Implementation of the California Environmental Contaminant Biomonitoring Program: 2021-2023

Eighth Report to the California Legislature

July 2021 – June 2023

California Department of Public Health
In collaboration with
California Environmental Protection Agency's
Office of Environmental Health Hazard Assessment and
Department of Toxic Substances Control

Acknowledgements

We would like to acknowledge and express our appreciation to all Biomonitoring California staff who participated in producing this report.

In addition, we thank all the reviewers from CalEPA, CDPH, OEHHA, and DTSC for their insightful comments and suggestions.

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A legislative report describing Biomonitoring California's findings is required every two years (H&SC Section 105459(a)). This is the eighth report, covering Biomonitoring California's activities and findings from July 2021 through June 2023.

The recommendations in this report do not necessarily represent the views or opinions of CDPH, CalHHS, OEHHA, or DTSC

This report is available online at:

https://biomonitoring.ca.gov/biomonitoring-california-reports

Copies may also be requested from the Environmental Health Investigations Branch, California Department of Public Health,
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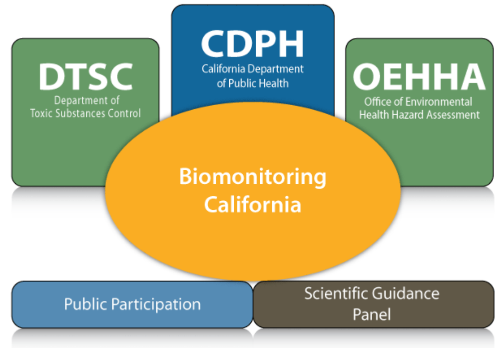
Executive Summary



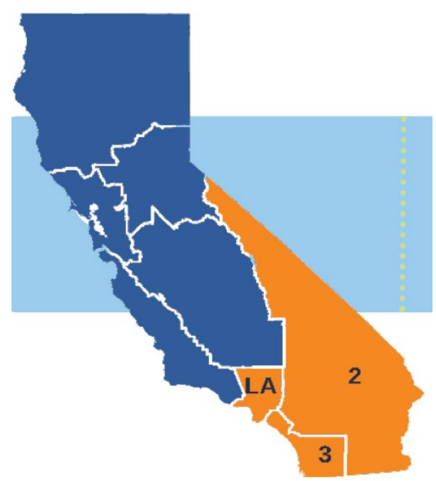
Biomonitoring California, a tri-departmental collaboration between the California Department of Public Health (CDPH), the Office of Environmental Health Hazard Assessment (OEHHA), and the Department of Toxic Substances Control (DTSC), was created through legislation (SB 1379, Perata and Ortiz, Chapter 599, Statues of 2006) to assess chemical exposures across the California population.

Through SB 1379, California legislators envisioned an ambitious program that would help policymakers and health advocates understand what chemicals Californians are exposed to, which communities experience a higher burden of exposure than others, and what exposure sources are significant in California.

This report summarizes programmatic activities from July 2021 – June 2023. The highlighted activities from this reporting period demonstrate the progress Biomonitoring California continues to make in line with efforts to measure and reduce chemical exposures.

Program accomplishments include:

- Conducted biomonitoring surveillance through the California Regional Exposure (CARE) Study.
- Developed a new biomonitoring surveillance plan, Studying Exposures in Prenatal Samples (STEPS), to measure chemical exposures in California's youngest population.
- Conducted and analyzed data from five community studies focused on highly impacted populations.
- Developed and distributed new fact sheets on chemical exposures and on CARE Study results.
- Worked in collaboration with academic researchers, community organizations, and other state programs.
- Developed and expanded laboratory methods for the detection of additional chemicals of concern, including nickel, volatile organic compounds (VOCs), and an expanded list of perfluoroalkyl and polyfluoroalkyl substances (PFASs).

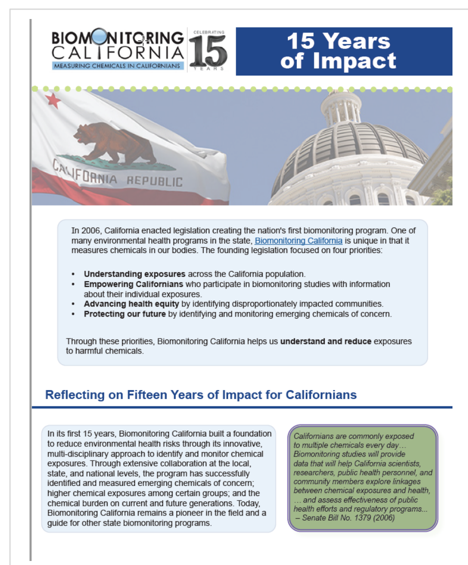


Counties included in the CARE Study are shown in orange

Key findings during this reporting period include:

- Over 99 percent of the Los Angeles and CARE Region 2 population have PFASs in their bodies.
- While lead levels have been diminishing in the environment and the population overall, 100 percent of the studied populations still have lead in their bodies.
- Racial disparities in exposures are evident: arsenic, mercury, and PFAS levels were highest in Asian populations, and in Los Angeles, cadmium levels were higher in the Black population.
- The Asian/Pacific Islander Community Exposures (ACE) Project found that PFAS levels in the study population were higher than national levels.
- PFAS levels were higher in men than women. Women's levels are generally lower because of PFAS losses during menstruation and the transmission of PFASs to offspring during pregnancy and breastfeeding, which lead to prenatal and perinatal PFAS exposures for infants.
- Differences in PFAS exposures by age were evident, with older participants having higher levels of PFASs.
- PFAS exposures prior to immigration are also an important consideration. Portion of life spent in the U.S., birth country, and primary language spoken were associated with different types of PFAS exposures.

During this reporting period, Biomonitoring California ("the Program") marked its 15th anniversary. Over the past fifteen years, Biomonitoring California has developed the expertise and tools needed to design and implement biomonitoring work. The Program provides critical data to help answer questions about how Californians are exposed to different chemicals, the implications of continued exposures, and the unequal burden of exposures facing some communities.



BIOMONITORING CALIFORNIA
MEASURING CHEMICALS IN CALIFORNIANS
CELEBRATING 15 YEARS

15 Years of Impact

In 2006, California enacted legislation creating the nation's first biomonitoring program. One of many environmental health programs in the state, Biomonitoring California is unique in that it measures chemicals in our bodies. The founding legislation focused on four priorities:

- **Understanding exposures** across the California population.
- **Empowering Californians** who participate in biomonitoring studies with information about their individual exposures.
- **Advancing health equity** by identifying disproportionately impacted communities.
- **Protecting our future** by identifying and monitoring emerging chemicals of concern.

Through these priorities, Biomonitoring California helps us **understand and reduce** exposures to harmful chemicals.

