Update on East Bay Diesel Exposure Project (EBDEP) Analyses

Biomonitoring California Scientific Guidance Panel Meeting

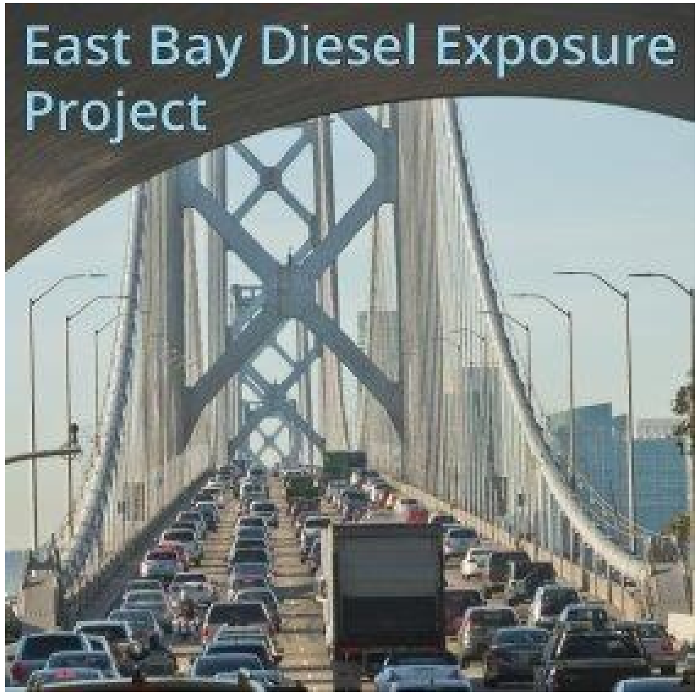
July 19th, 2024

Aalekhya Reddam

Biomonitoring California

Safer Alternatives Assessment and Biomonitoring Section, OEHHA

Project Goals



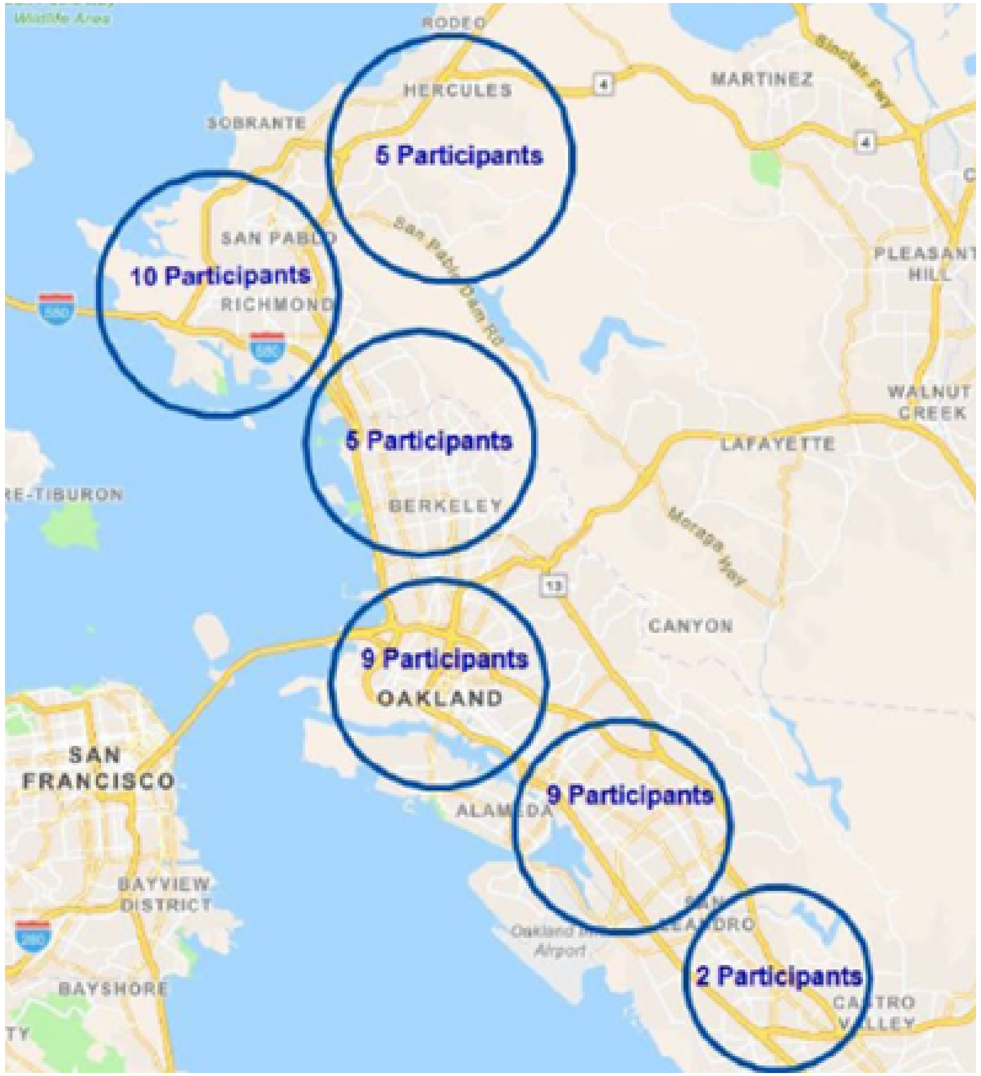
- Assess exposures to diesel exhaust in impacted communities of the East Bay
- Evaluate predictors of diesel exhaust exposure
- Compare exposures in parent - child pairs to increase understanding of exposure patterns
- Help evaluate the effectiveness of diesel regulations in California
- Engage with community and policymakers about study results

