS, XRF, Raman, and Windblown Dust Modeling. Aerosol and Air Quality Research, 19: 2518–2530, doi: 10.4209/aaqr.2019.05.0276.
    C. Castillo M, Kinney P, Wagner J, Freedman F, Eisl H, Casuccio G, West R, Wang Z, Yip K (2019) Field testing a low-cost passive aerosol sampler for long-term measurement of ambient PM2.5 concentrations. Atmospheric Environment 216, doi:10.1016/j.atmosenv.2019.116905.
    D. Wagner J and Casuccio G (2014) Spectral Imaging and Passive Sampling to Investigate Particle Sources in Urban Desert Regions. Environ. Sci.: Processes Impacts 16:1745-53. DOI:10.1039/C4EM00123K.
    E. Harnly M, Naik-Patel K, Wall S, Quintana P, Pon D, and Wagner J (2012) Agricultural burning: air monitoring and exposure reduction in Imperial County. California Agriculture, 66:85-90.
    F. Wagner J and Macher J (2012) Automated Spore Measurements Using Microscopy, Image Analysis, and Peak Recognition of Near-Monodisperse Aerosols. Aerosol Sci. Technology, 46: 862873.
    G. Wagner J, Naik-Patel K, Wall S, and Harnly M (2012) Measurement of ambient particulate matter concentrations and particle types near agricultural burns using electron microscopy and passive samplers. Atmospheric Environment 54:260-271.
    H. Kim T and Wagner J (2010) PM2.5 and CO concentrations inside an indoor go-kart facility. Journal of Occupational & Environmental Hygiene 7: 7, 397-406.
    I. Wagner J. and Macher J.M. (2003) Comparison of a passive aerosol sampler to size-selective pump samplers in indoor environments. Am. Ind. Hyg. Assoc. J 64:630-639.

2. Persistent environmental pollutants (POPs) in the environment

    A. Wagner J, Wang Z, Ghosal S, Cook A, Robberson W, Allen H (2019) Non-destructive Extraction and Identification of Microplastics from Freshwater Sport Fish Stomachs. Environmental Science & Technology, 53:14496−14506, http://dx.doi.org/10.1021/acs.est.9b05072.
    B. Ghosal S, Chen M, Wagner J, Wang Z, and Wall S (2018) Molecular identification of polymers and anthropogenic particles extracted from oceanic water and fish stomach - A Raman microspectroscopy study. Environmental Pollution 233:1113-1124.
    C. Wang Z, Wagner J, Ghosal S, Bedi G, and Wall S (2017) SEM/EDS and optical microscopy analyses of microplastics in ocean trawl and fish guts. Science of the Total Environment, 603-4: 616-26. DOI: 10.1016/j.scitotenv.2017.06.047 .

D. Wagner J, Wang,Z, Ghosal S, Rochman C, Gassel M, and Wall S (2017) Novel method for the extraction and identification of microplastics in ocean trawl and fish gut matrices. Analytical Methods, DOI: 10.1039/C6AY02396G .
E. Wagner J, Ghosal S, Whitehead T, and Metayer C (2013) Morphology, spatial distribution, and concentration of flame retardants in consumer products and environmental dusts using scanning electron microscopy and Raman micro-spectroscopy. Environment International 59:16–26.

F. Ghosal S and Wagner J. (2013) Correlated Raman micro-spectroscopy and scanning electron microscopy analyses of flame retardants in environmental samples: a micro-analytical tool for probing chemical composition, origin and spatial distribution. Analyst 138:3836-3844.

3. Airborne exposures to tobacco smoke and vaping products.

A. Heinzerling A, Armatas C, Karmarkar E, Attfield K, Guo W, Wang Y, Vrdoljak G, Moezzi B, Xu D, Wagner J, Fowles J, Cummings K, Wilken J (2020) Severe lung injury associated with use of e-cigarette, or vaping, products — California, 2019. Journal of the American Medical Association, submitted.
B. Wagner J., Sullivan D.P., Faulkner D., Fisk W.J., Alevantis L.E., Dod R.L, Gundel L.A., and Waldman J.M. (2004) Environmental tobacco smoke leakage from smoking rooms. Journal of Occupational and Environmental and Hygiene 1:110-118.
C. Alevantis LE, Wagner J, Fisk WJ, Sullivan D, Faulkner D, Gundel LA, Waldman JM, and Flessel CP (2003) Designing for smoking rooms. ASHRAE Journal 45:26-31.
D. Wagner J, Sullivan D, Faulkner D, Gundel LA, Fisk WJ, Alevantis LE, and Waldman JM (2002) Measurements and modeling of environmental tobacco smoke leakage from a simulated smoking room. In Proceedings of the 9th International Conference on Indoor Air Quality and Climate. Indoor Air 2002, Santa Cruz, CA, pp. II-121-126.

4. Potential asbestos and nanoparticle exposures from products and natural sources.

A. Wagner J (2015) Analysis of Serpentine Polymorphs in Investigations of Natural Occurrences of Asbestos. Environ. Sci.: Processes Impacts 17: 985–996. DOI: 10.1039/C5EM00089K
B. De Vita J, Wall S, Wagner J, Wang Z, and Rao L (2012) Determining the Frequency of Asbestos Use in Automotive Brakes from a Fleet of On-Road California Vehicles. Environmental Science & Technology 46 :1344-51.
C. Wang Z, Wagner J, and Wall S (2011) Characterization of Laser Printer Nanoparticle and VOC Emissions, Formation Mechanisms, and Strategies to Reduce Airborne Exposures. Aerosol Sci.Technol. 45: 1060-1068.

5. Fundamental aerosol studies.

A. Wagner, J. and Leith, D. (2001) Field Tests of a Passive Aerosol Sampler. J. Aerosol Sci. 32:3348.
B. Wagner, J. and Leith, D. (2001) Passive aerosol sampler. Part II: Wind tunnel experiments. Aerosol Sci.Technol. 34:193-201.
C. Wagner, J. and Leith, D. (2001) Passive aerosol sampler. Part I: Principle of operation. Aerosol Sci.
Technol. 34:186-192.
D. Wagner, J., Andrews E., Larson S. (1996). Sorption of vapor phase octanoic acid onto deliquescent salt particles. J. Geophys. Res., 101:19533-19540.

D. Research Support

Ongoing Research Support

Research grant to develop microplastic measurement methods, 2018-20. United States EPA / Army Corp of Engineers Contract W912P718C003. Role: Project lead.