Reflecting on Fifteen Years of Impact for Californians

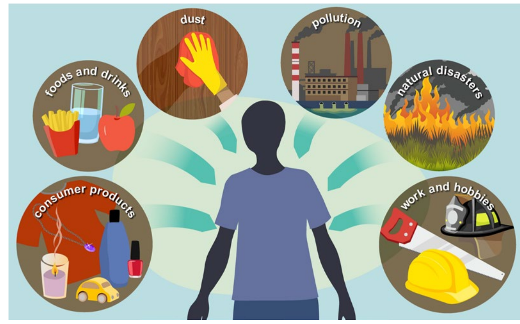
In its first 15 years, Biomonitoring California built a foundation to reduce environmental health risks through its innovative, multi-disciplinary approach to identify and monitor chemical exposures. Through extensive collaboration at the local, state, and national levels, the program has successfully identified and measured emerging chemicals of concern; higher chemical exposures among certain groups; and the chemical burden on current and future generations. Today, Biomonitoring California remains a pioneer in the field and a guide for other state biomonitoring programs.

Californians are commonly exposed to multiple chemicals every day… Biomonitoring studies will provide data that will help California scientists, researchers, public health personnel, and community members explore linkages between chemical exposures and health, … and assess effectiveness of public health efforts and regulatory programs... – Senate Bill No. 1379 (2006)

Biomonitoring California: 15 Years of Impact celebrates some of this unique Program's accomplishments and preparations for future challenges.

Introduction

Californians are exposed to thousands of chemicals every day. Many of the chemicals in our environment impact human health, from increased cancer risk to susceptibility to infectious disease[1,2]. Biomonitoring California identifies and measures chemical exposures—and how they differ among California communities—to help address health disparities and build a future where every California resident can be healthy and thrive.



Sources of human exposure to environmental chemicals

This report highlights programmatic activities from July 2021 – June 2023. During this reporting period, Biomonitoring California ("the Program") marked its 15th anniversary. Biomonitoring California: 15 Years of Impact, a summary of the Program's achievements and growth over its first 15 years, is available on the Biomonitoring California website.

Through continued local and statewide partnerships, Biomonitoring California has advanced knowledge of chemical impacts in California communities. The Program has also contributed to inter-agency collaborations for a more coordinated approach to environmental health.

Over fifteen years ago, environmental health advocates and California legislators shared the vision of a program that would assess chemical exposures to inform exposure reduction actions and improve health for Californians. The activities described in this report reflect the implementation of that vision.

About Biomonitoring California

The Biomonitoring California program uses measurements of chemicals and their break-down products, or metabolites, in blood and urine ("biomonitoring") to assess chemical exposures on an individual level. The detection of chemicals and their metabolites in Californians' bodies shows that the chemicals are not only in the environment and in products, but that they actually enter our bodies, often interacting with critical biological functions. These interactions can

[1] Woodruff, TJ, Rayasam, SDG, Axelrad, DA. et al. (2023). A science-based agenda for health-protective chemical assessments and decisions: overview and consensus statement. Environ Health 21 (Suppl 1), 132). https://doi.org/10.1186/s12940-022-00930-3

[2] Fuller, R, Landrigan, PJ, Balakrishnan, K, Bathan, G, Bose-O'Reilly S, Brauer, M. *et al.* (2022). Pollution and health: a progress update. *The Lancet Planetary Health* **V6**, Issue 6.

increase our risk of developing cancer or other disease; moreover, health impacts are often greater in sensitive groups such as children.

Data generated through biomonitoring are critical to understanding what chemicals Californians are exposed to, which communities experience a higher burden of exposure than others, and what sources of exposure are significant in California. Biomonitoring data also provide policymakers with evidence to guide decisions to protect vulnerable populations and future generations.

Biomonitoring California was created through legislation (SB 1379, Perata and Ortiz, Chapter 599, Statues of 2006) to assess chemical exposures across the California population. California's biomonitoring program, a tri-departmental collaboration between the California Department of Public Health (CDPH), the Office of Environmental Health Hazard Assessment (OEHHA), and the Department of Toxic Substances Control (DTSC), was the first state-level biomonitoring program in the United States, enabling the study of exposures and exposure trends specific to California (Appendix A – Biomonitoring Program Budget and Governance).

Governor Arnold Schwarzenegger signs the bill creating Biomonitoring California

Before Biomonitoring California was established, state labs did not yet have the capacity to measure many chemicals in biological media. In addition, providing biomonitoring results back to participants was not standard practice. Through SB 1379, California legislators envisioned an ambitious program with the goal of statewide surveillance, identification of emerging chemicals of concern, broad environmental education and communication of individual results, and tracking of exposure trends across populations and time. For more on Biomonitoring California, and how the Program is working towards these goals, please visit our website.

Biomonitoring California Studies (July 2021-June 2023)

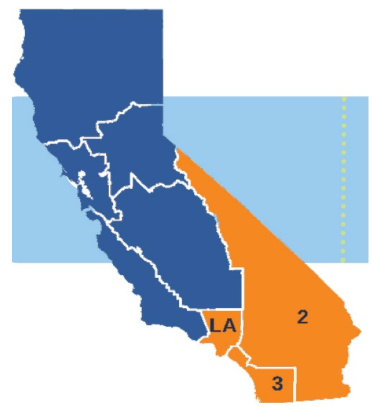
Biomonitoring California's approach to understanding environmental exposures in California involves the use of two types of studies: general population surveillance and community-focused studies. Data from both types of studies can be used together to identify populations and communities particularly vulnerable to chemical exposures. All Biomonitoring California study protocols are submitted to the Committee for the Protection of Human Subjects, the institutional review board (IRB) that ensures that studies conducted by the State follow ethical practices[3].

Biomonitoring Surveillance

General population surveillance measures exposure levels across California to understand how California compares to the overall nation, as well as temporal and demographic trends within the state. Conducting surveillance over time reveals how exposures might be changing in response to changing product formulations or evolving awareness of specific chemicals and provides data that can be used to assess the impact of chemical policies and environmental health programs in California.

California Regional Exposure (CARE) Study

The CARE Study was designed to assess California-wide exposures, addressing regions serially over time (see adjacent map). Starting in Los Angeles County in 2018 and proceeding to Region 2 (Riverside, San Bernardino, Imperial, Mono, and Inyo counties) in 2019 and Region 3 (San Diego and Orange counties) in 2020, the CARE Study collected information for counties representing 54 percent of the California population before being halted in 2020 due to the COVID-19 pandemic.



Sections in orange show the areas covered by the California Regional Exposure (CARE) Study.

All CARE participants were biomonitored for metals and perfluoroalkyl and polyfluoroalkyl substances (PFASs), and a subset of participants was biomonitored for additional chemicals.

The Program has prepared a comprehensive report on CARE findings, the first such report generated by Biomonitoring California. The CARE Study report includes summary statistics, study methodology, and descriptions of differences by demographics, including by region, race/ethnicity, age, sex, education, and income. A two-page summary of CARE Study findings was released in Summer 2023 and the report was released in 2024.

Key activities during this reporting period:

- Initiated work with the State Water Resources Control Board to evaluate the relationship between biomonitored PFAS levels and drinking water sources.

[3] For more information on how participants are recruited for Biomonitoring California studies and how individual results are returned, see How Biomonitoring Studies Work.

- Initiated work with Boston University School of Public Health to examine dietary contributions to PFAS levels.
- Continued work with Stockholm University to model pharmacokinetic parameters of PFASs using CARE data.
- Applied statistical weighting to CARE data to generate exposure estimates for the regional population. Population-level estimates for metals and PFASs for Los Angeles County and Region 2 are included in Appendix B – Weighted Data from CARE-LA and CARE-2.