Study Design

40 parent-child pairs in the East Bay
between January 2018 and February 2019

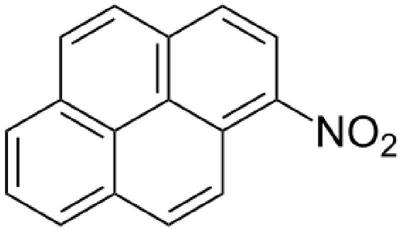
	Round 1	Round 2
Air	✓	✓
Dust	✓	
Urine	✓	✓

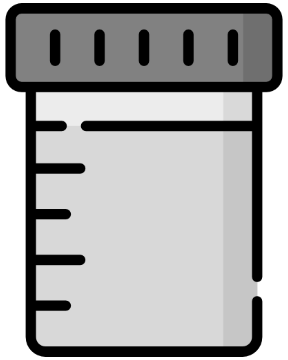
25 families gave 1 urine sample per participant per round
15 families gave 4 urine samples per participant per round

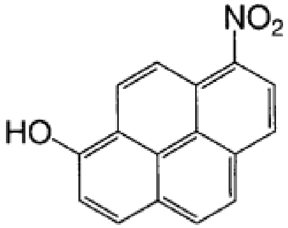


1-Nitropyrene (1-NP)

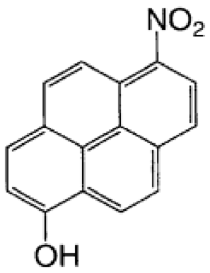
- 1-NP is the most abundant particle-associated nitro-polycyclic aromatic hydrocarbon (PAH) in diesel exhaust
- 6-hydroxy-1-nitropyrene (6-OHNP) and 8-hydroxy-1-nitropyrene (8-OHNP) are urinary metabolites of 1-NP







8-OHNP



6-OHNP

Scheepers et al. 1995; Toriba et al. 2007

Sample Analysis

Urine Samples

- 1-NP metabolites (6-OHNP and 8-OHNP)
- Pyrene metabolite (1-Hydroxypyrene)
- Volatile organic compound metabolites

Air Samples

- 1-NP
- 2-NP
- 2-Nitrofluoranthene
- Black carbon

Dust Samples

- 1-NP
- 2-NP
- 2-Nitroflouranthene

ARTICLE OPEN

Check for updates

The East Bay Diesel Exposure Project: a biomonitoring study of parents and their children in heavily impacted communities

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BACKGROUND: Diesel exhaust (DE) exposures pose concerns for serious health effects, including asthma and lung cancer, in California communities burdened by multiple stressors.
OBJECTIVE: To evaluate DE exposures in disproportionately impacted communities using biomonitoring and compare results for adults and children within and between families.
METHODS: We recruited 40 families in the San Francisco East Bay area. Two metabolites of 1-nitropyrene (1-NP), a marker for DE exposures, were measured in urine samples from parent–child pairs. For 25 families, we collected single-day spot urine samples during two sampling rounds separated by an average of four months. For the 15 other families, we collected daily spot urine samples over four consecutive days during the two sampling rounds. We also measured 1-NP in household dust and indoor air. Associations between urinary metabolite levels and participant demographics, season, and 1-NP levels in dust and air were evaluated.
RESULTS: At least one 1-NP metabolite was present in 96.6% of the urine samples. Detection frequencies for 1-NP in dust and indoor air were 97% and 74%, respectively. Results from random effect models indicated that levels of the 1-NP metabolite 6-hydroxy-1-nitropyrene (6-OHNP) were significantly higher in parents compared with their children (p-value = 0.005). Urinary 1-NP metabolite levels were generally higher during the fall and winter months. Within-subject variability was higher than between-subject variability (~60% of total variance versus ~40%, respectively), indicating high short-term temporal variability.

IMPACT: Biomonitoring, coupled with air monitoring, improves understanding of hyperlocal air pollution impacts. Results from these studies will inform the design of effective exposure mitigation strategies in disproportionately affected communities.

Keywords: Biomonitoring; Human exposure; Diesel exhaust; 1-nitropyrene; Urinary metabolites; Children

Journal of Exposure Science & Environmental Epidemiology; https://doi.org/10.1038/s41370-023-00622-1

INTRODUCTION

Diesel exhaust (DE) exposures vary widely in California, with low-income communities and communities of color often experiencing disproportionately higher exposures [1, 2]. The harmful effects of DE, including asthma, cancer, and cardiovascular disease [3–7], can be exacerbated by the multiple environmental, health, and social stressors faced by these communities [8]. Although regulations in California (13 CCR § 2025) have reduced emissions from diesel-powered vehicles overall, recent studies have found that heavily impacted areas, such as West Oakland, experience highly elevated air pollution in neighborhoods near traffic, rail, and maritime sources [9–11].

"Diesel exhaust" (i.e., the entire complex mixture) was recommended in 2009 as a priority chemical for the California Environmental Contaminant Biomonitoring Program (CECBP or Biomonitoring California) by the program's Scientific Guidance Panel (SGP), a legislatively mandated collaboration between OEHHA, the Department of Toxic Substances Control, and the California Department of Public Health (CDPH). The SGP reviews evidence for the degree of exposure, toxicity, and the ability to detect biomarkers at levels relevant to the general population when considering chemicals for the priority list.

