Overview of Biomonitoring California Activities on Perfluoroalkyl and Polyfluoroalkyl Substances (PFASs)

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BIOMONITORING CALIFORNIA

Center for Healthy Communities
Environmental Health Investigations Branch

Studies of PFASs situated within Biomonitoring California's mandate

- Determine biological levels of environmental chemicals in Californians
- Establish trends in the levels of these chemicals in Californians' bodies over time
- Help to assess the effectiveness of public health efforts and regulatory programs to decrease exposures to specific chemicals

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OEHHA California Office of Environmental Health Hazard Assessment

Department of Toxic Substances Control

Surveillance biomonitoring and targeted studies

Biomonitoring California's approach:

- Investigate overall population trends with surveillance activities

- Characterize populations of concern using community-based studies
  - Geographic areas
  - Specific racial/ethnic community or occupational group
  - Sensitive sub-populations, such as pregnant women

Today's PFAS topics

- Program's approaches for assessing levels in different populations in CA
- Demographic trends including ethnic/racial disparities
- Opportunities for further data analyses and prioritization
  - Impact on public health action and assessing regulatory efforts
  - Investigating potential links to exposure sources

Biomonitoring California Studies with PFASs – 2010-2020

Acronym	Study	12 PFASs	~30 PFASs
FOX	Firefighter Occupational Exposures Project	X	
MIEEP	Maternal and Infant Environmental Exposure Project	X	
PBEST	Pilot Biomonitoring Exposures Study	X	
MAMAS	Measuring Analytes in Maternal Archived Samples (3 Rounds)	X (round 1)	X (later rounds)
EBEST	Expanded Biomonitoring Exposures Study	X	
ACE 1 & 2	Asian/Pacific Islander Community Exposures Project 1 & 2		X
CARE	California Regional Exposure Studies (CARE-LA, CARE-2, CARE-3)	X	*

**Expanded panel may be added in later regions*

Today's highlighted studies

General population

BEST, Kaiser members
2011-2013

Asian Americans

ACE 1 & 2
2016-2017

Pregnant women

MAMAS
2012, 2015-16

General population 2018

CARE Study LA

CARE Study 2

General population 2019

Selected findings from prior PFASs investigations

For some PFASs, we found:

- High detection frequencies: PFNA, PFOA, PFOS, Me-PFOSA, PFHxS
  - EBEST, MAMAS, ACE
- Increasing levels with age
  - EBEST, ACE
- Differences observed by sex/gender – higher levels in males
  - EBEST, ACE
- Differences observed by race/ethnicity – Asians tend higher
  - EBEST, ACE (compared to national levels)

The California Regional Exposure (CARE) Study

CARE Study

CARE-LA

CARE-2

CARE Study

- CARE-LA
  - Spring of 2018
  - 430 participants
- CARE-2
  - Spring of 2019
  - 359 participants

CARE Study

- CARE-LA
  - 61% female
  - Median age 51
  - Larger percentage minorities
    - Asians 16%
    - Blacks 11%
- CARE-2
  - 56% female
  - Median age 51
  - Lower percentage minorities
    - Asians 6%
    - Blacks 5%

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CARE Study

- CARE-LA
  - 61% female
  - Median age 51
- CARE-2
  - 56% female
  - Median age 51

Currently weighting the data to improve population estimates

Detection frequencies of 12 PFAS

	Detection frequency (%)	
	CARE-LA 2018	CARE-2 2019
Me-PFOSA-AcOH	100	79
PFHxS	99	99.7
PFOA	99	99
PFOS	98	98
PFNA	97	92
PFUdA	82	58
PFDeA	69	66
PFHpA	53	43
Et-PFOSA-AcOH	31	19
PFOSA	25	20
PFBS	5	11
PFDoA	2	0

- **At least 1 PFAS in almost all participants**
- **6-7 PFASs above 65% detection frequency**