Key findings of the CARE Study include:

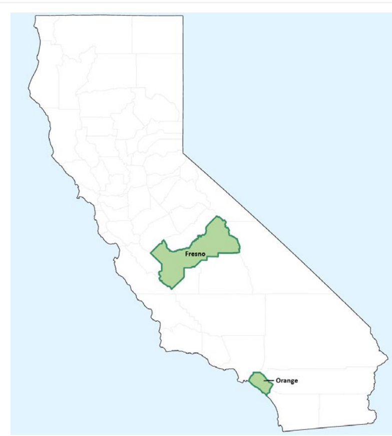
- Over 99 percent of the Los Angeles and Region 2 population had PFASs in their bodies.
- While lead levels have been diminishing in the environment and the population overall, 100 percent of the studied population still had lead in their bodies.
- Racial disparities in exposures are evident: arsenic, mercury, and PFAS levels were highest in Asian populations, and in Los Angeles, cadmium levels were higher in the Black population.

Analysis of CARE Study data continues to generate important exposure information on these regions. Leveraging the lessons learned from CARE, the Program has pivoted to a study design that is less resource-intensive but will still generate high-quality population-level data.

Studying Trends in Exposures in Prenatal Samples (STEPS)

During this reporting period, the Program has devoted a substantial effort to designing its next surveillance project, which will characterize PFAS exposures in pregnant Californians in two counties and provide insights into how the next generation of Californians is exposed to PFASs.

STEPS was designed to increase program efficiency by utilizing samples collected by the [CDPH Prenatal Screening Program](#) and archived by the Genetic Disease Screening Program (GDSP) Biobank. The broad coverage of the Prenatal Screening Program allows for the use of random sampling and the generation of population-based estimates. The GDSP Biobank enables STEPS to sample from different time points and evaluate temporal trends in PFAS exposures. In addition, STEPS will generate data on a greater suite of PFASs than prior studies due to



STEPS will include samples collected in Orange and Fresno counties.

the Environmental Chemistry Lab's recent development of an expanded method that measures both historically used PFASs as well as PFASs that have been more recently introduced.

STEPS will focus on Orange and Fresno counties and retrospectively track a 7-year timespan (samples from 2015, 2018, and 2021). In addition to understanding how PFAS levels are changing over time, this data will allow us to compare levels between two different geographic regions that have different water quality and PFAS management strategies. Additional linkage with birth record information will provide an opportunity for further work with collaborators to investigate the impacts of PFAS exposures on newborn health in California.

Key activities during this reporting period:

- Designed study methodology for STEPS.
- Submitted study plans and obtained data and sample acquisition permissions from the Committee for the Protection of Human Subjects (CPHS), Vital Statistics, and the GDSP Biobank.
- Obtained 1044 blood samples for laboratory analysis of PFASs.

Community-Focused Studies

To address exposures of concern at a more local level and/or among a particular group, Biomonitoring California also conducts community-focused studies. These studies help us to understand how exposures within a specific group (such as people with a similar cultural identity or occupation) compare with the general population and to identify exposure sources within a community. Some Biomonitoring California studies focus on communities impacted by air pollution, with the goal of supporting Assembly Bill (AB) 617 and the California Air Resources Board's Community Air Protection Program.

Asian/Pacific Islander Community Exposures (ACE) Project

Collaborators: APA Family Services and Vietnamese Voluntary Foundation

The ACE Project was conducted in 2016-2017 to better understand why metals and PFAS levels have been higher in specific Asian populations in California. The ACE Project included 100 Chinese American participants in the San Francisco area and 100 Vietnamese American participants in the San Jose area. Prior legislative reports have described the field and lab work, return of individual results to participants, and reporting of summary results to the community.

Key activities during this reporting period:

- Conducted initial analyses of participant diet, lifestyle, and occupational data to identify potential exposure sources.
- Collaborated with the State Water Resources Control Board's Surface Water Ambient Monitoring Program, the San Francisco Estuary Institute, and OEHHA to examine safe fish consumption guidance in the context of dietary data collected in the ACE Project.

The ACE Project included participants from the San Francisco and San Jose areas.

The work to understand important sources of PFAS exposures is on-going; key findings thus far include:

- PFAS levels in the ACE population were found to be higher than national levels.
- PFAS levels were higher in men than women. Women's levels are generally lower because of PFAS losses during menstruation and the transmission of PFASs to offspring during pregnancy and breastfeeding, which lead to prenatal and perinatal PFAS exposures for infants.
- Differences in exposure by age were evident, with older participants having higher levels of PFASs.
- Exposures prior to immigration are also an important consideration. Portion of life spent in the U.S., birth country, and primary language spoken were associated with different types of PFAS exposures.

East Bay Diesel Exposure Project (EBDEP)

Collaborators: Center for Environmental Research and Community Health (University of California, Berkeley) and the University of Washington

EBDEP, conducted from 2018 – 2019, was designed to measure exposures to diesel exhaust and determine how exposures vary within families, between communities, and at different time points. Previous legislative reports have described the field and lab work and return of most individual results for this project. Each of the chemicals discussed below are either found in diesel exhaust or formed through metabolism of chemicals found in diesel exhaust.

EBDEP enrolled participants from East Bay communities, including Oakland and Richmond.

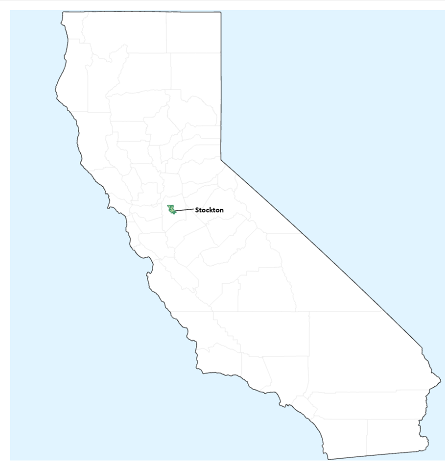
Key activities during this reporting period:

- Provided individual 1-hydroxypyrene (1-OHP) biomonitoring results to participants. 1-OHP is a metabolite of pyrene, a polycyclic aromatic hydrocarbon (PAH).
- Provided participants with data on the levels of 2-nitropyrene and 2-nitrofluoranthene found in their home's indoor air and dust, and black carbon found in their home's indoor air.

Stockton Air Pollution Exposure Project (SAPEP)

Collaborators: *Center for Environmental Research and Community Health (University of California, Berkeley); University of California, Merced; University of California, San Francisco; Little Manila Rising; All Saints Academy of Stockton*

SAPEP, conducted in December 2021, was designed to assess children's exposures to pollutants in a community heavily impacted by air pollution. SAPEP also examined the impacts of classroom air filtration on exposure levels. Urine samples from All Saints Academy students were tested for metabolites of polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and indicators of exposures to air pollutants (biomarkers of oxidative stress, inflammation, and lung injury) on two days of two consecutive weeks. Air quality both inside and around the school was also monitored to provide context for the biomonitoring data.



SAPEP enrolled participants from All Saints Academy in Stockton.

Key activities during this reporting period:

- Conducted field work, including participant recruitment (18 participants), air sampling, and urine sample collection.
- Completed laboratory analysis for urinary metabolites of PAHs and VOCs.
- Provided individual PAH and VOC biomonitoring results to participants.