Based on reviews of the scientific literature [4, 12–17] and a series of discussions with invited experts at SGP meetings from 2008 to 2016, metabolites of 1-nitropyrene (1-NP) were identified as the most viable biomarkers for DE exposures. 1-NP is preferentially formed by high-temperature combustion processes in diesel engines and is the most abundant nitro-polyaromatic hydrocarbon (PAH) observed in

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- At least one 1-NP metabolite was present in 97% of the urine samples
- Urinary 1-NP metabolite levels were generally higher during the fall and winter months
- Urinary 6-OHNP was significantly higher in parents compared with their children
- Children's urinary 8-OHNP were weakly correlated with 1-NP in air and dust
- Air and dust 1-NP levels were higher in homes with high CalEnviroScreen diesel PM score

Demographics

Parents	
Gender identity	%
Female	95
Male	5
Age: mean (SD) = 36.6 (7.9) years	
20-35	47.5
36-50	47.5
>50	5
*Race/Ethnicity**	
American Indian/Alaskan Native or Native Hawaiian/Other Pacific Islander	5
Asian	5
Black/African American	20
Hispanic/Latino	40
White	35
Prefer not to identify	2.5
Education	
High school diploma, GED, technical/trade school	20
Some college	20
College/graduate degree	60
Income	
0 - $25,000	20
$25,000 - $75,000	40
>$75,000	30
Prefer not to answer/don't know	10

*Some individuals selected more than one ethnicity

One participant was a smoker

Children	
Gender identity	%
Female	52.5
Male	47.5
Age: mean (SD) = 4.7 (2.1) years	
2-5	82.5
6-10	17.5
*Race/Ethnicity**	
American Indian/Alaskan Native or Native Hawaiian/Other Pacific Islander	5
Asian	7.5
Black/African American	22.5
Hispanic/Latino	45
White	40
Prefer not to identify	5
Not reported	5

Analysis Aims

Aim 1: Examine Geospatial Predictors of Diesel Exposure

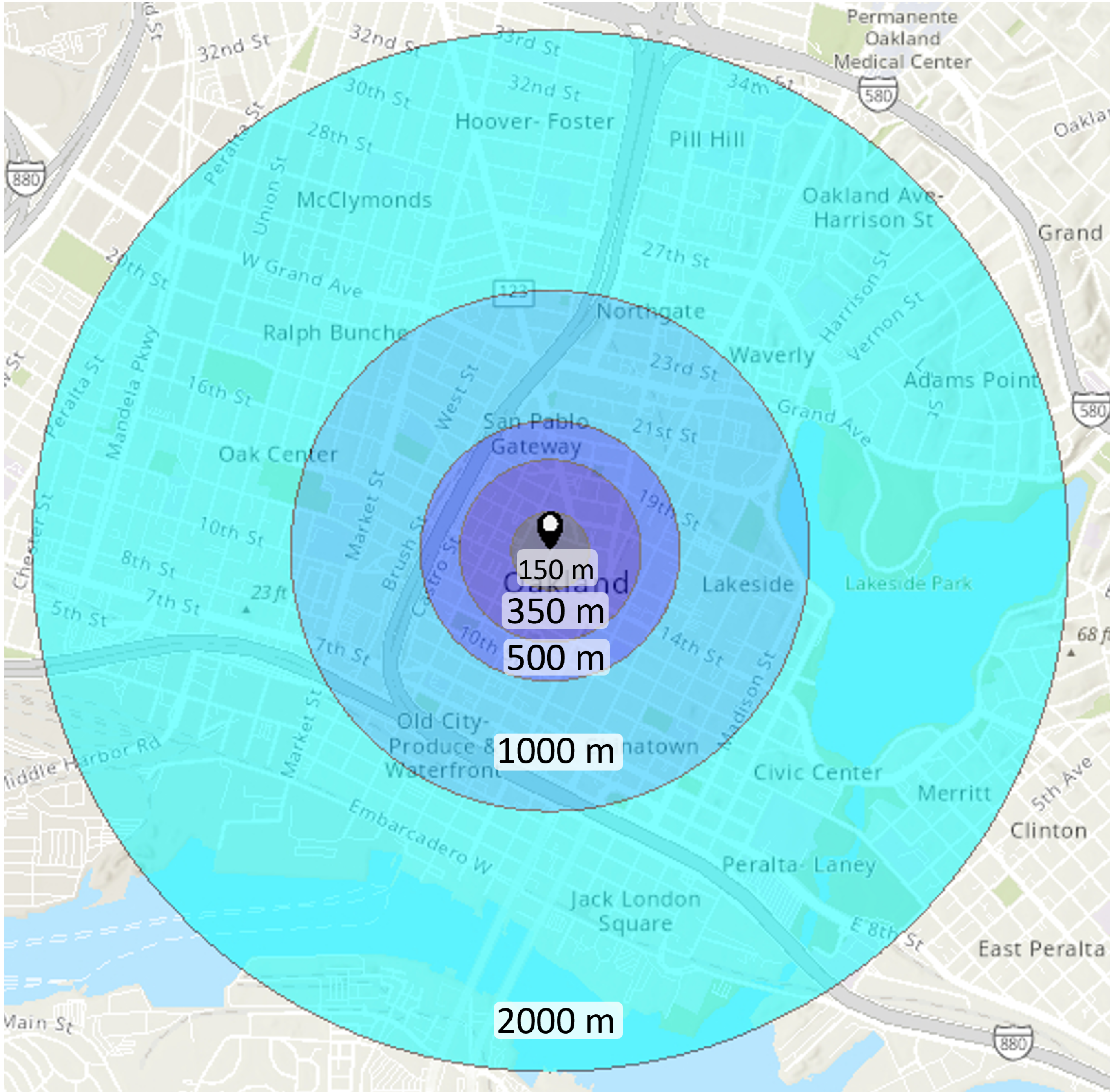
Aim 2: Examine Predictors of Volatile Organic Compound Metabolites

Aim 1: Examine Geospatial Predictors of Diesel Exposure

Geospatial Predictors of Diesel Exposure

- Spatial characteristics such as traffic volume, road density, and population density have been used to predict traffic-related air pollution.

- ArcGIS was used to create individual spatial predictor variables for each household.