Comparisons to NHANES 2017-2018

-data re-censored with higher NHANES LOD for comparability

	CARE-LA 2018	CARE-2 2019	NHANES 2017-18
	Unweighted geometric mean		
PFOS	2.19	2.39	4.50
PFOA	1.06	0.98	1.45
PFHxS	0.65	0.80	1.11
PFNA	0.33	0.22	0.42

*PFDeA, PFUA, Me-PFOSA-AcOH GM's not comparable to NHANES after re-censoring

Comparisons to NHANES 2017-2018

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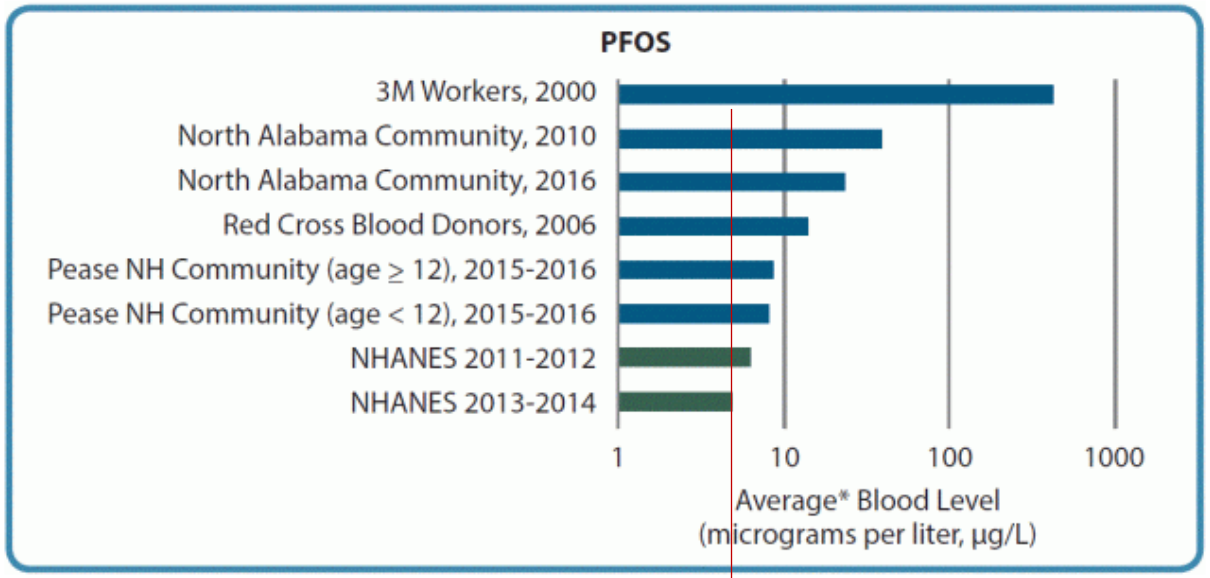
PFHxS	0.65	0.80	1.11
PFNA	0.33	0.22	0.42