Biomonitoring Component of the San Joaquin Valley Pollution and Health Environmental Research Study (BiomSPHERE)

Collaborators: University of California, Berkeley; University of California, Merced; University of California, San Francisco; Little Manila Rising; Central California Asthma Collaborative (CCAC)

BiomSPHERE aims to assess exposures to air pollutants among families living in Fresno and Stockton, two communities highly impacted by air pollution. BiomSPHERE will measure exposures to metabolites of PAHs and VOCs among adults and children and assess how exposures differ between individuals and across communities. Samples from BiomSPHERE will also be analyzed for indicators of exposures to air pollutants (biomarkers of oxidative stress, inflammation, and lung injury). Air quality data will be collected concurrently to assist in the interpretation of the biomonitoring data. Results from BiomSPHERE will help to better map hyperlocal air pollution exposures and provide comparative data for current and future Biomonitoring California studies.

BiomSPHERE includes participants from Fresno and Stockton.

Key activities during this reporting period:

- Designed study methodology and obtained IRB approval.
- Initiated fieldwork, including partial participant recruitment and sample collection.

Farmworker women and Respiratory Exposure to Smoke from Swamp Cooler Air (FRESSCA–Mujeres) Study

Collaborators: Public Health Institute; University of California, San Francisco; and Central California Environmental Justice Network (CCEJN)

FRESSCA–Mujeres aims to assess exposures to air pollutants among female agricultural workers in Fresno, Kern, and Kings counties, which are highly impacted by air pollution. The study involves installation of filters on evaporative coolers at participants' homes and the collection of urine samples at three time points to evaluate how well the filters reduce overall air pollutant exposures. Samples will be analyzed for heavy metals and metabolites of PAHs and VOCs, as well as biomarkers of oxidative stress and inflammation, which will be used to study the impacts of air pollution exposure.

FRESSCA-Mujeres includes participants from Fresno, Kern, and Kings counties.

Key activities during this reporting period:

- Designed study methodology and obtained IRB approval.
- Initiated fieldwork, including partial participant recruitment and sample collection.

Laboratory Analyses and Other Activities

Biomonitoring involves the measurement of chemicals at very low levels, which requires highly trained staff and sophisticated machinery. Biomonitoring California includes two nationally recognized laboratories: the Environmental Health Laboratory (CDPH) and the Environmental Chemistry Laboratory (DTSC). These labs conduct analyses for Program studies and provide analytical services for external collaborations. Both labs continually work to improve lab testing and develop methods to increase the number of chemicals that the Program can measure. The labs maintain a biorepository, ensure sample integrity, and participate in proficiency testing and certification programs to ensure maintenance of the highest standards of quality control.

Key activities during this reporting period:

- Provided aliquoting, sample management, and multi-lab specimen distribution for Program studies.
- Provided specific gravity and creatinine measurements for normalization of results for Program studies.

- Provided laboratory services to external partners
    - Analyzed 67 samples from the Women Workers Biomonitoring Collaborative for metabolites of PAHs.
    - Developed new methods to analyze serum for cannabis and tobacco metabolites; analyzed over 1000 samples for the Pregnancy Exposure to Cannabis and Tobacco [PRECATO] Study.
- Developed and finalized method to measure an expanded list of 42 PFASs in plasma and serum.
- Refined metals analytical methods to add nickel, a pollutant often released by industrial processes or combustion.
- Worked on the development of methods to identify different forms of mercury and to measure metabolites of volatile organic compounds (VOCs).
- Explored the use of novel screening methods to expand analytical range for metabolites of PAHs and PFASs.
- Ensured maintenance of high-quality methods with inter-lab proficiency testing.
- Increased biobanking capacity to 32 freezers and refrigerators with networked temperature sensors and real-time alarm notification systems.

Communications and Engagement

The Program designs educational materials to communicate study findings and exposure reduction information to a wide variety of audiences, including study participants.

Results materials provided to participants include individual biomonitoring results, summary results from the study, and comparison values from other state or national studies. Results materials also include chemical fact sheets that describe where chemicals can be found; potential impacts of exposure; and ways to try to reduce exposures. The fact sheets are periodically updated to reflect new scientific understanding of exposures and health impacts and are made available as a resource to the public and other biomonitoring and environmental health programs.

Biomonitoring California also engages in a wide range of communication efforts to reach many different audiences. The Program participates in public forums such as the AB 617 Community Steering Committee meetings and presents findings to scientific audiences through publications in peer-reviewed journals and presentations at technical conferences. A full list of program publications and presentations from this reporting period is included in Appendix C – Publications and Presentations.

Key activities during this reporting period:

- Developed or updated fact sheets on VOCs and PAHs.
- Released a 2-page graphic summary of the CARE Study in English and Spanish.
- Produced the CARE Study report.
- Developing additional fact sheets focused on reducing chemical exposures.

Scientific Guidance Panel

The Program is advised by a Scientific Guidance Panel (SGP) made up of expert scientists appointed by the Governor and State legislature. The Program organizes meetings with the SGP each year, providing a public forum for discussions about Program projects and priorities. More information on SGP members and meeting topics covered during this reporting period is available on the Biomonitoring California website.

The SGP also provides guidance and approves additions to Biomonitoring California's lists of Designated and Priority chemicals. Designated chemicals are the entire pool from which the Program can select chemicals to biomonitor and include:

- All chemicals in the National Biomonitoring Program conducted by the Centers for Disease Control and Prevention (CDC). CDC publishes the national results in the National Report on Human Exposure to Environmental Chemicals.
- Additional chemicals recommended by Biomonitoring California's Scientific Guidance Panel (SGP).

Some chemicals on the Designated List are further defined as Priority Chemicals. Prioritization is based on the potential for chemical exposure, the likelihood and severity of public health impacts, the availability of analytical methods to measure a specific chemical, and other factors.

Over this time period, the Program published updated lists of Designated and Priority chemicals based on new additions from the CDC's National Report on Human Exposure to Environmental Chemicals, as well as input from the SGP. This is an on-going task as new chemicals and product formulations continue to emerge.

External Collaborations

The Program meets with external entities such as other state agencies, community organizations, and academic researchers to identify ways we can collaborate and share information. Data and materials produced by Biomonitoring California are also regularly used by other organizations.

Key activities during this reporting period:

- Met with staff at other California departments, including OEHHA and the State Water Resources Control Board, to discuss approaches to understanding PFAS exposures.
- Consulted with academic partners for input on surveillance study design and methodology.
- Shared exposure information with the California Safer Consumer Products Program and California Communities Environmental Health Screening Tool (CalEnviroScreen) staff.
- Met with the CDC, the National Biomonitoring Network, and other states' biomonitoring programs to share information on study design and laboratory methods.
- Data from nine Biomonitoring California studies were cited as evidence of widespread PFAS exposures to Californians for the Attorney General's lawsuit against over a dozen PFAS manufacturers.
- Collaborated with researchers at the University of California (Berkeley, San Francisco, and Merced), Public Health Institute, and Illinois Institute of Technology to study associations between air quality and human exposures.
- Created partnerships with community organizations such as Little Manila Rising, the Central California Asthma Collaborative, and the Central California Environmental Justice Network.