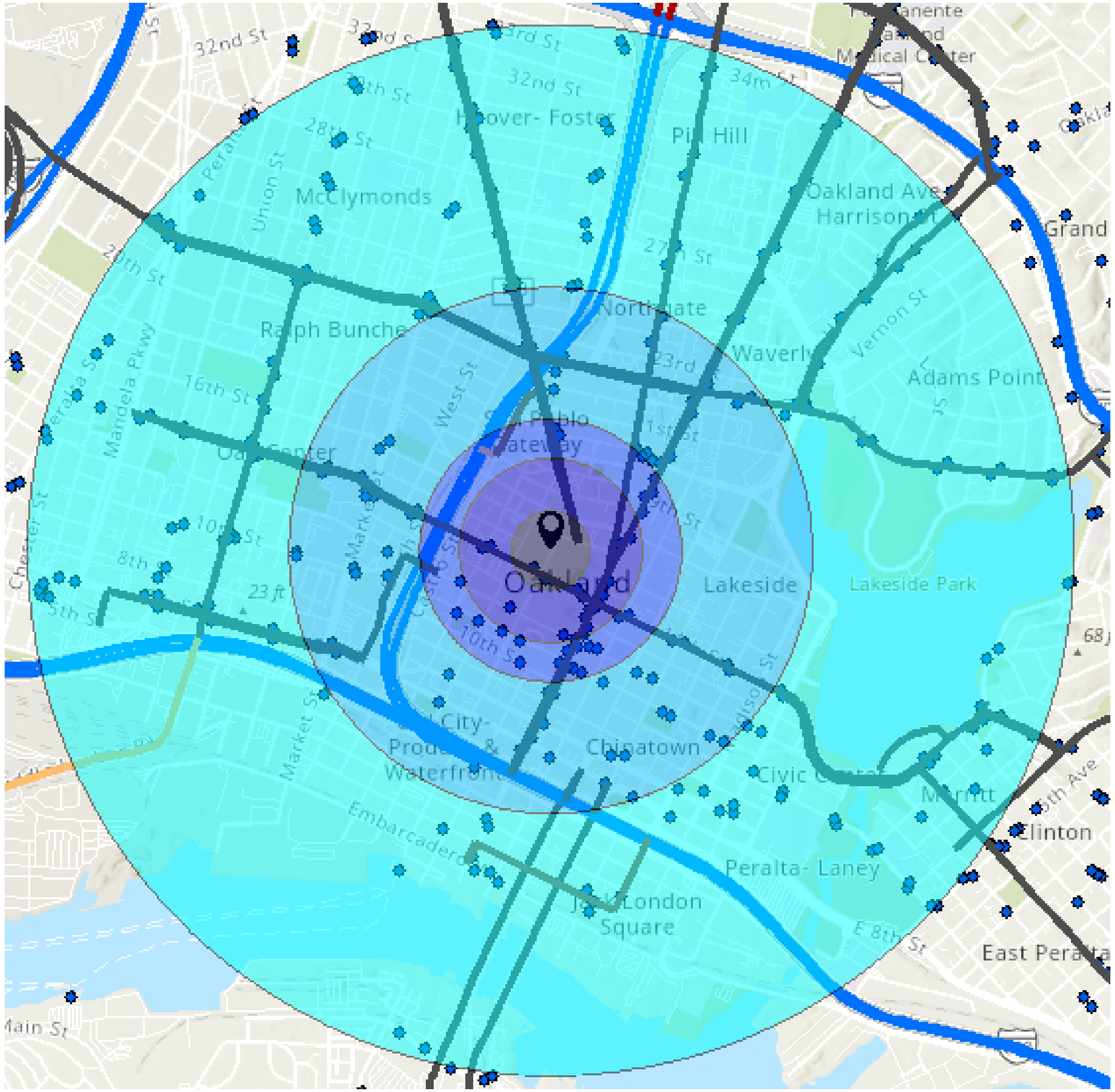


Geospatial Predictors

	Description	units	Buffer Radius (m)
Distance To	- Major road - Bottleneck road - Truck network road	$\log_{10}$ m	NA
Length of	- Bus route - Major road - Bottleneck road - Truck network road - HPMS roads*	m	150, 350, 500, 1000, 2000
Traffic Density	- All - Truck - Heavy Vehicle - Combined truck and heavy vehicle	VMT/m^2	150, 350, 500, 1000, 2000
Count of	- Permitted sources** - Bus stops	count	150, 350, 500, 1000, 2000

*HPMS: Highway Performance and Monitoring System

**Number of sources with permits from BAAQMD to emit diesel exhaust



Statistical Analysis

- Concentrations were log transformed
  - Urinary concentrations were adjusted for specific gravity
- Linear regression models were used for associations between 1-NP in dust and geospatial predictors
- Mixed effects models were used for associations between 1-NP in air and 1-NP metabolites and geospatial predictors
  - Models with metabolites were adjusted for season, income, candle use, sweep frequency, grilled and bbq food consumption, and presence of gas dryer and washer in adults
  - Models with metabolites were adjusted for season in children

Associations of 1-NP and Geospatial Predictors

	150m			*350m*			*500m*			*1000m*			*2000m*		
	Air	Dust	Urine	Air	Dust	Urine	Air	Dust	Urine	Air	Dust	Urine	Air	Dust	Urine
Traffic Density (VMT/m^2)															
All		✓			✓			✓			✓		✓	✓	
Truck		✓			✓			✓			✓			✓	
Heavy Vehicle		✓			✓			✓			✓				
Truck and Heavy Vehicle		✓			✓			✓			✓				
Count															
Permitted sources		✓			✓		✓	✓		✓			✓	✓	
Bus stops							✓			✓			✓	✓	
Length of (m)															
Major road		✓	✓		✓	✓		✓	✓		✓	✓		✓	
Bus route								✓		✓	✓		✓	✓	
Bottleneck Road		✓													
Truck Network Roads		✓						✓			✓			✓	
HPMS roads					✓			✓			✓		✓	✓	