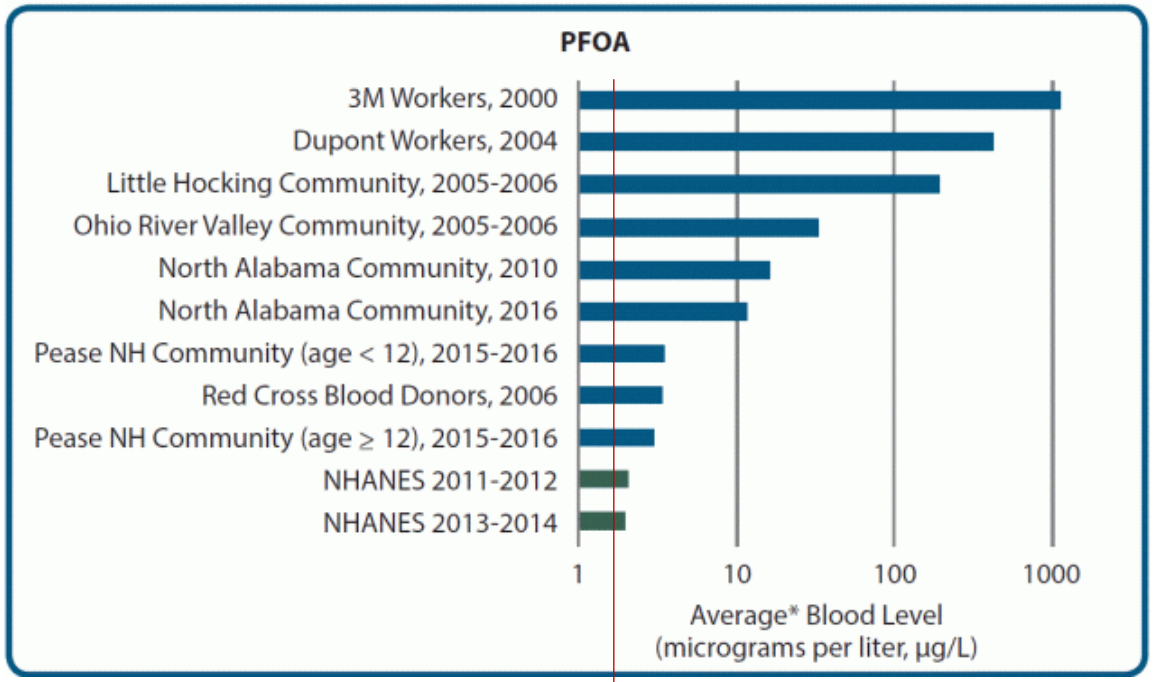
Lower than NHANES, though temporal effects may play a role

Highly impacted communities not evident so far in CARE surveillance



* Average = geometric mean

95%ile
CARE LA: 8.3 ug/L
CARE-2: 8.7 ug/L



95%ile
CARE-LA: 3.1 ug/L
CARE-2: 2.7 ug/L

Image source: https://www.atsdr.cdc.gov/pfas/pfas-in-population.html

Gender: Males often higher than females

	CARE-LA % change	CARE-2 % change
Me-PFOSA-AcOH	ns	ns
PFOA	25%	24%
PFHxS	87%	80%
PFOS	57%	52%
PFNA	18%	ns
PFDeA	ns	ns

Unweighted data, adjusted for race and age
ns = no statistical change by gender
No statistical differences between studies

Age: Increasing age and higher concentrations

	CARE-LA 2018 % change by decade	CARE-2 2019 % change by decade
PFOS	22%	20%
Me-PFOSA-AcOH	18%	17%
PFHxS	14%	19%
PFNA	12%	14%
PFOA	11%	15%
PFDeA	7.8%	8.5%

Unweighted data, adjusted for race and gender, where appropriate.
No statistical differences between studies

Race/ethnicity

General trends:
Asians > Whites >
Hispanics > Blacks

% Change

Comparisons	Study	PFOA	PFHxS	PFNA	PFOS	PFDeA
Asians > Blacks	CARE-LA	80	82	107	132	144
	CARE-2	ns	ns	ns	ns	110
Asians > Hispanics	CARE-LA	60	52	91	102	103
	CARE-2	64	ns	79	89	78
Asians > Whites	CARE-LA	ns	ns	63	ns	84
	CARE-2	ns	ns	ns	ns	ns

Unweighted data, adjusted for age and gender, where appropriate; Tukey's test, $p<0.05$, ns= non-significant

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	CARE-2	64	ns	79	89	78
Asians > Whites	CARE-LA	ns	ns	63	ns	84
	CARE-2	ns	ns	ns	ns	ns
Whites > Blacks	CARE-LA	43	56	ns	ns	ns
	CARE-2	ns	ns	ns	ns	ns
Whites > Hispanics	CARE-LA	28	ns	ns	ns	ns
	CARE-2	ns	ns	ns	ns	ns

Unweighted data, adjusted for age and gender, where appropriate; Tukey's test, $p<0.05$, ns= non-significant