Stakeholder Recommendations

Biomonitoring California must remain strategic in its pursuits and priorities to meet new challenges as Californians continue to face chemical exposures and environmental health disparities. One of the Program's strengths is its emphasis on collaboration and dedication to continuous improvement.

During this reporting period, we continued to cultivate these strengths by engaging with a range of stakeholders – academic partners, environmental health advocates, and other governmental programs – to solicit input on ways the Program can improve, and where they saw emerging needs in the years ahead. In addition to supporting current Program priorities, such as surveillance and community-focused projects, recommendations from stakeholders included a wide-range of emerging chemicals and exposure assessment strategies, illustrating the need for a robust and active biomonitoring program.

While the Program cannot currently implement all the recommendations, the input helps identify how the Program can best serve our partners and the public. Recommendations included:

- Increase dissemination of information on Program activities with newsletters, blogs, articles on the website, and/or media presence.
- Increase engagement with communities so that Program activities address priority issues.
- Continued collaboration with other state partners and academic researchers to complement biomonitoring with other methods of exposure assessment, such as the use and analysis of silicone wristbands.
- Bring more attention to microplastics and plastic-related chemicals, bisphenols, antimicrobials, and pesticides.
- Identify changes in chemical exposures, documented through biomonitoring, that are a result of chemical substitution and regulatory actions.
- Conduct studies to measure the impacts of wildfires on firefighters and the general population.
- Make data publicly available more quickly.

In addition to solicited recommendations, the Program regularly communicates with and receives feedback from key stakeholders, collaborators, and the Scientific Guidance Panel. On-going interactions with the National Biomonitoring Network and other exposure scientists help Biomonitoring California keep abreast of the latest advances in exposure science and inform the Program's future activities. As a pioneer and key player in the field nationally, Biomonitoring California plays a pivotal role in supporting the advancement of this work throughout the nation for even greater impact.

Conclusions

Over the past two years – and over the fifteen-year life of the Program – Biomonitoring California has laid a crucial foundation to help answer questions about how Californians are exposed to different chemicals, the implications of continued exposures, and the unequal burden of exposures facing some communities. The Program plays an important role in assessing how state efforts to reduce exposures are progressing and identifying areas for improvement.

New chemicals of concern continue to emerge, and Biomonitoring California is well poised to meet the challenge. Using the unique set of tools the Program has developed, and its authentic local and state collaborations, Biomonitoring California will continue to help protect the health of all Californians.

Appendices

Biomonitoring California
Eighth Report to the California Legislature
July 2021 – June 2023

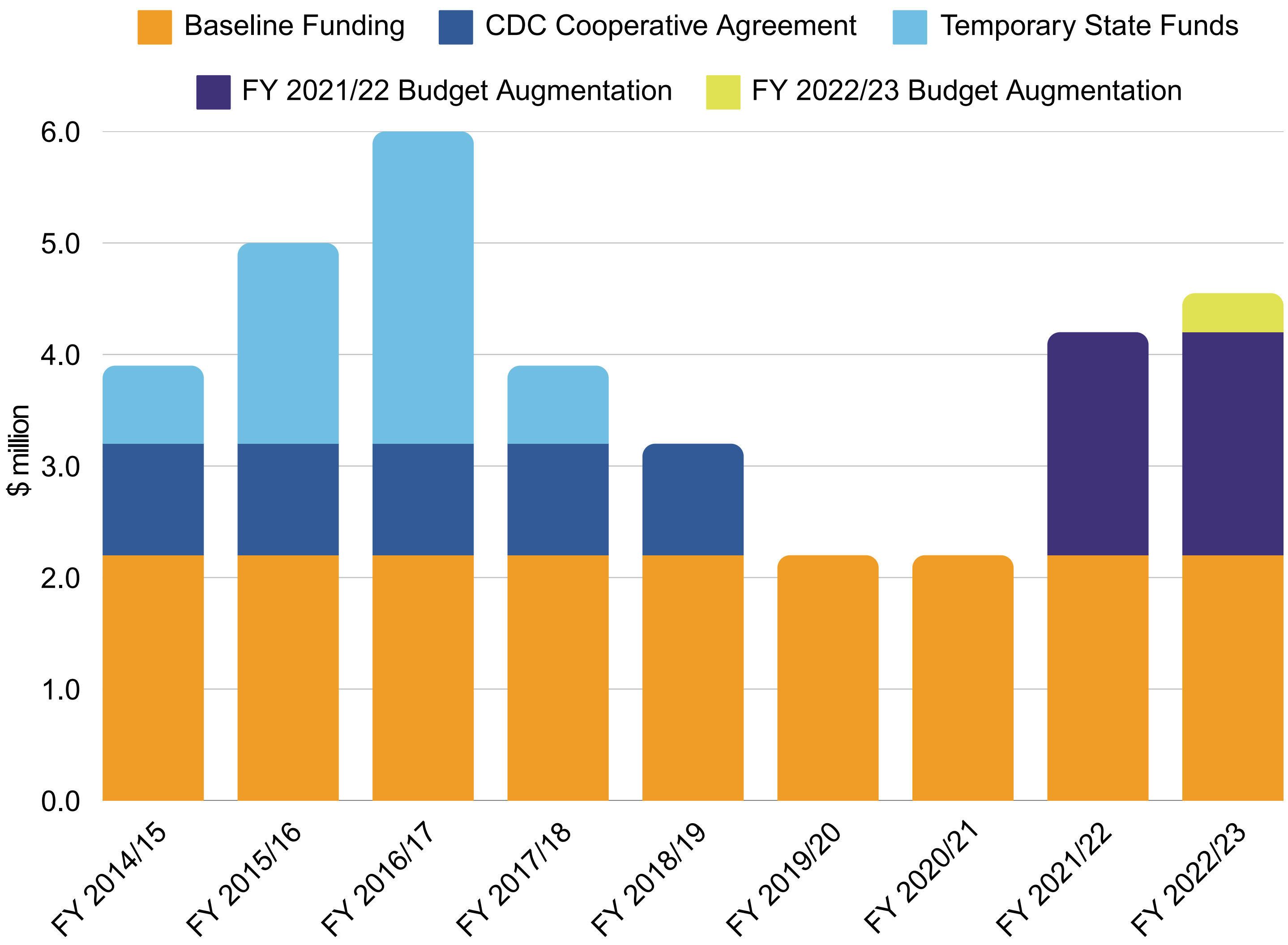
Appendices

Appendix A: Biomonitoring California Budget and Governance

About the budget

Biomonitoring California (BC) has historically received approximately $2.2 million in baseline State funding through five special funds. This has been supplemented by temporary State and federal funding. The Program budget was increased in Fiscal Year (FY) 21/22. The Program also received designated funding, starting in FY 22/23, to use biomonitoring as a tool to support communities heavily impacted by air pollution and identify potential exposure sources and mitigation strategies

Program Budget (FY 2014/15 - FY 2022/23)



Appendix A: Biomonitoring California Budget and Governance

Table A1: Biomonitoring California Budget (FY 2014/15 – 2022/23)

Funding/Source	Note
Baseline State funding: $2.2 million	• On-going funding starting in 2007 supported by the Toxic Substances Control Account, the Air Pollution Control Fund, the Department of Pesticide Regulation Fund, the Childhood Lead Poisoning Prevention Fund, and the Birth Defects Monitoring Program Fund • Split between CDPH, OEHHA, and DTSC • Supports 13 full-time positions
CDC Cooperative Agreement: $1.0 million per year	• Federal Fiscal Year (FFY) 14/15 –18/19
State special funds	• $700,000, FY 14/15 & 17/18 • $1.15 million, FY 15/16 – 16/17 • $1 million Stakeholder bill for environmental justice activities, FY 16/17
Augmentation to State funding	• The Program budget was increased by $2 million in General Funds starting in FY 21/22. Funding was allocated to create new staff positions and support field and lab operations.
FY 2022/23 Budget Augmentation	• The Program received designated funding, starting in FY 22/23, to use biomonitoring as a tool to support work in communities vulnerable to the impacts of air pollution.

