Implementation of the California Environmental Contaminant Biomonitoring Program: 2019-2021

Seventh Report to the California Legislature

July 2019 – June 2021

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 of 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 seventh report, covering Biomonitoring California's activities and findings from July 2019 to June 2021.

The recommendations and conclusions in this report are those of the Scientific Guidance Panel and do not necessarily represent the views or opinions of CDPH, CalHHS, OEHHA, or DTSC.

This report is available online at:

Biomonitoring California Reports

Copies may also be requested from the Environmental Health Investigations Branch, California Department of Public Health, by calling 510-620-3620, or writing to:

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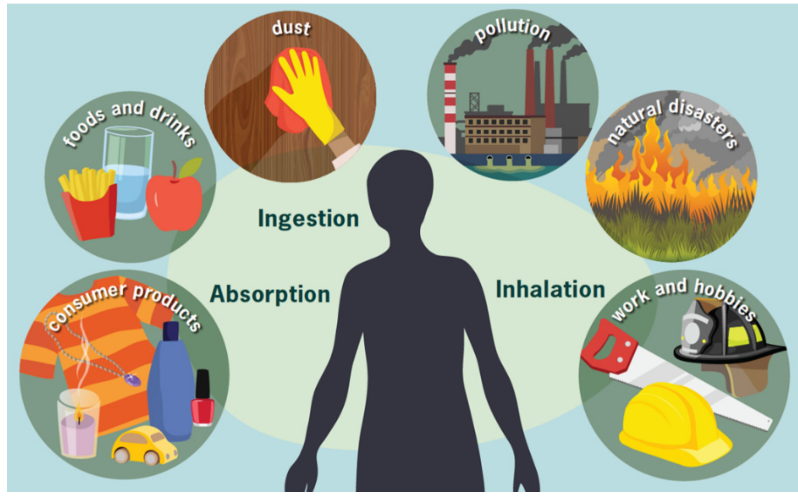
Executive Summary



People are exposed to harmful chemicals every day through their environment, home, and workplace. The health impacts of chemical exposures are felt across California, especially in communities facing the cumulative impacts of poverty, stress, and other socioeconomic factors. Reducing chemical exposures is an essential component of disease prevention, and biomonitoring is critical to this effort.

Biomonitoring is an exposure assessment method that involves analyzing chemicals and their metabolites in blood, urine, or other biological material. Biomonitoring data can be used to identify *which* chemicals, and *how much* of those chemicals, get into our bodies. This data can be used to identify and inform highly exposed individuals or groups; educate the public about chemical exposures; and inform policymakers as they develop and evaluate laws or programs that address chemical hazards.

BIOMONITORING CALIFORNIA

The California Environmental Contaminant Biomonitoring Program (Biomonitoring California) was established through legislation in 2006 to conduct biomonitoring across the state. The program is 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).

During the reporting period of the Seventh Legislative Report, primary Biomonitoring California activities included surveillance, with the California Regional Exposure (CARE) Study, and community-focused efforts, with the East Bay Diesel Exposure Project (EBDEP). In addition, the Program continued to work with the Genetic Disease Screening Program on Measuring Analytes in Maternal

Archived Samples (MAMAS), to understand how banked samples could be used to understand chemical exposures among pregnant women.

Key Findings

During this reporting period, samples collected from CARE Study participants living in Region 2 (Riverside, San Bernardino, Imperial, Mono, and Inyo counties) were analyzed for metals and perfluoroalkyl and polyfluoroalkyl substances (PFASs), a class of compounds used in consumer products and industrial applications. PFASs have been found to impact fertility and the developing fetus, alter immune response, and increase cancer risk. Key findings from CARE-2 include:

- About 9% of CARE-2 participants had a high enough level of arsenic, mercury, lead, or cadmium to trigger personalized follow-up by the Program.
- 100% of CARE-2 participants had lead in their blood. Over 95% had cadmium and mercury in their blood.
- Mercury was detected in 87% of urine samples.
- All participants but one had at least one PFAS in their blood. On average, participants had seven PFASs in their blood.
- CARE-2 levels of some PFASs were between 24-81% higher in men than women, consistent with other studies.
- PFAS levels increased with age, by 8-20% per decade.
- Overall, Asian participants had the highest levels of PFASs and Hispanic participants had the lowest levels.