Race/ethnicity

General trends: Asians > Whites > Hispanics > Blacks

- But, levels in Blacks were highest in Me-PFOSA-AcOH in both regions
  - 38% higher compared to Hispanics in LA, other comparisons don't reach significance

% Change

Comparisons	Study	PFOA	PFHxS	PFNA	PFOS	PFDeA
Asians > Blacks	CARE-LA	80	82	107	132	144
	CARE-2	ns	ns	ns	ns	110
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	CARE-2	ns	ns	ns	ns	ns
Whites > Blacks	CARE-LA	43	56	ns	ns	ns
	CARE-2	ns	ns	ns	ns	ns
Whites > Hispanics	CARE-LA	28	ns	ns	ns	ns
	CARE-2	ns	ns	ns	ns	ns

Contribution of fish and shellfish

- Large, local PFAS contamination sites not known in these regions
  - Some drinking water systems and groundwater detections
- Fish and shellfish contributions noted in studies with recent biomarkers
  - BEST 2013 – fish and PFNA, PFDeA, PFUdA
  - NHANES 2003-2014 - fish with PFDeA, shellfish with PFNA, PFDeA, PFOS (Christensen et al. 2017 and Susmann et al. 2019)
  - SF pregnant mothers 2014-2016 - fish/shellfish with PFOS, PFDeA, PFUdA (Eick et al. 2021)
- Other dietary contributors in these studies:
  - packaged foods, ice cream, soda, fast food, restaurant food, microwave popcorn, poultry, red meat

Multivariable associations with fish and shellfish in CARE-2

- PFDeA was the only PFAS positively associated with:
  - Fish bought in store
  - Fish caught by someone known to participant
  - Shellfish bought in store
  - Shellfish caught by someone known to participant

*Multivariable analyses using unweighted data

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Multivariable associations with fish and shellfish in CARE-2: PFDeA

	% adjusted change	p-value
Fish meals, caught and bought*		
over 3 times per week of each	60.6	0.02
1-3 times per week of either/both	22.4	0.02
less than once per week	ref	
Race/ethnicity		
Asian alone	62.4	<0.01
Black alone	-9.8	0.59
Hispanic any	1.4	0.87
Non-Hispanic multi-racial and Other	-4.6	0.79
White alone	ref	
Age (decades)	6.6	0.01

Shellfish associated in demographic analyses only

*Fish meal frequency: combined variables caught by someone known to participant and/or bought in store, also adjusted for margarine and take out food consumption

PFDeA – fish meals may impact race/ethnicity differences

	% adjusted change with fish	% adjusted change without fish
Fish meals, caught and bought		
over 3 times per week of each	60.6	-
1-3 times per week of either/both	22.4	-
less than once per week		
Race/ethnicity		
Asian alone	62.4	73.4
Black alone	-9.8	-6.0
Hispanic any	1.4	0.15
Non-Hispanic multi-racial and Other	-4.6	-8.8
White alone	ref	ref
Age (decades)	6.6	6.3

*Fish meal frequency: combined variables caught by someone known to participant and/or bought in store, also adjusted for margarine and take out food consumption

Multivariable associations with fish and shellfish and demographics in CARE-LA

PFDeA	% adjusted change with fish	p-value	% adjusted change without fish	p-value
Fish meals, caught and bought				
over 3 times per week of each	43.5	<0.01		
1-3 times per week of either/both	29.1	0.06		
less than once per week	ref	-		
Race/ethnicity				
Asian alone	84.9	<0.01	89.3	<0.01
Black alone	-23	0.05	-22.3	0.06
Hispanic any	-4.8	0.62	-6.7	0.48
Non-Hispanic multi-racial and Other	22.6	0.25	14.9	0.42
White alone	ref		ref	
Age (decades)	7.3	<0.01	8.1	<0.01