FY 21-22 Budget Augmentation

State funding for Biomonitoring California remained static for many years. The budget increase in FY 21/22 allowed the Program to:

- Create nine new positions, including four laboratory scientists, two health educators, and three epidemiologists
- Create a designated unit to oversee program communications and outreach
- Increase Program capacity to analyze data and output results more quickly
- Support field and laboratory operations

Appendix A: Biomonitoring California Budget and Governance

Program Governance

CDPH Environmental Health Investigations Branch	• Program lead; responsible for overall coordination of program components and partners • Liaison to National Biomonitoring Network • Design and implementation of statewide biomonitoring surveillance studies • Management and analysis of epidemiologic data • Dissemination of information to the public • Generation of reports to the Legislature
CDPH Environmental Health Laboratory	• Laboratory analyses of blood samples for metals and urine samples for metals and non-persistent chemicals • Quality assurance and interpretation of laboratory data • Processing, storage, and long-term management of blood and urine samples
OEHHA Reproductive and Cancer Hazard Assessment Branch	• Scientific and administrative support of the Scientific Guidance Panel • Evaluation of scientific information for chemical selection, choice of biomarkers, and interpretation of results • Development of chemical fact sheets • Updates and improvements to the Program website • Design and implementation of community-based biomonitoring studies
DTSC Environmental Chemistry Laboratory	• Laboratory analyses of blood samples for persistent chemicals that accumulate in people • Quality assurance and interpretation of laboratory data • Non-targeted and semi-targeted screening to identify new chemicals of emerging concern in California

Appendix B: Weighted Data from CARE-LA and CARE-2

Calculation of weights to generate regional population data was conducted during this reporting period. The weighted data generated during this reporting period (July 2021- June 2023) are summarized below. This includes:

- Comparison of the CARE-LA and CARE-2 study populations with regional demographic breakdowns
- Number of study participants with elevated metals levels and corresponding weighted population percentages
- Overall weighted metals and PFAS data from CARE-LA and CARE-2

These data and data from other Program studies are available in the online Biomonitoring California results database.

Summary results include:

- **Geometric Mean**: The geometric mean is an estimated middle value of a set of numbers. This is different than the average, also called the "arithmetic mean". A geometric mean is sometimes calculated when the set of numbers contains some extreme values. An asterisk (*) means the geometric mean was not calculated because the chemical was found in less than 65% of the study group.
- **Percentiles**: Four percentiles (25^{th}, 50^{th}, 75^{th}, and 90^{th} or 95^{th}) describe chemical levels across the study populations.
- **Detection Frequency:** The percentage of study participants with a measurable level of a chemical in their blood or urine sample.

Unweighted data for CARE-LA and CARE-2 was previously reported as part of the Seventh Report to the California Legislature and is available in the CARE Study Report.

Table B1: CARE-LA study population and regional demographic characteristics (N=420 participants)

Demographic characteristic	Number[1]	Percent (%)[1]	Weighted Percent (%)[1]	Regional Population Percent (%)[2]
18-39 years	148	34.4	40.7	41.9
40-59 years	179	41.6	31.8	33.4
60 years or over	103	24.0	27.5	24.6
Male[3]	165	38.4	51.0	48.8
Female	262	60.9	49.0	51.2
Asian[4]	70	16.3	13.9	14.6
Black	48	11.2	8.9	7.8
Hispanic or Latino	156	36.3	44.7	48.6
White	129	30.0	29.1	25.9
Other	25	5.8	3.3	3.1
No high school degree	42	9.8	17.6	19.4
High school diploma/GED	24	5.6	18.6	21.4
College, some college, or trade/technical school	241	56.0	52.7	49.3
Graduate degree	120	27.9	11.1	9.9
Income ≤$25,000	98	22.8	21.4	18.8
Income $25,001-$75,000	134	31.2	36.2	35.2
Income $75,001-$150,000	106	24.7	25.5	28.3
Income >$150,000	37	8.6	17.0	17.8

[1]Numbers may not total 430, and unweighted percentages may not sum to 100% because of missing data. Weighted percentages include imputed values for missing data and sum to 100%.
[2]From ACS 2018, using the 1-year estimates provided for large US counties.
[3]Three participants did not select male or female and indicated another gender identity. Information on sex assigned at birth was not collected from participants in CARE-LA; therefore, gender identity was used as an approximate comparison to ACS data on sex in order to weight data and calculate regional population percentages.
[4]Definitions of race/ethnicity categories: Asian (single identification), Black (single identification), Hispanic or Latino (any race), White (single identification), Other (Non-Hispanic multi-racial, American Indian or Alaskan Native, Native Hawaiian or Other Pacific Islander). Additional race/ethnicity breakdowns are available in Appendix D of the CARE Study Report.

Table B2: CARE-2 study population and demographic characteristic (N = 359 participants)

Demographic characteristic	Number[1]	Percent (%)[1]	Weighted Percent (%)[1]	Regional Population Percent (%)[2]
18-39 years	102	28.4	38.3	42.2
40-59 years	142	39.6	35.5	33.4
60 years or over	115	32.0	26.3	24.4
Male[3]	156	43.5	47.4	49.4
Female	202	56.3	52.6	50.6
Asian[4]	22	6.1	6.9	6.4
Black	16	4.5	7.3	6.7
Hispanic or Latino	166	46.2	49.4	52.1
White	131	36.5	32.9	31.5
Other	17	4.7	3.4	3.3
No high school degree	20	5.6	15.0	18.3
High school diploma/GED	54	15.0	27.2	27.9
College, some college, or trade/technical school	216	60.2	49.9	47.2
Graduate degree	67	18.7	8.0	6.6
Income ≤$25,000	90	25.1	19.6	18.3
Income $25,001-$75,000	137	38.2	37.4	38.4
Income $75,001-$150,000	65	18.1	30.1	29.8
Income >$150,000	20	5.6	12.9	13.6

[1]Numbers may not total 359, and unweighted percentages may not sum to 100% because of missing data. Weighted percentages include imputed values for missing data and sum to 100%.
[2]From ACS 2019, using the 5-year estimates provided for smaller US counties.
[3]No participants indicated another gender identity. Sex assigned at birth and gender were both collected in CARE-2, and participants' responses were concordant, with one missing for both.
[4]Definitions of race/ethnicity categories: Asian (single identification), Black (single identification), Hispanic or Latino (any race), White (single identification), Other (Non-Hispanic multi-racial, American Indian or Alaskan Native, Native Hawaiian or Other Pacific Islander). Additional race/ethnicity breakdowns are available in Appendix D of the CARE Study Report.