Research Support Completed During the Last Three Years

Research grant to determine sources of high PM2.5, 2018-9. San Joaquin Valley Air Pollution Control District Agreement 2017-06-22. Role: Project lead.

Research grant to develop microplastic measurement methods, 2016-18. United States EPA / Army Corp of Engineers Contract W912P7-16-P-0019. Role: Project lead.

Ricardo Cisneros
University of California, Merced
Public Health
Email: rcisneros@ucmerced.edu

Education

PhD, University of California, Merced, 2008.
Major: Environmental Systems
Minor: Air Quality

Master of Public Health (MPH), California State University, Fresno, 2004.
Major: Environmental Health and Safety option

BS, California State University, Fresno, 2000.
Major: Health Science, Environmental Health/Industrial Hygiene

Professional Positions

Associate Professor I, PUBLIC HEALTH, Public Health, University of California, Merced (2018-present).

Assistant Professor IV, Public Health, University of California, Merced (2016-2018).

Assistant Professor III, Public Health, University of California, Merced (2013-2016).

Assistant Professor II, Public Health, University of California, Merced (2012-2013).

Air Quality Specialist, U.S. Forest Service, Region 5. (2011 - 2012).

Postdoctoral position, UC Davis. (2009 - 2011).
Exposure Assessment and Environmental Health. University of California President's Postdoctoral Fellowship Program.

Air Quality Specialist, U.S. Forest Service, Region 5. (2003 - 2009).

Graduate Research Assistant, UC Merced. (2005 - 2007).

Teaching Assistant, UC Merced. (2005).
Spatial Analysis and Modeling course (Fall 2005)

Juvenile Correctional Officer, Fresno County Probation Department. (2003 - 2004).

Group Counselor, Valley Group Home, Inc. (2002 - 2003).

Ecologist, U.S. Forest Service, Sierra National Forest. (2001 - 2003).

GIS Computer Specialist, U.S. Forest Service, Sierra National Forest. (2000 - 2001).

Air Quality Technician, Aerosol Dynamics/Desert Research Institute. (1998 - 2000).

GIS Computer Specialist, U.S. Forest Service, Sierra National Forest. (1998).

Biological Science Technician, U.S. Forest Service, Sierra National Forest. (1998).

Professional Memberships

International Society for Environmental Epidemiology. (January 2015 - Present).

American Public Health Association. (November 2012 - Present).

Associate member, Sigma Xi. (May 2007 - Present).

Awards and Honors

First Place, UC Merced Research Poster Contest. (2008).

First Place, UC Merced Inaugural Research Poster Contest. (2007).

RESEARCH

Intellectual Contributions

(*Indicates corresponding author when not the first author) (#indicates graduate student)

Book Chapters

1. Schweizer, D., Nichols, T., **Cisneros, R.**, Navarro, K., Procter, T. Wildland fire, extreme weather, and society: implications of a history of fire suppression in 2 California, USA. In R. Akhtar (Ed.), *Extreme Weather Events and Human Health.* Springer Nature. Publisher - Springer Nature. (Current Status: Accepted; Date Accepted - June 4, 2019).

2. **Cisneros, R.**, Schweizer, D. W., Navarro, K., Veloz, D., Tarnay, L., Procter, C. T. (2018). Climate Change, Forest Fires and Health in California. In R. Akhtar, C. Palagiano (Eds.), *Climate Change and Air Pollution.* Springer. Publisher - Springer. (Current Status: Submitted; Date of Prior Status - June 30, 2018, Date Submitted - June 12, 2017).

3. Bytnerowicz, A., Fenn, M., Allen, E. B., **Cisneros, R**. (2016). Atmospheric Chemistry. In H. Mooney, E. Zavaleta (Eds.), Ecosystems of California. (pp. 107-128). University of California Press. Publisher - University of California Press. (Current Status: Published; Date of Prior Status - June 30, 2016, Date Published - January 2016, Date Accepted - June 22, 2015).

Journal Articles

1. Schweizer, D., **Cisneros, R.,** Navarro, K. (2020). The effectiveness of adding fire for the air quality benefits challenged: A case study of increased fine particulate matter from wilderness fire smoke with more active fire management. *Forest Ecology and Management 458, 117761.*

2. #Veloz, D., Gonzalez, M., Brown, P., #Gharibi, H., ***Cisneros, R.** (2020). Perceptions about air quality of individuals who work outdoors in the San Joaquin Valley, California. *Atmospheric Pollution Research. 11(4), 825-830.*

Schweizer, D., Nichols, T., **Cisneros, R.,** Navarro, K., Procter, T. (2020). Wildland Fire, Extreme Weather and Society: Implications of a History of Fire Suppression in California, USA. *Extreme Weather Events and Human Health, 41-57.*

3. Navarro, K.M., **Cisneros, R.,** Schweizer, D., Chowdhary, P., Noth, E.M., Balmes, J.R. Hammond, S.K. (2019). Incident command post exposure to polycyclic aromatic hydrocarbons and particulate matter during a wildfire. *Journal of Occupational and environmental hygiene 16 (11), 735-744.*

4. #Gharibi, H., #Entwistle, M.R., Ha, S., Gonzalez, M., Brown, P., Schweizer, D., ***Cisneros, R.** (2019). Ozone pollution and asthma emergency department visits in the Central Valley, California, USA, during June to September of 2015: a time-stratified case-crossover analysis. *Journal of Asthma 56 (10), 1037-1048.*

5. #Gharibi, H., #Entwistle, M.R., Schweizer, D., #Tavallali, P., #Thao, C., ***Cisneros, R**. (2019). Methyl-Bromide and asthma emergency department visits in California, USA from 2005 to 2011. Journal of Asthma, 1-10.
6. #Alcala, E., Brown P., Gonzalez, M., ***Cisneros R**. (2019). Cumulative impact of environmental pollution and population vulnerability on pediatric asthma hospitalizations: A multilevel analysis of CalEnvironScreen. International Journal of environmental research and public health 16(15), 2683.

7. Perez, M. A., Santos, A. A., Cisneros, R., Tongson-Fernandez, M. Stress, stressors, and academic performance among Asian students in Central California. American Journal of Health Studies, 34(1).

8. #Gharibi, H., #Entwistle, M. R., Schweizer, D., Tavallali, P., ***Cisneros, R**. (2019). The association between 1,3-dichloropropene and asthma emergency department visits in California, USA from 2005 to 2011: a bidirectional-symmetric case crossover study. Journal of Asthma. Publisher - Taylor & Francis.