The Program provides one-on-one follow-up for participants with elevated levels of metals exposures. CARE-2 identified a participant with elevated blood mercury levels. Individual follow-up revealed that the participant was experiencing health symptoms, and that the use of imported skin-lightening cream was the likely source of mercury exposure.

CARE-2 findings of near universal detections of metals and PFASs and the differential exposures in race/ethnic groups are consistent with prior Biomonitoring California studies. Comparisons of levels between different demographic groups and between CARE regions and national data will be available in an upcoming CARE Study report and in the next Legislative Report.

EBDEP, a collaboration with the Center for Environmental Research and Children's Health at the University of California, Berkeley, and the University of Washington, was designed to measure exposures to diesel exhaust in Oakland and Richmond/San Pablo. EBDEP key findings included:

- More than 90% of samples contained 1-nitropyrene(1-NP) metabolites, indicating widespread exposure to diesel exhaust in EBDEP communities. 1-NP is formed during the combustion of diesel fuel and is present in diesel exhaust.
- Levels of the 1-NP metabolite 6-OHNP were significantly higher in parents compared with their children.

1-NP levels measured in adult EBDEP participants were overall higher than levels measured in the CARE studies (LA County and Region 2), potentially due to EBDEP's focus on high-traffic areas. Comparisons for children are not available, due to a lack of comparable data.

Additional Program Activities

Additional Program activities included:

- Initiation of sample collection in Region 3: San Diego and Orange counties.
- Analysis of subsets of CARE Study samples for 1-NP metabolites and environmental phenols.
- Delivery of individual biomonitoring results to over 400 study participants.
- Organization and facilitation of six Scientific Guidance Panel meetings to discuss:
    - Program updates, goals, and priorities,
    - Laboratory methods and study design, and
    - Adding quaternary ammonium compounds (QACs) to the Program's lists of designated and priority chemicals.

More on Biomonitoring California, including the full legislative report, can be found at Biomonitoring California.

Introduction

Californians experience widespread exposures to environmental chemicals, many of which pose health concerns. Recognizing that preventing exposures to harmful chemicals can reduce disease burden across the state, the Legislature established the California Environmental Contaminant Biomonitoring Program (also known as Biomonitoring California) to measure and track chemical exposures across the California population. Biomonitoring California was the first legislatively mandated, ongoing state biomonitoring program in the country.

This Seventh Report to the Legislature provides an overview of Program activities from July 2019 through June 2021. During this reporting period, Biomonitoring California primarily focused on the California Regional Exposure (CARE) Study and the East Bay Diesel Exposure Project (EBDEP). However, many Biomonitoring California staff at the California Department of Public Health (CDPH) were also redirected to emergency responses related to the 2019-2020 outbreak of "E-cigarette or vaping use-associated lung injuries" (EVALI) and the COVID-19 pandemic. Biomonitoring fieldwork, which involves interacting with study participants and collecting biological samples, was halted prematurely in March 2020, also due to the pandemic. These factors impacted the CARE study and other Program activities during the reporting period, but despite these challenges, the Program continued to make progress.

During the final month of this reporting period, the Program was informed that a budget augmentation would be enacted starting in July 2021. Subsequent program expansion will be covered in the Eighth Report to the Legislature.

About the Program

Biomonitoring California was established through legislation in 2006 by Senate Bill 1379 (Perata and Ortiz, Chapter 599, Statutes of 2006) and codified in Health and Safety Code Sections 105440 et seq. In passing this law, the California Legislature stated that:

> *"… the establishment of a statewide biomonitoring program will assist in the evaluation of the presence of toxic chemicals in a representative sample of Californians, establish trends in the levels of these chemicals in*

Californians' bodies over time, and assess effectiveness of public health efforts and regulatory programs to decrease exposures of Californians to specific chemical contaminants. A statewide and community-based biomonitoring program will expand biomedical, epidemiological, and behavioral public health research."

The Program is a collaborative effort of the CDPH as the lead, the Office of Environmental Health Hazard Assessment (OEHHA), and the Department of Toxic Substances Control (DTSC). For more information on program structure and budget, see Appendices A and B. The Scientific Guidance Panel (SGP) provides oversight and technical advice, and input from the public is actively sought. Biomonitoring California conducts studies to measure levels of environmental chemicals in Californians and how they change over time. Biomonitoring data are an essential cornerstone of the State's efforts to reduce exposures to harmful chemicals and evaluate the effectiveness of those efforts. For more information about Biomonitoring California, visit the Program website at Biomonitoring California.