Table B3: Number of CARE-LA and CARE-2 participants with metals concentrations above the 2020 levels of concern, and corresponding weighted study population percentages

Analyte	Level of concern	CARE-LA Number	CARE-LA Weighted %	CARE-2 Number	CARE-2 Weighted %
Arsenic (urine)	≥ 20 µg/L inorganic arsenic	20	5.1	10	4.8
	≥ 50 µg/L total arsenic	31	6.3	16	4.3
Cadmium (blood)	≥ 5 µg/L	0	0	0	0
Cadmium (urine)	> 3 µg/g creatinine	0	0	0	0
Lead (blood)	≥ 4.5 µg/dL[1]	1	<0.1	3	0.6
Mercury (blood)	≥ 5.8 µg/L if pregnant or may become pregnant[2]	9	2.6	6	8.9
	≥ 10 µg/L for all other adults	8	3.3	3	0.9
	≥ 5.8 µg/L applied to all participants[3]	27	5.4	14	5.1
Mercury (urine)	≥ 10 µg/L	0	0	1	<0.1

[1]Since CARE-LA and CARE-2 were conducted, the CDC blood lead reference level has been lowered to ≥ 3.5 µg/dL. Applying this LOC to CARE-LA and CARE-2 would result in increased numbers of exceedances.
[2]Persons who are or may become pregnant are defined here as those assigned female at birth and 18-49 years of age. Sex assigned at birth was not captured in CARE-LA; gender identity was used as a proxy.
[3]Program follow-up was provided to all participants with blood mercury levels that exceeded 5.8 µg/L, regardless of sex or gender.

Metal concentrations in CARE-LA and CARE-2

The following tables present weighted results for the 10 metals measured in CARE-LA and CARE-2, with and without adjustment for hydration using creatinine measurements.

Table B4: CARE-LA blood metal concentrations (in µg/L for cadmium, manganese, and mercury, and µg/dL for lead), weighted

Analyte	Detection Frequency (%)	GM (95% CI)	50th percentile	95th percentile	Total	LOD
Cadmium	99.6	0.258 (0.232, 0.286)	0.248	0.785	425	0.0750
Lead	100	0.768 (0.683, 0.862)	0.730	2.32	425	0.0250
Manganese	100	10.6 (10.1, 11.2)	10.4	20.3	425	0.750
Mercury	92.9	0.975 (0.794, 1.20)	1.04	6.02	425	0.125

Table B5: CARE-LA urinary metal concentrations (in µg/L), weighted

Analyte	Detection Frequency (%)	GM (95% CI)	50th percentile	95th percentile	Total	LOD
Antimony	26.2	*	<LOD	0.101	428	0.0300
Arsenic	100	8.06 (6.69, 9.71)	7.91	67.2	428	0.100
Cadmium	100	0.153 (0.130, 0.182)	0.169	0.743	428	0.0100
Cobalt	100	0.217 (0.184, 0.256)	0.210	1.37	428	0.0100
Manganese	15.2	*	<LOD	0.174	428	0.100
Mercury	97.1	0.202 (0.159, 0.256)	0.232	2.63	428	0.0100
Molybdenum	100	36.0 (30.5, 42.5)	39.6	160	428	0.300
Thallium	99.8	0.154 (0.134, 0.178)	0.169	0.527	428	0.0100
Uranium	48.6	*	<LOD	0.116	428	0.0100

Table B6: CARE-LA urinary metal concentrations (in µg/g creatinine), weighted

Analyte	Detection Frequency (%)	GM (95% CI)	50th percentile	95th percentile	Total	LOD (µg/L)
Antimony	26.6	*	<LOD	0.180	426	0.0300
Arsenic	100	10.6 (9.06, 12.3)	9.14	59.7	426	0.100
Cadmium	100	0.199 (0.175, 0.227)	0.187	0.691	426	0.0100
Cobalt	100	0.284 (0.251, 0.321)	0.262	1.18	426	0.0100
Manganese	15.4	*	<LOD	0.611	426	0.100
Mercury	97.3	0.262 (0.218, 0.314)	0.277	1.73	426	0.0100
Molybdenum	100	47.1 (41.7, 53.2)	44.9	194	426	0.300
Thallium	100	0.200 (0.183, 0.218)	0.197	0.491	426	0.0100
Uranium	49.3	*	<LOD	0.116	426	0.0100

Table B7: CARE-2 blood metal concentrations (in µg/L for cadmium, manganese, and mercury, and µg/dL for lead), weighted

Analyte	Detection Frequency (%)	GM (95% CI)	50th percentile	95th percentile	Total	LOD
Cadmium	99.1	0.275 (0.246, 0.307)	0.266	0.793	359	0.0750
Lead	100	0.661 (0.591, 0.739)	0.712	1.80	359	0.0250
Manganese	100	10.1 (9.71, 10.6)	9.96	15.9	359	0.250
Mercury	94.8	0.719 (0.581, 0.889)	0.778	6.12	359	0.0750

Table B8: CARE-2 urinary metal concentrations (in µg/L), weighted

Analyte	Detection Frequency (%)	GM (95% CI)	50th percentile	95th percentile	Total	LOD
Antimony	19.2	*	<LOD	0.343	357	0.0500
Arsenic	100	6.40 (5.16, 7.96)	6.27	42.1	357	0.100
Cadmium	95.1	0.172 (0.145, 0.205)	0.186	0.901	357	0.0300
Cobalt	92.9	0.182 (0.154, 0.215)	0.200	1.05	357	0.0300
Manganese	15.4	*	<LOD	0.212	357	0.100
Mercury	91.6	0.165 (0.138, 0.197)	0.168	0.922	357	0.0300
Molybdenum	100	33.5 (28.2, 39.8)	35.6	168	357	0.300
Thallium	100	0.148 (0.130, 0.169)	0.158	0.472	357	0.0100
Uranium	49.6	*	<LOD	0.0805	357	0.0100

Table B9: CARE-2 urinary metal concentrations (in µg/g creatinine), weighted

Analyte	Detection Frequency (%)	GM (95% CI)	50th percentile	95th percentile	Total	LOD (µg/L)
Antimony	19.2	*	<LOD	0.309	357	0.0500
Arsenic	100	8.40 (7.10, 9.94)	6.86	50.4	357	0.100
Cadmium	95.1	0.226 (0.195, 0.262)	0.227	1.05	357	0.0300
Cobalt	92.9	0.238 (0.209, 0.272)	0.200	1.11	357	0.0300
Manganese	15.4	*	<LOD	0.555	357	0.100
Mercury	91.6	0.216 (0.184, 0.254)	0.213	1.34	357	0.0300
Molybdenum	100	43.9 (38.8, 49.7)	42.9	161	357	0.300
Thallium	100	0.194 (0.177, 0.214)	0.182	0.525	357	0.0100
Uranium	49.6	*	<LOD	0.112	357	0.0100

PFAS concentrations in CARE-LA and CARE-2

The following tables present weighted results for the 12 PFASs measured in CARE-LA and CARE-2.