9. #Entwistle, M. R., #Gharibi, H., Tavalli, P., ***Cisneros, R**., Brown, P., Schweizer, D., Ha, S. (2019). Ozone pollution and asthma emergency department visits in Fresno, CA, USA, during the warm season (June–September) of the years 2005 to 2015: a time-stratified case-crossover analysis. Air Quality, Atmosphere & Health, 12(6), 661–672. Publisher - Springer.

10. Schweizer, D., **Cisneros, R**., Buhler, M. (2019). Coarse and Fine Particulate Matter Components of Wildland Fire Smoke at Devils Postpile National Monument, California, USA. Aerosol and Air Quality Research.

11. Bytnerowicz, A., Fenn, M., **Cisneros, R**., Schweizer, D., Burley, J., Schilling, S. L. (2019). Nitrogenous air pollutants and ozone exposure in the central Sierra Nevada and White Mountains of California – Distribution and evaluation of ecological risks. Science of the Total Environment, 654, 604-615. Publisher - Elsevier.

12. Schweizer, D., Preisler, H., **Cisneros, R**. (2019). Assessing relative differences in smoke exposure from prescribed, managed, and full suppression wildland fire. Air Quality, Atmosphere & Health, 12(1), 87-95. Publisher - Springer.

13. #Alcala, E., **Cisneros, R**., Capitman, J. A. (2018). Health care access, concentrated poverty, and pediatric asthma hospital care use in California's San Joaquin Valley. Journal of Asthma, 55(11), 1253-1261. Publisher - Taylor & Francis.

14. #Gharibi, H., #Entwistle, M. R., Gonzalez, M., Brown, P., D. S., ***Cisneros, R.** (2018). Ozone pollution and asthma emergency department visits in the Central Valley, California, USA, during June to September of 2015: a time-stratified case-crossover analysis. Journal of Asthma.

15. **Cisneros, R**., #Alcala, E., Schweizer, D., Burke, N. (2018). Smoke complaints caused by wildland fire in the southern Sierra Nevada region, California. International Journal of Wildland Fire.

16. **Cisneros, R**., Schweizer, D. (2018). The efficacy of news releases, news reports, and public nuisance complaints for determining smoke impacts to air quality from wildland fire. Air Quality, Atmosphere & Health, 11(4), 423-429.

17. Navarro, K. M., Schweizer, D., Balmes, J. R., **Cisneros, R**. (2018). A Review of Community Smoke Exposure from Wildfire Compared to Prescribed Fire in the United States. Atmosphere, 9(5), 185. Publisher - MDPI.

18. #Schweizer, D., **Cisneros, R**., Ghezzehei, T. A., Traina, S. J., Shaw, G. (2017). Using National Ambient Air Quality Standards for fine particulate matter to assess regional wildland fire smoke and air quality management. Journal of Environmental Management, 201, 345-356. Publisher - Elsevier.

19. Navarro, K., **Cisneros, R**., North, E., Balmes, J., Hammond, K. S. (2017). Occupational Exposure to Polycyclic Aromatic Hydrocarbon of Wildland Firefighters at Prescribed and Wildland Fires. Environmental science & technology. Publisher - ACS Publications. (DOI: 10.1021/acs.est.7b00950).

20. **Cisneros, R**., Brown, P., Cameron, L., Gaab, E., Gonzalez, M., Ramondt, S., Veloz, D., Song, A. V., Schweizer, D. (2017). Understanding Public Views about Air Quality and Air Pollution Sources in the San Joaquin Valley, California. Journal of Environmental and Public Health, 2017. Publisher - Hindawi Publishing Corporation.

21. Schweizer, D. W., **Cisneros, R**. (2017). Forest fire policy: change conventional thinking of smoke management to prioritize long-term air quality and public health. Air Quality, Atmosphere & Health, 10(1), 33-36. Publisher - Springer.

22. #Navarro, K. M., *__Cisneros, R__., O'Neill, S. M., Schweizer, D., Larkin, N. K., Balmes, J. R. (2016). Air-Quality Impacts and Intake Fraction of PM2.5 during the 2013 Rim Megafire. Environmental science & technology, 50(21), 11965-11973. 0013-936X.

23. **Cisneros, R**., Gonzalez, M., Brown, P., Schweizer, D. (2016). Soda consumption and hospital admissions among California adults with asthma. Journal of Asthma, 54(4), 371-375.

24. Brown, P., Cameron, L., **Cisneros, R**., Cox, R., Gaab, E., Gonzalez, M., Ramondt, S., Song, V. (2016). Latino and Non-Latino Perceptions of the Air Quality in California's San Joaquin Valley. International journal of environmental research and public health, 13(12). 1661-7827.

25. #Schweizer, D. W., **Cisneros, R**., Shaw, G. (2016). A comparative analysis of temporary and permanent beta attenuation monitors: The importance of understanding data and equipment limitations when creating PM2.5 air quality health advisories. Atmospheric Pollution Research, 7(5), 865-875.

26. Burley, J., Bytnerowicz, A., Buhler, M., Zielinska, B., Schweizer, D., **Cisneros, R**., Schilling, S., Varela, J. C., McDaniel, M., Horn, M., Dullen, D. (2016). Air Quality at Devils Postpile National Monument, Sierra Nevada Mountains, California, USA. Aerosol and Air Quality Research, 16, 2315-2332.

27.Preisler, H. K., Schweizer, D., **Cisneros, R**., Procter, T., Ruminski, M., Tarnay, L. (2015). A Statistical Model for Determining Impact of Wildland Fires on Particulate Matter (PM2.5) in Central California aided by Satellite Imagery of Smoke. Environmental Pollution, 205, 340-349.

28. **Cisneros, R**., Schweizer, D., Preisler, H., Bennett, D., Shaw, G., Bytherowicz, A. (2014). Spatial and Seasonal Patterns of Particulate Matter less than 2.5 Microns in the Sierra Nevada, California. *Atmospheric Pollution Research, 5(4)*, 581-590. Publisher - Elsevier.

29. #Schweizer, D., **Cisneros, R**. (2014). Wildland fire management and air quality in the southern Sierra Nevada: Using the Lion Fire as a case study with a multi-year perspective on PM2.5 impacts and fire policy. Journal of Environmental Management, 144, 265-278. Publisher - Elsevier.