Associations of 1-NP and Geospatial Predictors

	150m			*350m*			*500m*			*1000m*			*2000m*		
	Air	Dust	Urine	Air	Dust	Urine	Air	Dust	Urine	Air	Dust	Urine	Air	Dust	Urine
Traffic Density (VMT/m²)															
All		✓			✓			✓			✓		✓	✓	
Truck		✓			✓			✓			✓			✓	
Heavy Vehicle		✓			✓			✓			✓				
Truck and Heavy Vehicle		✓			✓			✓			✓				
Count															
Permitted sources		✓			✓		✓	✓		✓			✓	✓	
Bus stops							✓			✓			✓	✓	
Length of (m)															
Major road		✓	✓		✓	✓		✓	✓		✓	✓		✓	
Bus route								✓		✓	✓		✓	✓	
Bottleneck Road		✓													
Truck Network Roads		✓						✓			✓			✓	
HPMS roads					✓			✓			✓		✓	✓	

Associations of 1-NP and Geospatial Predictors

	150m			*350m*			*500m*			*1000m*			*2000m*		
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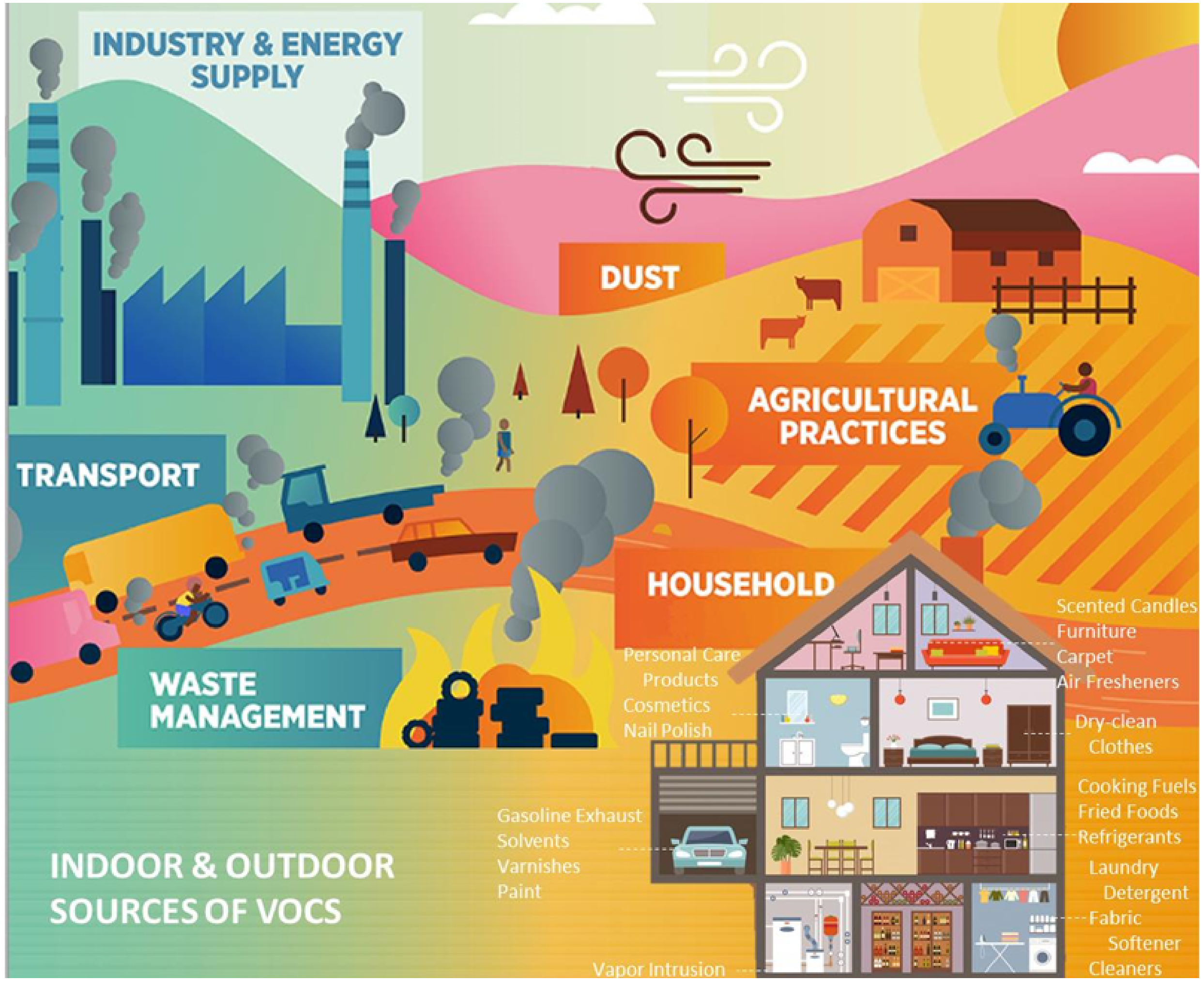
Traffic Density (VMT/m^2)															
All		✓			✓			✓			✓		✓	✓	
Truck		✓			✓			✓			✓			✓	
Heavy Vehicle		✓			✓			✓			✓				
Truck and Heavy Vehicle		✓			✓			✓			✓				
Count															
Permitted sources		✓			✓		✓	✓		✓			✓	✓	
Bus stops							✓			✓			✓	✓	
Length of (m)															
Major road		✓	✓		✓	✓		✓	✓		✓	✓		✓	
Bus route								✓		✓	✓		✓	✓	
Bottleneck Road		✓													
Truck Network Roads		✓						✓			✓			✓	
HPMS roads					✓			✓			✓		✓	✓	