Table B10: CARE-LA serum PFAS concentrations (in ng/mL), weighted

Analyte	Detection Frequency (%)	GM (95% CI)	50th percentile	95th percentile	Total	LOD
Et-PFOSA-AcOH	35.7	*	<LOD	0.0554	425	0.0115
Me-PFOSA-AcOH	100	0.0678 (0.0589, 0.0780)	0.0558	0.340	425	0.0114
PFBS	5.5	*	<LOD	0.0357	425	0.0303
PFDA	62.3	*	0.0795	0.321	425	0.0560
PFDoA	0.3	*	<LOD	<LOD	425	0.110
PFHpA	52.0	*	0.0280	0.0981	425	0.0256
PFHxS	98.5	0.689 (0.585, 0.813)	0.787	2.39	425	0.0177
PFNA	96.9	0.298 (0.263, 0.339)	0.320	1.16	425	0.0424
PFOA	99.8	1.04 (0.920, 1.17)	1.17	3.06	425	0.0606
PFOS	98.0	2.20 (1.87, 2.60)	2.38	8.78	425	0.0615
PFOSA	26.7	*	<LOD	0.0611	425	0.0144
PFUnDA	77.6	0.0721 (0.0619, 0.0840)	0.0735	0.350	425	0.0285

Table B11: CARE-2 serum PFAS concentrations (in ng/mL), weighted

Analyte	Detection Frequency (%)	GM (95% CI)	50th percentile	95th percentile	Total	LOD
Et-PFOSA-AcOH	16.4	*	<LOD	0.0312	358	0.0115
Me-PFOSA-AcOH	81.2	0.0344 (0.0298, 0.0397)	0.0355	0.204	358	0.0114
PFBS	9.8	*	<LOD	0.0379	357	0.0303
PFDA	63.3	*	0.0768	0.252	358	0.0560
PFDoA	0.01	*	<LOD	<LOD	358	0.110
PFHpA	43.6	*	<LOD	0.101	358	0.0256
PFHxS	99.8	0.798 (0.669, 0.953)	0.837	3.20	358	0.0177
PFNA	89.5	0.211 (0.181, 0.246)	0.256	0.775	358	0.0424
PFOA	98.8	0.987 (0.866, 1.12)	1.13	2.53	358	0.0606
PFOS	98.5	2.41 (2.05, 2.82)	2.88	7.14	357	0.0615
PFOSA	14.9	*	<LOD	0.0329	358	0.0144
PFUnDA	61.3	*	0.0416	0.258	358	0.0285

Appendix C - Publications and Presentations
Biomonitoring California Staff
July 2021 – June 2023

Publications:

- Abrahamsson D, Wang A, Jiang T, Wang M, Siddharth A, Morello-Frosch R, Park J-S, Sirota M, Woodruff TJ. (2021). Comprehensive non-targeted analysis of prenatal exposome reveals significant differences in exposures between maternal and fetal samples. *Environ Sci Technol*, 55(15):10542-10557.

- Chao F, Xu Q, Qui X, Jin Y, Ji J, Lin Y, Le S, Xue L, Chen Y, She J, Xiao P, Lu D, Wang G. Profiling of pesticides and pesticide transformation products in Chinese herbal teas. (2022). *Food Chem*, 383:132431.

- Choe KY, Gajek R, Waldman J, She J. (2022) Evaluation of trace-element contamination from serum collection tubes used by the California Biobank Program, *Journal of Trace Elements in Medicine and Biology*, 71: 126946.

- Ding YC, Hurley S, Park JS, Steele L, Rakoff M, Zhu Y, Zhao J, LaBarge M, Bernstein L, Chen S, Reynolds P, Neuhausen SL. (2021). Methylation biomarkers of polybrominated diphenyl ethers (PBDEs) and association with breast cancer risk at the time of menopause. *Environ Int* 156.

- Eick SM, Enright EA, Padula AM, Aung M, Geiger SD, Cushing L, Trowbridge J, Keil AP, Baek HG, Smith S, Park J-S, DeMicco E, Schantz SL, Woodruff TJ, Morello-Frosch R. (2022). Prenatal PFAS and psychosocial stress exposures on fetal growth in two pregnancy cohorts: applying environmental mixture methods to chemical and non-chemical stressors. *Environ Int,* 163.

- Eick SM, Goin DE, Trowbridge J, Cushing L, Abrahamsson D, Smith SC, Park J-S, DeMicco E, Padula AM, Woodruff TJ, Morello-Frosch R. (2021). Dietary predictors of prenatal per- and poly-fluoroalkyl substances (PFAS) exposure. *J Expo Sci Environ Epidemiol,* 33: 32-39.

- Goin DE, Abrahamsson D, Wang M, Park J-S, Sirota M, Morello-Frosch R, Trowbridge J, DeMicco E, Ladella S, Woodruff TJ. (2022). Investigating geographic differences in environmental chemical exposures in maternal and cord sera using non-targeted screening and silicone wristbands in California. *J Expo Sci Environ Epidemiol*, 33: 548-557.

- Iyer S, Kauffman D, Steinmaus C, Hoover S. (2023). Biomonitoring California protocol for following up on elevated levels of urinary arsenic. *Int J Environ Res Public Health,* 20(7):5269.

Posters

- D'Amico A, Attfield K, She J, Choe KY, DeGuzman J, Baehner L, Wu N. Disparities in Arsenic Exposure in the 2019 California Regional Exposure Study (CARE-2). Presented at International Society of Exposure Science Annual Conference, September 2021.

- Gallardo J, Behniwal P, She J. Isotope Dilution UPLC-ESI-MS/MS Method for the determination of urinary VOC metabolites. Presented at APHL Annual Conference, May 2023.

- Li Y, DeGuzman J, Behniwal P, Wang SZ, Ip HS, She J. Simultaneous analysis of nicotine and cannabis metabolites in serum by isotope dilution UPLC-MS/MS method. Presented at APHL Annual Conference, May 2023.

Presentations

- Attfield K. Biomonitoring California program updates. Presented at Scientific Guidance Panel Meeting [July 2022, March 2023]

- Attfield K. Overview of Biomonitoring California activities on perfluoroalkyl and polyfluoroalkyl substances (PFASs). Presented at Scientific Guidance Panel Meeting, November 2021.

- Attfield K, Berger B, Dodson R, Bennett D, Rogers K, Moran R, Stoiber T, Smith S, Park JS, Blum A, Wu N. Flame retardant biomarker changes with furniture replacement. Presented at International Society of Exposure Science, September 2022

- Attfield K, Smith S, Park JS, Baek HG, Gao SM, Jiang T, Wu N. Racial/ethnic PFAS disparities in California regional biomonitoring. Presented at International Society of Exposure Science Annual Meeting, September 2021

- D'Amico A, Kauffman D. Assessing environmental exposures in California. 7th Annual Nursing Research Symposium, April 2022.

- Hurley S. AB 617 Biomonitoring update. Presented at Scientific Guidance Panel Meeting. [July 2021, March 2022, July 2022]

- Hurley S. BiomSPHERE: Biomonitoring to assess community air pollution exposures. Presented at the Stockton AB 617 Community Steering Committee meeting, April 2022.

- Jarmul S. Introduction to biomonitoring and example community projects. Presentation to the Community Advisory Council for the Bay Area Air Quality Management District, March 2022.

- Wu N. Biomonitoring California program updates. Presented at Scientific Guidance Panel Meeting [July 2021, November 2021, March 2022, November 2022]