30. Shaw, G. D., **Cisneros, R**., Schweizer, D., Sickman, J. O., Fenn, M. E. (2013). Critical Loads of Acid Deposition for Wilderness Lakes in the Sierra Nevada (California) Estimated by the Steady-State Water Chemistry Model. Water Air Soil Pollut, 225, 1804-1820. Publisher - Springer.

31. Panek, J., Saah, D., Esperanza, A., Bytnerowicz, A., Fraczek, W., **Cisneros, R**. (2013). Ozone distribution in remote ecologically vulnerable terrain of the southern Sierra Nevada, CA. Environmental Pollution, 182, 343-356. Publisher - Elsevier.

32. Bytnerowicz, A., Burley, J. D., **Cisneros, R**., Preisler, H. K., Schilling, S., Schweizer, D., Ray, J., Dulen, D., Beck, C., Auble, B. (2013). Surface ozone at the Devils Postpile National Monument receptor site during low and high wildland fire years. Atmospheric Environment, 65, 129-141.

33. Cisneros et al. (2012). Analysing the effects of the 2002 McNally fire on air quality in the San Joaquin Valley and southern Sierra Nevada, California. International Journal of Wildland Fire, 21(8), 1065-1075. Publisher - CSIRO Publishing.

34. **Cisneros, R**., Bytnerowicz, A., Schwizer, D., Zhong, S., Traina, S. J., Bennett, D. H. (2010). Ozone, nitric acid, and ammonia air pollution is unhealthy for people and ecosystems in southern Sierra Nevada, California. Environmental Pollution, 158(10), 3261-3271.

35. Hunsaker, C., Bytnerowicz, A., Auman, J., **Cisneros, R**. (2007). Air pollution and Watershed Research in the Central Sierra Nevada of California: Nitrogen and Ozone. The Scientific World JOURNAL, 79(S1), 206-221.

36. **Cisneros, R**., Perez, M. (2007). A comparison of Ozone Exposure in Fresno and Shaver Lake, California. Journal of Environmental Health, 69(7), 38-44.

Technical Reports

1. Bytnerowicz, A., Arbaugh, M., Fenn, M. E., Musselman, R., Padgett, P. E., Procter, T., **Cisneros, R.** (2004). *JFSP Report Improving Model Estimates of Smoke Contributions to Regional Haze Using Low-cost Sampler Systems*. Joint Fire Science Program.

Contracts, Grants and Sponsored Research

Fellowship

Cisneros, Ricardo, "University of California President's Postdoctoral Fellowship," UC. (August 2009 - September 2011).

Cisneros, Ricardo, "Atmospheric Aerosols and Health Fellowship," UC Davis/ UC TSR&TP. (August 2006 - September 2008).

Cisneros, Ricardo, "STAR Fellowship," EPA - Environmental Protection Agency. (August 2005 - September 2008).

Grant

Cisneros, Ricardo (Principal Investigator), "Smoke Impacts to California's Central Valley from Wildland Mega Fires," USDA - US Dept of Agriculture, $76,000.00. (January 2018 - June 2019).

Cisneros, Ricardo (Principal Investigator), "Smoke Impacts to California from Forest Fires," USDA - US Dept of Agriculture, $7,000.00. (June 2018 - August 2018).

Cisneros, Ricardo (Principal Investigator), Schweizer, Donald (Collaborator), Preisler, Haiganoush (Collaborator), "Determining the added human health impacts caused by smoke (PM2.5) from wildland fires," NIH - National Institutes of Health, $2,500,000.00.

Cisneros, Ricardo (Principal Investigator), "Determining the added human health impacts caused by smoke (PM2.5) from wildland fires," NIH - National Institutes of Health.

Cisneros, Ricardo (Collaborator), Hoyer, Katrina (Principal Investigator), Nobile, Clarissa Jane (Collaborator), Hernday, Aaron (Collaborator), Brown, Paul (Collaborator), Cameron, Linda (Collaborator), Sil, Anita (Collaborator), "Predictors and Impact of Valley Fever in California," UC President's Catalyst Research Awards.

Cisneros, Ricardo (Principal Investigator), "Determining the human health impacts caused by smoke (PM2.5) from wildland fires on communities of Central California and Sierra Nevada," Hellman Faculty Fellows Fund, $20,000.00. (July 2014 - July 2015).

Cisneros, Ricardo, "Exposure and Risk Assessment (ERA) - Determining the human health impacts caused by smoke (PM2.5) from wildland fires on communities of Central California," JFSP/Department of Agriculture and Interior, $500,000.00.

Cisneros, Ricardo (Co-Principal Investigator), "Tools for Estimating Contributions of Wildland and Prescribed Fires to Air Quality in the Southern Sierra Nevada, California," Joint Fire Science Program (http://jfsp.nifc.gov). (2006 - 2008).

Multiple Campus Award

Cisneros, Ricardo (Collaborator), Lopez-Carr, David (Principal Investigator), Smith, Woutrina A (Principal Investigator), Conrad, Patricia (Co-Principal Investigator), "UCGHI Center of Expertise on Planetary Health: Innovation to achieve healthy people and healthy environments in the 21st century," University of California Global Health Institute. (August 2016 - July 2019).

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors in the order listed on Form Page 2. Follow this format for each person. **DO NOT EXCEED FOUR PAGES.**

NAME Kazukiyo Kumagai	POSITION TITLE California Department of Public Health Indoor Air Quality Program Chief (Research Scientist Supervisor II)
eRA COMMONS USER NAME (credential, e.g., agency login)	

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	MM/YY	FIELD OF STUDY
Tokyo University of Science, Japan	B.Sc.(Eng.)	03/92	Arch. Eng.
Tokyo University of Science, Japan	M.Sc.(Eng.)	03/94	Arch. Eng.
The Institute of Public Health, Japan	M.P.H.	03/98	Environ. Health Sci.
The University of Tokyo, Japan	Ph.D.	03/07	Environ. Studies

A. Personal Statement

I have been working on environmental health science including indoor air quality from the point of pollutant source characterization, exposure assessment, and developing engineering measures for over 20 years.

On the pollutant emission side which relates to e-cigarette vapor characteristics, I have been involved in developing VOCs emission testing methods (JIS, JAS) from building materials and among them one has been selected as an ISO standard. Moreover my team already has publish a few papers on the gas generation from the e-liquid carrier decomposition.