What is Biomonitoring?

Biomonitoring is an exposure assessment method used to identify *which* chemicals, and *how much* of those chemicals, get into our bodies. Biomonitoring involves analyzing chemicals and their metabolites in blood, urine, and other biological material. The results of these analyses provide an overall measure of human exposure to potentially harmful chemicals from all sources, including air, water, food, soil, dust, and consumer products.

Importance of Biomonitoring

People are exposed to harmful chemicals every day through their environment, home, and workplace. Chemical exposures have been linked to serious health impacts, including cancer, respiratory disease, birth defects, and lower fertility. About 30 percent of childhood asthma cases and 10 percent of neurobehavioral disorders in California have been attributed to environmental pollutants.[1] Further, in the U.S., disease burden associated with certain environmental chemical exposures carries an estimated annual cost of $340 billion.[2] We continue to learn how chemical exposures play a role in a wide range of health outcomes. For example, exposures to perfluoroalkyl and polyfluoroalkyl substances (PFASs) and air pollutants, such as from traffic and wildfires, can impact immune response and susceptibility to disease and illness. This includes reduced antibody response following COVID-19 and other vaccines.

The health consequences of environmental contaminants are felt across California, especially in neighborhoods facing the cumulative impacts of poverty, stress, crime, and other socioeconomic factors. Infants and children are particularly vulnerable to chemical exposures because they are in a sensitive period of development and often have increased exposures from behaviors more typical to children, such as frequent hand-to-mouth activity. Reducing chemical exposures is an essential component of disease prevention, and biomonitoring is critical to this effort. Information from Biomonitoring California can:

Identify

- Which chemicals get into people's bodies, and at what levels
- Highly exposed individuals or groups
- Changes in levels of chemicals in the California population over time
- Differences in chemical levels measured in people across the state
- Emerging chemical exposures that pose health threats

Inform

- Individuals and the public about their chemical exposures, and actions they can take to protect their health
- Policy makers and regulatory managers as they set public and environmental health priorities and develop new laws or programs to address chemical hazards

[1] California Environmental Health Tracking Program. Costs of Environmental Health Conditions in California Children. https://www.phi.org/uploads/files/2015ROI_CEHTP.pdf. Published June 2015. Accessed May 5, 2021.
[2] Attina et al. (2016). Lancet Diabetes Endocrinol 4(12):996-1003. doi: 10.1016/S2213-8587(16)30275-3.

Evaluate

- Effectiveness of regulatory and public health efforts to reduce harmful chemical exposures

Biomonitoring can be used to assess a wide range of chemical exposures, such as mercury poisonings caused by the use of certain imported skin care products; exposures to PFASs from multiple sources, including drinking water impacted by airports with fire training areas and municipal solid waste landfills; consumer exposures to brominated flame retardants released from older foam furniture; occupational exposures among firefighters and other first responders battling wildfires; and some air pollutant exposures in disproportionately impacted communities. Combined with other exposure assessment tools, such as environmental monitoring, biomonitoring is also used to identify important routes of exposure, which may be targeted for reduction.

Some of the chemicals measured by Biomonitoring California pose significant, known health concerns, while many are less well studied. For most chemicals we biomonitor, there is insufficient scientific information to determine the specific health risks associated with levels measured in people. By combining information from biomonitoring studies with other research, scientists can learn how chemicals affect our health and support efforts to reduce exposures to harmful substances.

Measuring Harmful Chemical Exposures

Two nationally recognized laboratories are integral parts of Biomonitoring California. The Environmental Health Laboratory (EHL), a branch of CDPH, has a highly advanced and sensitive method for measuring metals in blood and urine. This is an essential public health tool for California’s efforts to address exposures to toxic metals, such as lead and mercury. EHL also has extensive capability to measure urinary levels of many non-persistent[3] organic chemicals, such as phenols, which are found in cosmetics and many other consumer products, and polyaromatic hydrocarbons (PAHs), which are a byproduct of combustion.

[3] Non-persistent chemicals are those that enter the body and are generally metabolized and/or eliminated with urine or stool within hours to weeks.