Shellfish associated in combination with demographic analyses only

Multivariable associations with fish and shellfish and demographics in CARE-LA

PFUdA	% adjusted change with fish	P-value	% adjusted change without fish	P-value
Fish meals, caught and bought				
over 3 times per week of each	181.1	<0.01		
1-3 times per week of either/both	77.7	<0.01		
less than once per week	ref	-		
Race/ethnicity				
Asian alone	118.8	<0.01	131.9	<0.01
Black alone	-30.0	0.01	-26.7	0.04
Hispanic any	-28	<0.01	-31.4	<0.01
Non-Hispanic multi-racial and Other	37.4	0.09	17.5	0.4
White alone	ref		ref	
Age (decades)	4.9	0.1	5.9	0.05

Shellfish associated in combination with demographic analyses only

Correlations with blood mercury

- indicator of fish and shellfish consumption

	CARE-LA		CARE-2	
	Rho	p-value	Rho	p-value
PFOA	0.22	<0.01	0.09	0.09
PFOS	0.29	<0.01	0.07	0.17
PFUdA	0.71	<0.01	0.44	<0.01
PFDeA	0.45	<0.01	0.24	<0.01
PFNA	0.36	<0.01	0.15	0.01
PFHxS	0.17	<0.01	-0.05	0.35