On the indoor environmental or exposure assessment side, I lead or was involved in the first national study done in Japan on indoor VOCs and also a pilot study held in China which both were cited when both countries were developing its national indoor VOC standard.

I am currently a member/observer in committee related to e-cigarette organized by the California Tobacco Control Unit of CDPH, Center or Disease Control and Prevention, Ministry of Health Labour and Welfare, Japan and World Health Organization.

In summary, I have leaded research multiple projects to success. My unique knowledge combination on environmental engineering influenced by environmental health science and the experience on working in academic, industrial and government organization would help generate applicable science from the proposed project that would support develop public policy.

B. Positions and Honors

Positions and employment

04/17 - Adjunct Professor, Graduate School of Engineering, Tokyo University of Science
10/11 - Affiliate Scientist, Indoor Environment Group, Lawrence Berkeley National Laboratory
03/10 - Chief, Indoor Air Quality Program, California Department of Public Health
04/09 - 03/11 Guest Professor, Research and Education Center of Carbon Resources, Kyushu Univ
04/07 - 03/09 Associate Professor, Department of Environmental Systems, The University of Tokyo
04/07 - 03/09 Associate Professor, Department of Chemical System Engineering, The University of Tokyo 09/07 - 12/07 Guest Scientist, Exposure, Epidemiology, and Risk Program, Harvard School of Public Health
04/03 - 03/07 Assistant Professor, Department of Environmental Systems, The University of Tokyo
04/01 - 03/03 Research Associate, Department of Environmental Systems, The University of Tokyo
04/04 - 03/03 Founder & CEO, Environmental Research Institute International, Japan
04/99 - 03/01 Guest Researcher, Research Institute for Science and Engineering, Waseda University
04/97 - 03/99 Lecturer, Department of Architectural Hygiene, The Institute of Public Health, Japan
04/99 - 03/97 Researcher, Research and Development Division, Ando Corporation

C. Selected Peer-reviewed Publications

Publication on e-cigarette

1. Chen W, Wang P, Ito K, Fowles J, Shusterman D, Jaques P, **Kumagai K**. 2018. Measurement of Heating Coil Temperature for E-Cigarettes with a “Top-Coil” Clearomizer. PLoS One. doi.org/10.1371/journal.pone.0195925
2. Kuga K, Ito K, Yoo SJ, Chen W, Wang P, Liao J, Fowles J, Shusterman D, **Kumagai K**. 2017. First- and second-hand smoke dispersion analysis from e-cigarettes using a computer-simulated person with a respiratory tract model. Indoor and Built Environment. In print. doi: 10.1177/1420326x17694476. [Epub ahead of print].
3. Wang P, Chen W, Liao J, Matsuo T, Ito K, Fowles J, Shusterman D, Mendell M, **Kumagai K**. 2017. A device-independent evaluation of carbonyl emissions from heated electronic cigarette solvents. PLoS ONE 12(1): e0169811. doi:10.1371/journal.pone.0169811.
4. Wang P, Chen W, Liao J, Matsuo T, Ito K, Fowles J, Shusterman S, and **Kumagai K**, 2015. Temperature Effect on the Formation of Volatile Carbonyls from Electronic (E-) Cigarette Solvents. ISES 25th Annual Meeting, Henderson, NV, October 18-22, 2015.
5. Liao J, Parthasarathy S, Sklar R, Vinnikov D, Perrino C, Wang P, Chen W, **Kumagai K**, Liu S, and Hammond H. 2015. Second-hand Exposure to Electronic Cigarette Vapors – a Pilot Field Sampling. ISES 25th Annual Meeting, Henderson, NV, October 18-22, 2015.

Additional recent publications of importance to the field

1. Shusterman D, Wang P, **Kumagai K**. 2017. Nasal trigeminal perception of two representative microbial volatile organic compounds (MVOCs): 1-octen-3-ol and 3-octanol - A Pilot Study. Chemosensory Perception. [Accepted]
2. Gaspar FW, Maddalena R, Williams J, Castorina R, Wang ZM, **Kumagai K**, McKone TE, Bradman A. 2017. Ultrafine, fine, and black carbon particle concentrations in California child-care facilities. Indoor Air, doi. 10.1111/ina.12408. [Epub ahead of print].
3. Chen W, Persily AK, Hodgson AT, Offermann FJ, Poppendieck D, **Kumagai K**. 2014. Area-Specific Airflow Rates for Evaluating the Impacts of VOC Emissions in U.S. Single-Family Homes. Building and Environment. 71:204-211.
4. Sidheswaran M, Chen W, Chang A, Miller R, Cohn S, Sullivan D, Fisk WJ, **Kumagai K**, Destaillats H. 2013. Formaldehyde Emissions from Ventilation Filters Under Different Relative Humidity Conditions. Environmental Science & Technology 47(10):5336-5343.

5. Fujii M, Shinohara N, Lim A, Otake T, Kumagai K, Yanagisawa Y. 2003. A study on emission of phthalate esters from plastic materials using a passive flux sampler. Atmospheric Environment, 37:5495-5504. DOI: 10.1016/j.atmosenv.2003.09.026
6. Shinohara N, Kai Y, Mizukoshi A, Fujii M, Kumagai K, Okuizumi Y, Jona M, Yanagisawa Y. 2009. Onsite passive flux sampler measurement of emission rates of carbonyls and VOCs from multiple indoor sources. Building and Environment. 44:859-863. DOI: 10.1016/j.buildenv.2008.06.007

D. Research Support

Funder: California Air Resources Board (ARB) via Inter-agency Agreement, 07/10 – 06/15
Testing composite wood products for formaldehyde emissions
The goal of this project was to provide laboratory technical support for implementation of ARB's airborne toxic control measure (ATCM) to reduce formaldehyde emissions from composite wood products.
Role: Project Director

BIOGRAPHICAL SKETCH

NAME: Robert Gunier

eRA COMMONS USER NAME (credential, e.g., agency login): GUNIER

POSITION TITLE: Assistant Researcher

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
University of California, San Diego	BS	06/1991	Bioengineering
University of California, Berkeley	MPH	05/1997	Environmental Health Sciences
University of California, Berkeley	PhD	12/2013	Environmental Health Sciences