The Environmental Chemistry Laboratory (ECL), a division of DTSC, has been on the forefront of developing and implementing methods to measure persistent[4] organic chemicals, such as polybrominated diphenyl ether (PBDE) flame retardants and chemicals of emerging national concern, such as PFASs in serum.[5] ECL also analyzes serum for legacy pollutants, like polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs).

During the two-year period covered by this report (July 2019 through June 2021), Biomonitoring California analyzed more than 1700 specimens from over 800 individuals for toxic chemicals or their breakdown products. The chemicals measured during this time period by Biomonitoring California labs or external collaborators are highlighted below. Appendix C provides the complete list of chemical groups that the Program's laboratories can measure.

- **Metals**, including arsenic, cadmium, cobalt, lead, and mercury. Metals are used in many industries and are found in a variety of products. Exposures to metals are linked to a range of potential health effects, including cancer; cardiovascular disease; toxicity to the respiratory system, nervous system, and kidneys; and harm to the developing infant and child.
- **PFASs**, a class of thousands of chemicals which are used in a variety of consumer and industrial applications (e.g., grease-repellent food containers, non-stick cookware, stain-repellent carpets and clothing, and fire-fighting foams). PFASs may affect the developing fetus and child, decrease fertility, increase the risk of thyroid disease, interfere with the body's natural hormones and the immune system, and increase cancer risk.
- **Phenols**, a broad class of chemicals that are often used in personal care products, consumer products, and some plastics. Examples include bisphenol A (BPA), used in hard plastics, fabric adhesives, and some cash register receipts; bisphenol S (BPS) and bisphenol F (BPF), which are used as replacements for BPA in some applications; parabens, which are added as preservatives to many products; and benzophenone-3 (BP-3),

[4] Persistent chemicals are those that are eliminated from the body very slowly (years to decades) and may accumulate in specific areas of the body (often fat tissue or bone).
[5] Serum is the clear liquid component of blood from which cells, platelets, and clotting proteins have been removed.

which is a UV stabilizer and the active ingredient in many sunscreens. Many phenols affect the endocrine system.

- **1-Nitropyrene (1-NP)**, a marker of exposure to diesel exhaust, which is associated with cancer, asthma, and other serious health effects.
- **Quaternary Ammonium Compounds (QACs)**, often the active ingredient in disinfectants and antibacterial hand soaps. QACs are also used in other consumer products like hair conditioners and fabric softeners, and for a range of applications in oil and gas operations (including hydraulic fracturing). Some QACs are associated with skin sensitization and induction of work-related asthma and may affect reproduction/ development and lipid metabolism.

Biomonitoring California Studies

The Biomonitoring California studies conducted during the time period covered by this report (July 2019 – June 2021) are described in more detail below and include:

- Surveillance studies, which provide information about baseline levels of chemicals across the state. Surveillance data can help us identify high-exposure individuals and communities for follow up. Surveillance data can also help us understand how exposures vary between communities and change over time, in the context of changing environmental policies and product formulations. Statewide surveillance is the primary mandate established by Biomonitoring California's founding legislation.

- Targeted investigations, which increase understanding of how certain groups may be exposed to chemicals. Targeted investigations may be focused on geographic communities, occupational workgroups, or subpopulations defined by demographics or other parameters.

The main components of Biomonitoring California studies generally include participant recruitment, sample collection, questionnaires to help determine potential exposure sources, returning results to participants, and epidemiologic analyses of results. All studies are approved by the Committee for the Protection of Human Subjects, which is the State's Institutional Review Board (IRB).

Summary results for all Biomonitoring California studies are posted to the Program's interactive online database as they become available. Selected new findings within the reporting period are included below; summary data from the reporting period are provided in Appendix D. Information on current and past Biomonitoring California studies is available through the Program's online project archive.

California Regional Exposure (CARE) Study

The CARE Study was designed to provide surveillance data from across California. The state was divided into eight regions to facilitate field work, and the CARE Study was projected to visit one region per year. Recruitment was conducted by advertising to a broad audience through mass mailings, on-line postings, and social and professional networks. Interested, eligible individuals were then selected to reflect specific regional demographics.

The current reporting period covers CARE Study activities in three regions: Region 1 (Los Angeles [LA] County), Region 2 (Riverside, San Bernardino, Imperial, Mono, and Inyo counties), and Region 3 (San Diego and Orange counties).