Aim 2: Examine Predictors of Volatile Organic Compound Metabolites

Volatile Organic Compounds (VOCs) in EBDEP



University of Louisville Superfund Research Center

- Traffic related air pollution (Geospatial predictors)
- Household sources (Questionnaires)
  - Gas appliances
  - Candle use
  - Attached garage

VOC Metabolites Measured in Urine

Parent Compounds	Analyte	Adults		Children	
		Detection Frequency	Geometric Mean (ng/g)	Detection Frequency	Geometric Mean (ng/g)
Acrolein	CEMA	98%	90	99%	140
	HPMA	98%	220	99%	340
Acrylonitrile	CYMA	81%	2.3	87%	1.9
Benzene	MUCA	90%	52	97%	110
	PMA	31%	*	36%	*
1,3-Butadiene	MHB3	92%	3.7	97%	6.5
Crotonaldehyde	HPMM	100%	190	100%	330
Isoprene	IPM3	73%	3.7	82%	5.3
Propylene oxide	HPM2	93%	35	98%	52
Ethylbenzene/ styrene	MADA	99%	150	99%	210
	PHGA	90%	130	89%	140
Xylene	2MHA	72%	14	81%	22
	3 & 4MHA	98%	72	98%	120

* Not calculated: proportion of results below limit of detection was too high to provide a valid result

VOC Metabolites Measured in Urine

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	3 & 4MHA	98%	72	98%	120

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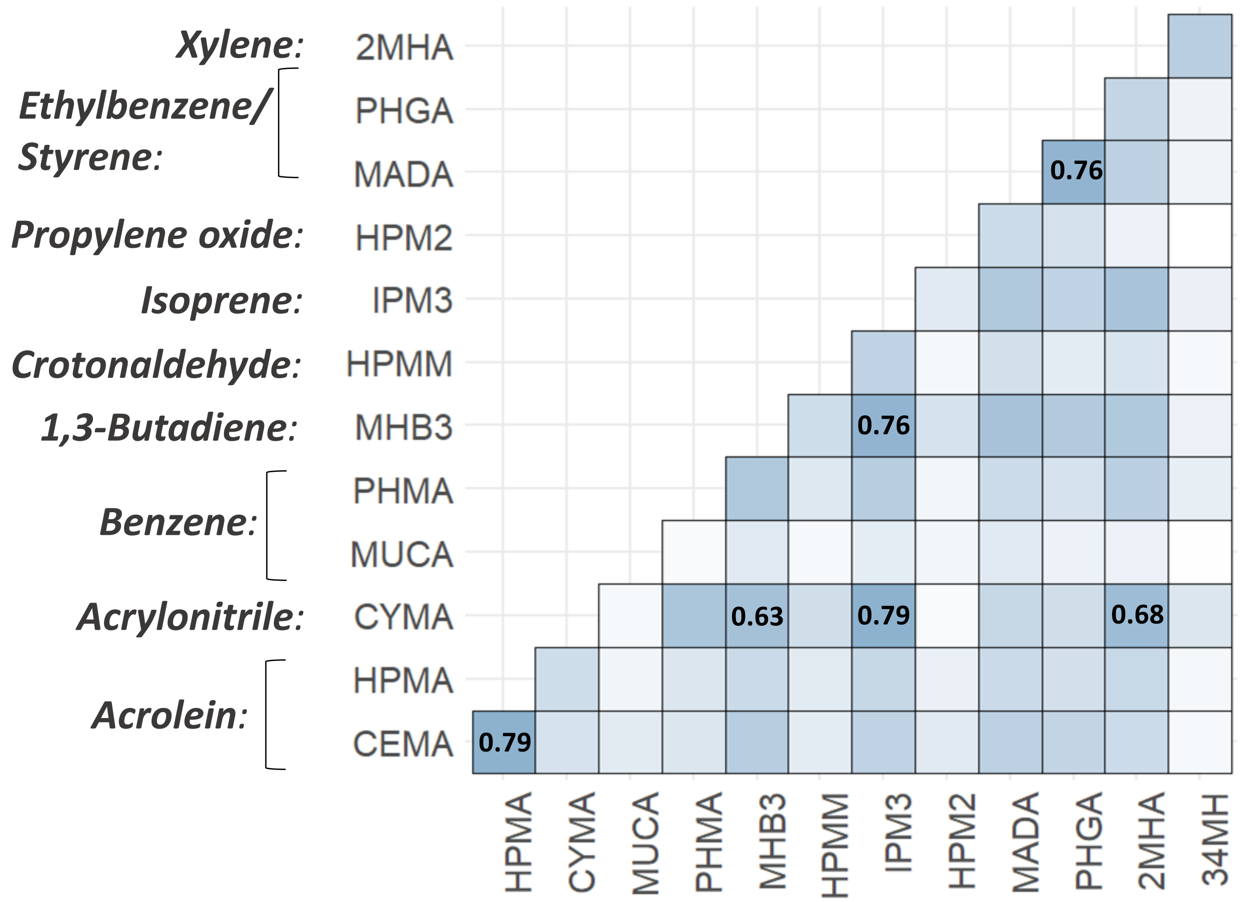
Statistical Analysis