A. Personal Statement

I have a strong background in environmental health science, with specific expertise in exposure assessment, environmental epidemiology, biostatistics, toxicology and the use of Geographic Information Science (GIS). With this training, I will be collaborating with Dr. Asa Bradman to evaluate exposure to air pollutants. I have the expertise, experience and motivation necessary to successfully carry out the proposed work. I have worked with Dr. Eskenazi's research group at the School of Public Health for the past ten years studying the effects of exposure to pesticides and other environmental pollutants on child development, with a particular emphasis on child neurodevelopment. In the past, I have worked with multi-disciplinary teams at the California Department of Public Health and Cancer Prevention Institute of California on epidemiological studies studying the effects of environmental exposures to air pollutants and pesticides on childhood and breast cancers that utilized large, complex data sets for the entire state of California. I was largely responsible for estimating exposure and the biostatistical analyses of these data sets. My particular research focus has been on the use of biomarkers, questionnaire data and GIS to estimate environmental exposures. As a doctoral student at UC Berkeley, my dissertation focused on exposure to manganese from agricultural fungicides and neurodevelopment in young children. The proposed study expands my previous research to include monitoring and modeling of air pollutants in disadvantaged communities. My previous training in environmental health, biostatistics and epidemiology combined with previous research on the relationships between environmental exposures and children's health have provided me with the expertise needed to be a co-investigator with significant contributions on this project. Examples of publications in which I had a critical role include:

1. **Gunier** RB, Raanan R, Castorina R, Holland NT, Harley KG, Balmes JR, Fouquette L, Eskenazi B, Bradman A. 2018. Residential proximity to agricultural fumigant use and respiratory health in 7-year old children. Environmental Research. 164:93-99. PMCID: PMC5911232.
2. **Gunier** RB, Hertz A, Von Behren J, Reynolds P. Traffic density in California: socioeconomic and ethnic differences among potentially exposed children. J Expo Anal Environ Epidemiol. 2003; 13(3):240-6. PMID: 12743618.
3. **Gunier** RB, Reynolds P, Hurley SE, Yerabati S, Hertz A, Strickland P, Horn-Ross PL. Estimating exposure to polycyclic aromatic hydrocarbons: a comparison of survey, biological monitoring, and

geographic information system-based methods. Cancer Epidemiol Biomarkers Prev. 2006; 15(7):137681. PMID: 16835339.

4. Windham GC, Zhang L, **Gunier** R, Croen LA, Grether JK. Autism spectrum disorders in relation to distribution of hazardous air pollutants in the San Francisco Bay Area. Environ Health Perspect. 2006; 114(9):1438-44. PMCID: PMC1570060.

B. Positions and Honors

Positions and Employment

1997 – 2006	Research Scientist, Environmental Health Investigations Branch, California Department of Public Health, Oakland, CA.
2006 – 2011	Environmental Health Scientist, Cancer Prevention Institute of California, Berkeley, CA.
2011 – 2015	Data Analyst, Center for Environmental Research and Children's Health, School of Public Health, University of California, Berkeley, CA.
2015 –	Assistant Researcher, Center for Environmental Research and Children's Health, School of Public Health, University of California, Berkeley, CA.

Other Experience and Professional Memberships

1999 – Present: Member, International Society of Exposure Science
2010 – Present: Member, International Society of Environmental Epidemiology
2012 – Graduate Student Instructor, Geographic Information Science for Public and Environmental Health

Honors

1995 – 1997 U.S. Public Health Service Traineeship
2008 – 2010 Recipient of Reshetko Family Scholarship

C. Contributions to Science

1. **Determinants of environmental exposures:** I have investigated the relationship between biomarkers of exposure and determinants of exposure obtained from questionnaire and GIS data. The goal of this work has been to evaluate the accuracy exposure estimates derived from questionnaires and GIS data as compared to more expensive and intrusive collection and analyses of biological samples. We found that questionnaire and GIS data are often well correlated with biomarkers of exposure. I helped design these studies, conducted the exposure assessment, and carried out the statistical analyses.
    a. **Gunier** RB, Horn-Ross PL, Canchola AJ, Duffy CN, Reynolds P, Hertz A, Garcia E, Rull RP. Determinants and within-person variability of urinary cadmium concentrations among women in northern California. Environ Health Perspect. 2013;121(6):643-9. PMCID: PMC3672909.
    b. **Gunier** RB, Bradman A, Jerrett M, Smith DR, Harley KG, Austin C, Vedar M, Arora M, Eskenazi B. Determinants of manganese in prenatal dentin of shed teeth from CHAMACOS children living in an agricultural community. Environ Sci Technol. 2013;47(19):11249-57. PMCID: PMC4167759.
    c. **Gunier** RB, Mora AM, Smith D, Arora M, Austin C, Eskenazi B, Bradman A. Biomarkers of manganese exposure in pregnant women and children living in an agricultural community in California. Environ Sci Technol. 2014;48(24):14695-702. PMCID: PMC4270392.
    d. Harley KG, Parra KL, Camacho J, Bradman A, Nolan JES, Lessard C, Anderson KA, Poutasse CM, Scott RP, Lazaro G, Cardoso E, Gallardo D, **Gunier** RB. Determinants of pesticide concentrations in silicone wristbands worn by Latina adolescent girls in a California farmworker community: The COSECHA youth participatory action study. Sci Total Environ. 2019; 652:1022-1029. PMCID: PMC6309742.

2. **Pesticide exposure:** One theme of my research has been characterizing exposure to pesticides in agricultural communities. We have utilized the unique California Pesticide Use Reporting (PUR) data to prioritize agricultural pesticides for a study of childhood cancer and we have also conducted some of the

only studies that have evaluated the relationship between PUR data and measured pesticide concentrations in environmental samples of house dust and ambient air. We recently evaluated silicone wristbands for assessing personal exposure to pesticides in girls living in a farmworker community. My role was study design, exposure assessment, and statistical analysis in these studies.

a. **Gunier** RB, Ward MH, Airola M, Bell EM, Colt J, Nishioka M, Buffler PA, Reynolds P, Rull RP, Hertz A, Metayer C, Nuckols JR. Determinants of agricultural pesticide concentrations in carpet dust. Environ Health Perspect. 2011;119(7):970-6. PMCID: PMC3222988.
b. **Gunier** RB, Harnly ME, Reynolds P, Hertz A, Von Behren J. Agricultural pesticide use in California: pesticide prioritization, use densities, and population distributions for a childhood cancer study. Environ Health Perspect. 2001;109(10):1071-8. PMID: 11689348
c. **Gunier** RB, Arora M, Jerrett M, Bradman A, Harley KG, Mora AM, Kogut K, Hubbard A, Austin C, Holland N, Eskenazi B. Manganese in teeth and neurodevelopment in young Mexican-American children. Environ Res. 2015;142:688-695. PMCID: PMC4696558.
d. **Gunier** RB, Bradman A, Harley KG, Eskenazi B. Will buffer zones around schools in agricultural areas be adequate to protect children from the potential adverse effects of pesticide exposure? PLoS Biol. 2017. 15(12):e2004741. PMCID: PMC5739348.