Pearson's rho using natural log of PFAS and blood mercury

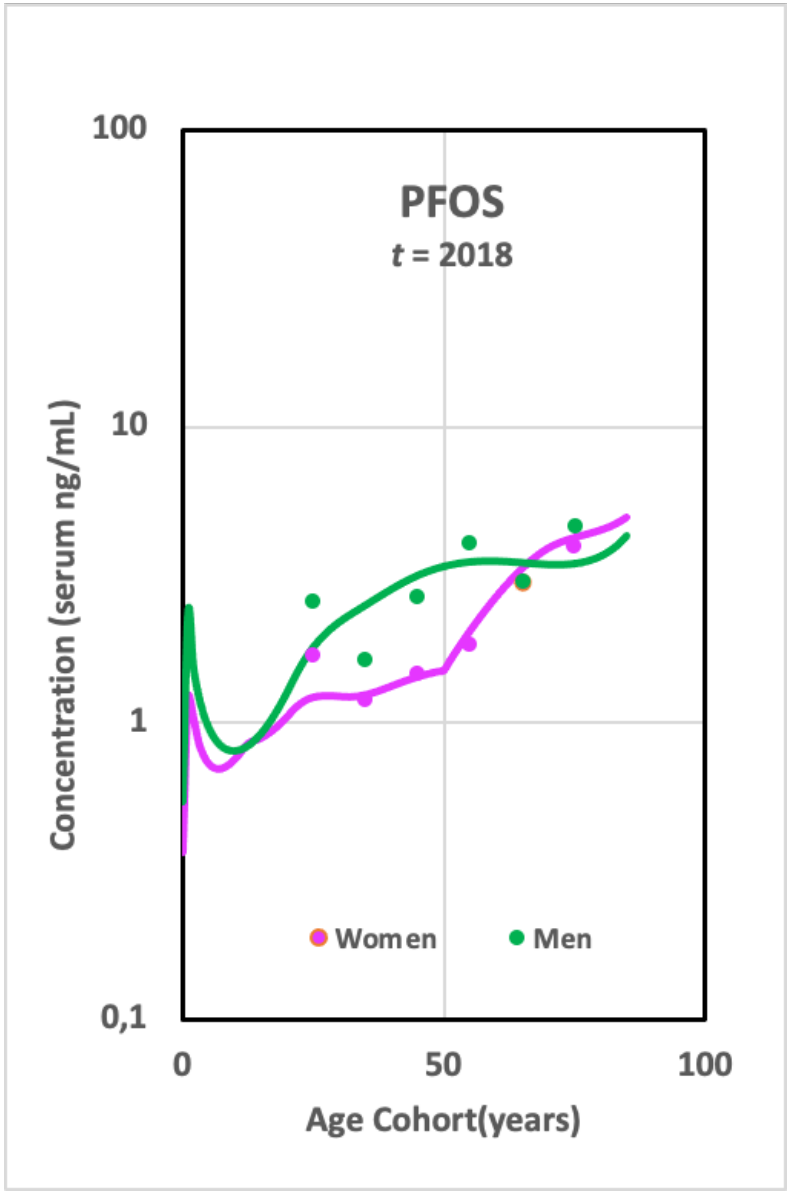
Strongest with PFUdA and PFDeA

Current work for CARE data

- CARE-3 distribution data to be placed on web repository
- Effort to weight participant data will allow better population estimates
- Report in progress
  - Distribution data and trends by demographics
- Population-based pharmacokinetic (PBPK) modeling

Population-based pharmacokinetic (PBPK) modeling

Collaboration with M. MacLeod of University of Stockholm



- Simulating lifetime intake, body burdens, and elimination kinetics at the population level using CARE data

Environmental Science & Technology
Article
pubs.acs.org/est

Enhanced Elimination of Perfluorooctane Sulfonic Acid by Menstruating Women: Evidence from Population-Based Pharmacokinetic Modeling

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Opportunities for CARE data

- Links to interventions – PFAS and fish consumption
- Broader work on other survey data on exposure source association
  - link to potential for evaluating policy efforts
- Investigate links to drinking water
- Investigate profiles of PFAS may reveal more information about relative sources

Broader look at PFASs in California:

Other populations under study beyond Biomonitoring California – 2010-present

- Middle aged women
  - California Teachers Study
- Female firefighters and office workers
  - Women Workers study
- Pregnant women or mothers +/- children
  - MAMAS-GWU/Harvard
  - Chemicals in Our Bodies/ECHO
  - CHARGE
  - DREAM
- Participants in ATSDR study in Orange county
- Military firefighters

Recent publications on PFAS data from California populations

- Descriptive distribution or detection data
  - Developing a suspect screening workflow for maternal/cord blood samples
  - Concentrations in female firefighters and office workers*
- Predictors
  - Dietary predictors
- Links to health endpoints
  - Telomere length*
  - Birth outcomes, offspring neurodevelopment

†Uses DTSC laboratory PFAS data, *Uses UCSF laboratory PFAS data
Wang et al. 2021, Eick et al. 2020, Eick et al. 2021A, Eick et al. 2021B, Trowbridge et al. 2020, Clarity et al. 2021

Current work and opportunities – BEST 2013

Prioritizing and seeking collaborations

- Current work
  - Calculate and place on web repository weighted distributions and central estimates
- Opportunities
  - Finalize and publish analyses on associations with demographics and potential dietary sources
  - Examine other potential data sources
    - Drinking water
  - More?

Opportunities - ACE 1&2, 2016-2017
Prioritizing and seeking collaborations

- Learn more about impact of current choices and conditions on PFAS
  - More detailed dietary questionnaire than other studies
    - Associations with organ meat consumption
- Learn more about contribution of prior experiences
  - Associations with birth country and time in US, truly a body burden issue?
- Learn potential limitations of data collection methodology
  - Possible limits due to homogeneity of exposure
  - Inform future targeted studies
- PFAS profiles
- More?

Current work and opportunities – MAMAS 2012, 2015, 2016
Prioritizing and seeking collaborations

- Current work
  - Finish processing lab for 2015 and 2016 data sets
  - Place distribution data in web repository
- Opportunities
  - Create weights and examine time trends
  - If continue to use Genetic Disease Screening Program/Biobank as a source:
    - Can create weighted time trend data
    - Identify emerging PFAS trends, nontargeted screening approaches
      - No report back required

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Thank you!

- Participants!
- Biomonitoring California Staff
- Kaiser Northern California
- ACE collaborating organizations
- CARE-LA supporting organizations
- CARE-2 supporting organizations
- CDPH Genetic Disease Screening Program
- State and CDC funding
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