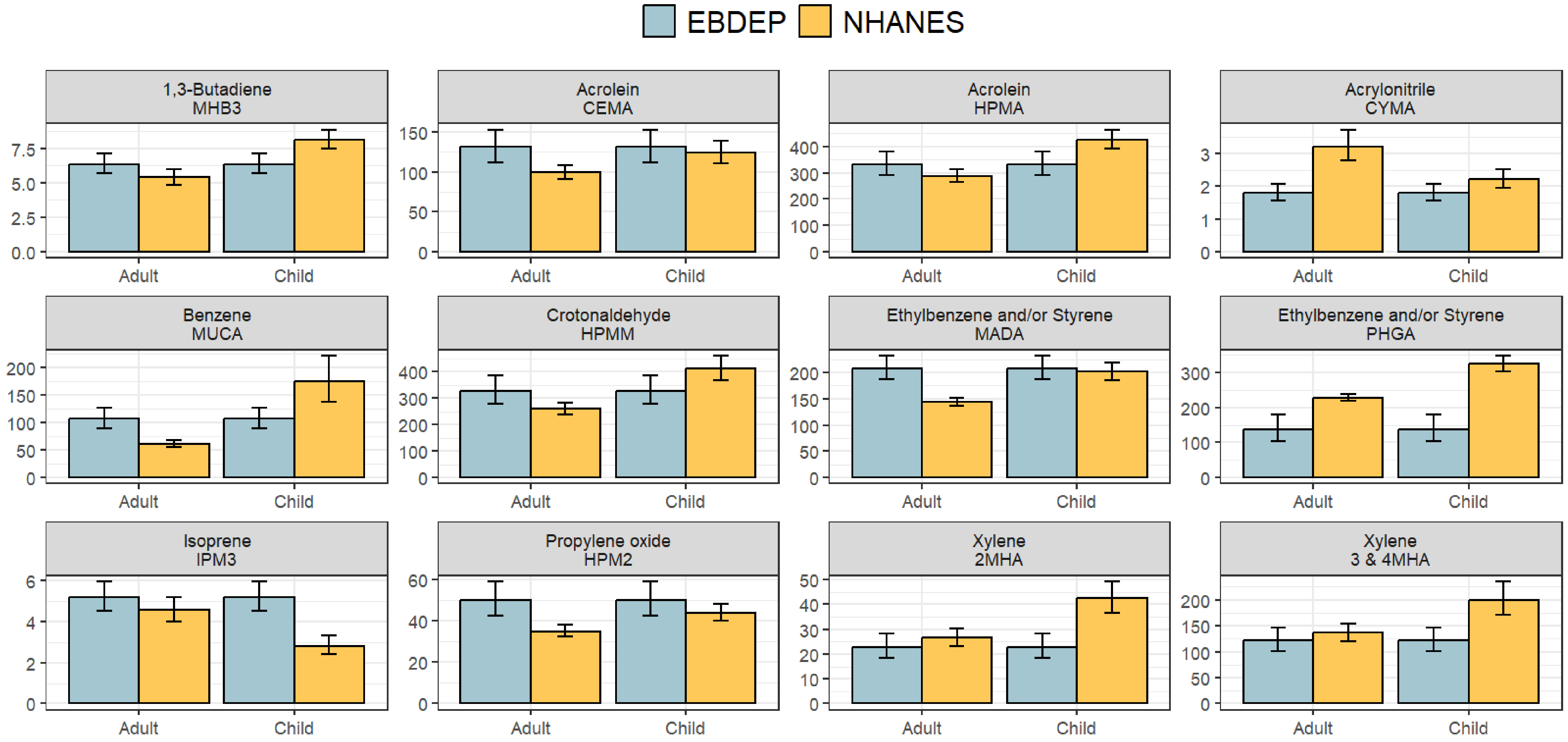
- Concentrations were adjusted for creatinine to compare to NHANES
- Concentrations were adjusted for specific gravity and log transformed for associations
- Mixed effects models were used for associations with
  - Models with geospatial predictors were adjusted for season, income, candle use, and presence of gas dryer in adults
  - Models with geospatial predictors were adjusted for season in children
- City was grouped into Richmond, Oakland, and Other to ensure a more even distribution