3. **Exposure to chemical mixtures and children's health.** My research has focused on developing exposure assessment and statistical methods for environmental epidemiological studies of chemical mixtures and children's health. I have worked on analyses of environmental exposure to chemical mixtures using advanced statistical methods including Bayesian hierarchical models for pesticides and childhood leukemia; Bayesian profile regression to evaluate pesticides and child IQ; Bayesian model averaging for chemicals in consumer products and neonatal thyroid hormone levels; and cluster analysis for hazardous air pollutants and autism. My role in these studies included GIS analyses, biostatistics and epidemiological analyses.

a. Rull RP, **Gunier** R, Von Behren J, Hertz A, Crouse V, Buffler PA, Reynolds P. Residential proximity to agricultural pesticide applications and childhood acute lymphoblastic leukemia. Environ Res. 2009;109(7):891-9. PubMed PMID: 19700145; PMCID: PMC2748130.
b. Coker E, **Gunier** R, Bradman A, Harley K, Kogut K, Molitor J, Eskenazi B. Association between Pesticide Profiles Used on Agricultural Fields near Maternal Residences during Pregnancy and IQ at Age 7 Years. Int J Environ Res Public Health. 2017;14(5). PMCID: PMC5451957.
c. Berger K, **Gunier** RB, Chevrier J, Calafat AM, Ye X, Eskenazi B, Harley KG. Associations of maternal exposure to triclosan, parabens, and other phenols with prenatal maternal and neonatal thyroid hormone levels. Environ Res. 2018;165:379-386. PMID: 29803919.

4. **Exposure to agricultural pesticides and health:** Another major theme of my research has been developing GIS methods to estimate pesticide exposures in agricultural communities for epidemiological studies. We have used the existing California Pesticide Use Report data to estimate exposure based on residential proximity to agricultural applications. We have observed associations between residential proximity to sulfur use and lung function, insecticides and fumigants and IQ in children, and fumigant use and birthweight. My role in these studies was environmental health scientist, toxicologist, and GIS analyst.

a. **Gunier** RB, Bradman A, Harley KG, Kogut K, Eskenazi B. Prenatal Residential Proximity to Agricultural Pesticide Use and IQ in 7-Year-Old Children. Environ Health Perspect. 2017;125(5). PMCID: PMC5644974.
b. **Gunier** RB, Bradman A, Castorina R, Holland NT, Avery D, Harley KG, Eskenazi B. Residential proximity to agricultural fumigant use and IQ, attention and hyperactivity in 7-year old children. Environ Res. 2017; 158:358-365. PubMed PMID: 28686950; PMCID: PMC5644974.
c. Raanan R, **Gunier** RB, Balmes JR, Beltran AJ, Harley KG, Bradman A, Eskenazi B. Elemental Sulfur Use and Associations with Pediatric Lung Function and Respiratory Symptoms in an Agricultural Community (California, USA). Environ Health Perspect. 2017;125(8). PMCID: PMC5783654.

d. Gemmill A, **Gunier** RB, Bradman A, Eskenazi B, Harley KG. Residential proximity to methyl bromide use and birth outcomes in an agricultural population in California. Environ Health Perspect. 2013;121(6):737-43. PMCID: PMC3672911.

5. Complete List of Published Work in MyBibliography:

https://www.ncbi.nlm.nih.gov/myncbi/robert.gunier.1/bibliography/public/

EXHIBIT A6

CURRENT & PENDING SUPPORT

University will provide current & pending support information for Key Personnel identified in Exhibit A2 at time of proposal and upon request from State agency. The "Proposed Project" is this application that is submitted to the State. Add pages as needed.

PI: Elizabeth Noth, UCB					
Status (currently active or pending approval)	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
CURRENTLY ACTIVE	20RD012	CARB	Total Exposure to Air Pollution and Noise in Disadvantaged Communities	4/1/2021	~~3/30/2024~~ **<u>3/29/2025</u>**
CURRENTLY ACTIVE	19-E0020	OEHHA - PI	Pilot Air Quality Study for Vallejo (PAQS-V)	5/1/20	4/30/22
CURRENTLY ACTIVE	R24 ES030888	NIEHS - PI	CHAPS Cohort Maintenance	2/15/20	2/14/25
CURRENTLY ACTIVE	N/A	The Koret Institute – Co Investigator	The Koret Institute for Precision Prevention	6/08/16	12/30/20
CURRENTLY ACTIVE	5R01AG02 6291	NIH/NIA – Co Investigator	Disease, Disability and Death in an Aging Workforce	6/01/06	5/31/22
CURRENTLY ACTIVE	19RD003	CARB	Support for Air Pollution Measurements, Exposure Assessment, and Evaluation of the Sources of Particulate Matter	3/15/20	3/14/23
CURRENTLY ACTIVE	R01 ES031261	NIH/NIEHS - Subaward PI	Wildfires and intentional biomass burning in California and Preterm Birth	6/18/20	3/31/25

Co-PI: Asa Bradman, UCM					
Status (currently active or pending approval)	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
CURRENTLY ACTIVE	20RD012	CARB	Total Exposure to Air Pollution and Noise in Disadvantaged Communities	4/1/2021	~~3/30/2024~~ **3/29/2025**
CURRENTLY ACTIVE	R01ES0269 94	NIH – Co-Investigator	Effect of Early Life Exposure to Social Adversity and Pesticides on Risk - Taking Behavior of 16 - 18 Year-Olds: The CHAMACOS Study	9/30/16	8/31/21
CURRENTLY ACTIVE	R24ES0285 29	NIH – Co Investigator	Maintaining and Expanding the CHAMACOS Epidemiology Cohort Infrastructure for Future Generations	7/01/17	6/30/22
CURRENTLY ACTIVE	1R01ES027 134 - 01A1	NIH NEIHS – Co - Investigator	Reducing Pesticide Exposures to Preschool-age Children in California Childcare Centers	9/30/17	8/31/22
CURRENTLY ACTIVE	18 - E0021	OEHHA - PI	Evaluation of the Neurologic and Neurobehavioral Impacts of FDA Approved Synthetic Food Dyes	1/01/19	1/31/21
CURRENTLY ACTIVE	19 - RD019	CARB - PI	Assessment of methods to collect and analyze Perfluoroalkyl and Polyfluoroalkyl substances	2/01/20	1/31/21
CURRENTLY ACTIVE	19-E0019	OEHHA - PI	Assessing Community Exposures to Air Pollution	6/01/20	5/31/22
PENDING APPROVAL	PAR - 17 - 339	NIH - Co - Investigator	Science teaching through the arts: Bringing state - of - the - art environmental health education to youth in agricultural communities.	3/01/20	2/28/24