Correlations of VOCs

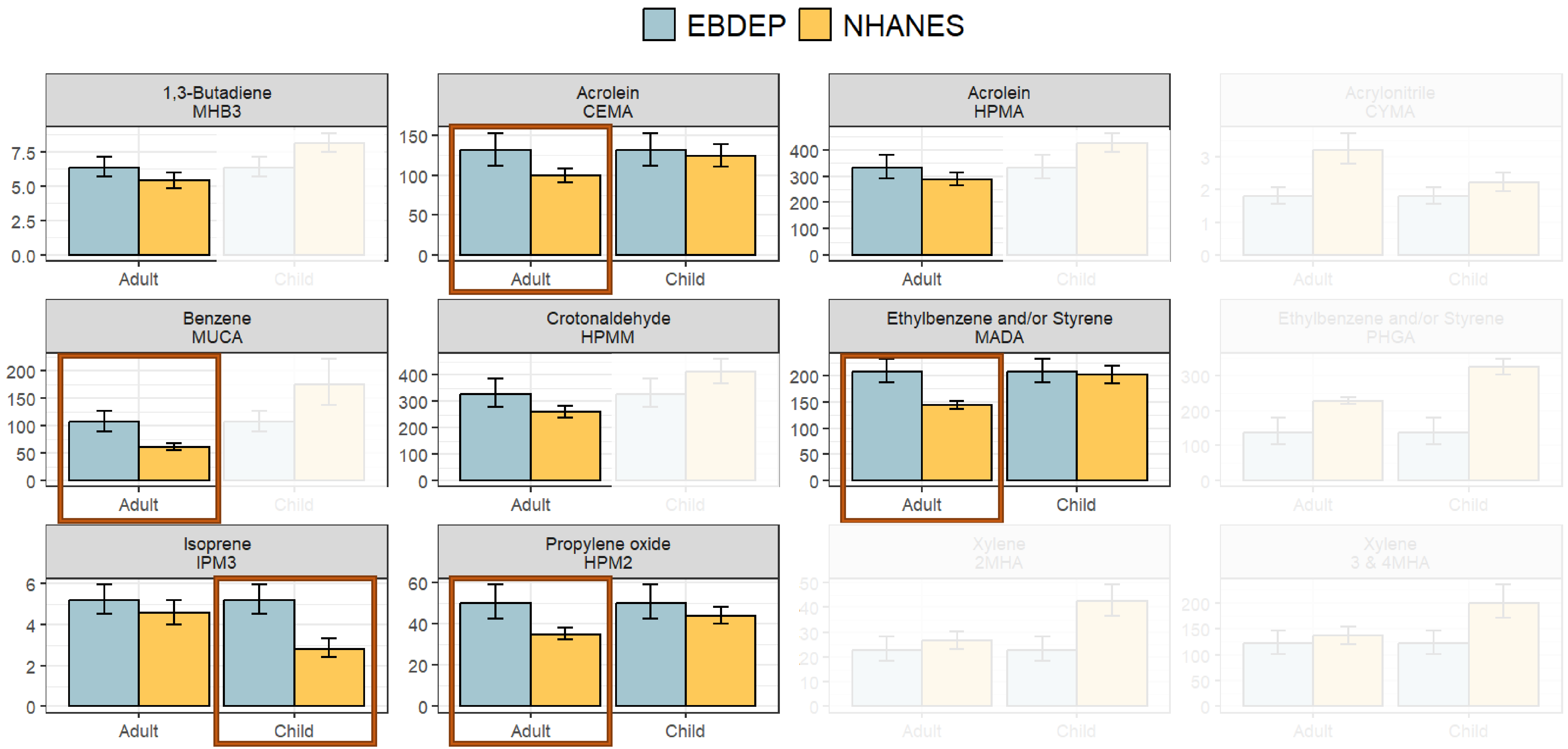


- Ethylbenzene/styrene metabolites (PHGA and MADA)
- Isoprene (IPM3), acrylonitrile (CYMA) and 1,3-butadiene (MHB3) metabolites
- Acrylonitrile metabolite (CYMA) and xylene metabolites (2MHA)
- Acrolein metabolites (CEMA and HPMA)

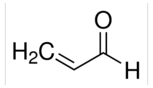
Comparison to NHANES

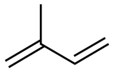
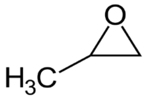


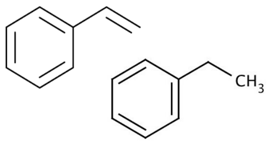
Comparison to NHANES



Some Sources of Significant VOCs





VOC	*Metabolite*	*Sources*
Acrolein	*CEMA*	**Combustion of petroleum fuels** and biodiesel; fried or burnt food; fungicide and pesticide
Benzene	*MUCA*	Natural component of gasoline and crude oil; **component of automobile exhaust**; plastics; additive to paints
Isoprene	*IPM3*	Naturally produced by plants, animals and bacteria; production of vehicle tires; synthetic rubber; **component of automobile exhaust**
Propylene Oxide	*HPM2*	Fumigant; production of polyurethane plastics and liquid for electronic cigarettes
Ethylbenzene Styrene	*MADA*	Production of plastic, synthetic rubber, resin, and other consumer products; **component of automobile exhaust**; ethylbenzene is also natural component of coal tar and petroleum

Demographic Associations with VOCs in Adults

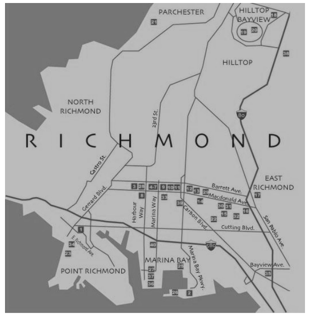
Household Income

Participants with the lowest income had:

↑ Total VOC metabolites

↑ Xylene metabolites (2MHA, 3 and 4MHA)

City of Residence



Participants who lived in Oakland compared to Richmond had:

↑ Total VOC metabolites

Race and/or Ethnicity

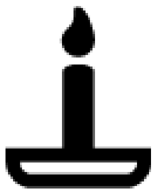
After adjusting for city of residence, Black participants had:

↑ Xylene metabolite (2MHA, 3 and 4MHA)

↑ Benzene metabolite (MUCA)

Predictors of VOCs

Candle use
in the past 3 days



↑ Total VOC metabolites in adults and children

↑ Benzene metabolite (MUCA) in adults

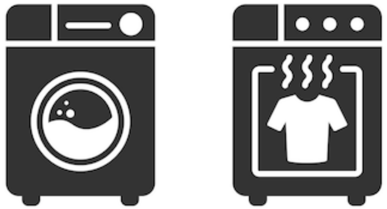
↑ Isoprene metabolite (IPM3) in adults

Gas stove use
in the past 3 days

↑ Ethylbenzene/styrene metabolite (MADA) in children

↑ Benzene metabolite (MUCA) in children

Gas washer and gas
dryer in the house



↑ Ethylbenzene/styrene metabolite (MADA) in children

↑ Total VOC metabolites in adults: *gas dryer only*

Associations of Total VOC Metabolites and Geospatial Predictors

	150m		*350m*	*500m*	*1000m*	*2000m*
	Child	Adult	Adult	Adult	Adult	Adult
Traffic Density (VMT/m^2)						
Truck		✓				
Length of (m)						
Major road	✓	✓	✓	✓		

Conclusions

- 1-NP in dust and air were *significantly associated* with geospatial predictors of traffic
  - 1-NP metabolites in urine were *positively associated* with length of major roads

- VOC metabolites were associated with
  - Demographic variables
  - Gas appliances and candle use
  - Traffic density and length of major roads

Acknowledgements

- Participants of EBDEP
- West Oakland Environmental Indicators Project
- University of Washington
- Lawrence Berkeley Lab
- Centers for Disease Control and Prevention
- Biomonitoring California staff