Co-I: Rosemary Castorina, UCB					
Status (currently active or pending approval)	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
CURRENTLY ACTIVE	20RD012	CARB	Total Exposure to Air Pollution and Noise in Disadvantaged Communities	4/1/2021	~~3/30/2024~~ **3/29/2025**
CURRENTLY ACTIVE	1R01ES027 134 - 01A1	NIH NEIHS – Co-Investigator	Reducing Pesticide Exposures to Preschool-age Children in California Child Care centers	9/30/17	8/31/22
CURRENTLY ACTIVE	18 - E0021	OEHHA - Co - Investigator	Evaluation of the Neurologic and Neurobehavioral Impacts of FDA Approved Synthetic Food Dyes	1/01/19	1/31/21
CURRENTLY ACTIVE	19 - RD019	CARB - Co-Investigator	Assessment of methods to collect and analyze Perfluoroalkyl and Polyfluoroalkyl substances	2/01/20	1/31/21
CURRENTLY ACTIVE	19-E0019	OEHHA – Co-Investigator	Assessing Community Exposures to Air Pollution	6/01/20	5/31/22
Co-I: Chelsea Preble, UCB					
Status	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
CURRENTLY ACTIVE	20RD012	CARB	Total Exposure to Air Pollution and Noise in Disadvantaged Communities	4/1/2021	~~3/30/2024~~ **3/29/2025**
CURRENTLY ACTIVE	20RD004	CARB - Co-Investigator	Plume capture measurement of vehicle emissions at the Caldecott Tunnel for Heavy-Duty Emission Program Development and Verification	2/1/2021	1/31/2025
CURRENTLY ACTIVE	Award#0497 08	Subaward - Co - Investigator	AB617 Community Air Grants for Richmond (via PSE Health Energy) and San Joaquin Valley (via Central California Asthma Coalition)	7/1/20	6/2022
PENDING APPROVAL	20203167	ICF International,	Assessment of Regulatory Air Pollution Dispersion Models to	6/2020	12/2020

		Inc. – Co - Investigator	Quantify the Impacts of Transportation Sector Emissions		
Statistical Consultant: Robert Gunier, UCB					
Status (currently active or pending approval)	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
CURRENTLY ACTIVE	20RD012	CARB	Total Exposure to Air Pollution and Noise in Disadvantaged Communities	4/1/2021	~~3/30/2024~~ **3/29/2025**
CURRENTLY ACTIVE	R01ES026994	NIH – Co Investigator	Effect of Early Life Exposure to Social adversity and pesticides on risk - taking behavior of 16 - 18 year olds: the CHAMACOS study	9/30/16	8/31/21
CURRENTLY ACTIVE	R24ES028529	NIH – Co - Investigator	Maintaining and Expanding the CHAMACOS Epidemiology Cohort Infrastructure for Future	7/01/17	6/30/22
CURRENTLY ACTIVE	044872	Alex's Lemonade Stand – Co - Investigator	Endocrine disrupting pesticides, neonatal hormones and risk of testicular germ cell tumors.	7/01/18	6/30/20
CURRENTLY ACTIVE	044732	Oxford University – PI	Early growth trajectories associated with growth and neurodevelopment	9/01/19	8/31/20
CURRENTLY ACTIVE	17 - E0025	OEHHA – PI	Dietary chlorpyrifos exposure and sociodemographic factors in California	7/01/18	6/30/20
PENDING APPROVAL	Not Available	OEHHA – Co - Investigator	Targeted Biomonitoring Community Exposures to Air Pollution	6/01/20	5/31/22

Co-I Kazukiyo Kumagi, CDPH					
Status	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
CURRENTLY ACTIVE	20RD012	CARB	Total Exposure to Air Pollution and Noise in Disadvantaged Communities	4/1/2021	~~3/30/2024~~ **3/29/2025**
CURRENTLY ACTIVE	587369	TRDRP - PI	Measuring Environmental Tobacco and Cannabis	7/1/18	6/30/21

Co-I Jeffrey Wagner, CDPH					
Status (currently active or pending approval)	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
CURRENTLY ACTIVE	20RD012	CARB	Total Exposure to Air Pollution and Noise in Disadvantaged Communities	4/1/2021	~~3/30/2024~~ **3/29/2025**
CURRENTLY ACTIVE	W912P718 C0003	U.S. EPA	Microscopy Analysis for micro - plastics from Sport Fish gut samples	2/5/18	6/30/20
CURRENTLY ACTIVE	W912P719 C0004	U.S. EPA	Analysis of microplastics from water and biota samples	9/19/19	6/30/21
Co-I Ricardo Cisneros, UC Merced					
CURRENTLY ACTIVE	20RD012	CARB	Total Exposure to Air Pollution and Noise in Disadvantaged Communities	4/1/2021	~~3/30/2024~~ **3/29/2025**

Advisor: Dr. Thomas Kirchstetter, UC Berkeley					
CURRENTLY ACTIVE	20RD012	CARB	Total Exposure to Air Pollution and Noise in Disadvantaged Communities	4/1/2021	~~3/30/2024~~ **3/29/2025**
CURRENTLY ACTIVE	20RD004	CARB	Plume Capture Measurement of Vehicle Emissions at the Caldecott Tunnel for Heavy-Duty Emission Program Development and Verification	2/1/2021	1/31/2025

EXHIBIT A7

THIRD PARTY CONFIDENTIAL INFORMATION REQUIREMENT

CONFIDENTIAL NONDISCLOSURE AGREEMENT

(Identified in Exhibit A, Scope of Work – will be incorporated, if applicable)

Exhibit A7 is not applicable for this Agreement.