Chemicals measured in the CARE Study were selected based on known or suspected health effects and widespread exposures across the state. Samples from all CARE Study participants were analyzed for 10 metals and 12 PFASs. Some participants were also biomonitored for phenols and 1-NP.

The following is a summary of activities in all three CARE regions for this reporting period. Findings from Region 2, which was completed during the reporting period, are also included.

Region 1 (CARE-LA) Activities (Samples collected in 2018)

- Posted summary results to the Biomonitoring California results database
- Presented CARE-LA findings at a public meeting focusing on environmental justice, held by the South Coast Air Quality Management District (SCAQMD)
- Conducted statistical analyses of biomonitoring results and exposure data
- Presented analysis of trends and summary results from CARE-LA at events including Biomonitoring California SGP meetings, a technical forum for the State Water Resources Control Board (SWRCB), and the International Society of Exposure Science annual meeting

Region 2 (CARE-2) Activities (Samples collected in 2019)

- Performed laboratory analyses of collected urine and blood samples
- Returned individual results to CARE-2 participants
- Conducted statistical analyses of biomonitoring results
- Posted summary results to the Biomonitoring California results database
- Presented analysis of trends and summary results from CARE-2 at events including Biomonitoring California SGP meetings, a technical forum for the State Water Resources Control Board (SWRCB), and the International Society of Exposure Science annual meeting

Region 3 (CARE-3) Activities (Samples collected in 2020)

- Met with San Diego and Orange county public health officials and other Region 3 stakeholders
- Opened recruitment for CARE-3
- Enrolled 323 CARE-3 participants
- Collected samples from 90 CARE-3 participants before sample collection was halted due to the COVID-19 emergency
- Performed laboratory analyses of collected urine and blood samples
- Returned individual results to 90 CARE-3 participants

CARE-2 Findings

We selected people to participate in CARE-2 with the goal of reflecting the demographic make-up of the population of the region. However, due to slightly unequal participation rates across demographic groups, study participants (n=359) were somewhat older than the region's population; more women (56%) participated than men (44%); and Hispanics and Blacks were slightly underrepresented. Demographic information on CARE-2 participants is available in Appendix D. The findings presented here are reflective of the CARE-2 study population. Weighted data and exposure estimates for the Region 2 population will be included in the CARE Study report.

CARE-2 identified a participant with elevated blood mercury. Individual follow-up revealed that the participant was experiencing health symptoms and that the use of imported skin-lightening cream was the likely source of mercury exposure. The Program provided information on exposure sources and potential health concerns. We invited the participant to speak with a Program physician, and to share the information received with their health care provider.

Mercury poisoning resulting from the use of skin lightening creams continues to be an important public health issue. For more information, please visit this CDPH website.

Metals

- 100 percent of CARE-2 participants had lead in their blood. Almost all (98 and 95 percent, respectively) had cadmium and mercury in their blood.
- Five of the nine urinary metals measured (arsenic, cadmium, cobalt, molybdenum, and thallium) were detected in 94-100% of participants. Urinary mercury was detected in 87% of samples.
- 14 participants (4%) had elevated blood mercury levels; one of these participants also had elevated urinary mercury.
- 16 participants (4%) had elevated total urinary arsenic levels. 10 participants (3%) had elevated levels of urinary inorganic arsenic, the form of arsenic that is toxic to humans.

- The Program conducts follow-up with all participants that have elevated levels of cadmium, lead, mercury, or arsenic.[6]
- Levels of urinary mercury were two times higher in participants who preferred Spanish-language study materials compared with participants who preferred English-language materials.
  Participants born in either Asia/Pacific Islands or in Central or South America or the Caribbean had higher levels of total urinary arsenic than participants born in the United States. This is likely due to elevated arsenobetaine (one type of organic arsenic), which is commonly found in seafood and not considered toxic.

PFASs

- All participants but one had at least one of the 12 PFASs tested in their blood. On average, participants had seven PFASs in their blood.
- Three PFASs (PFOA, PFOS, and PFHxS) were detected in over 98% of participants. PFNA was detected in 92% of participants.
- When adjusted for age and race, CARE-2 levels of PFOA, PFOS, and PFHxS were 24-81% higher in men than women, consistent with other studies. The largest difference was for PFHxS.
- PFAS levels increased with age, by 8-20% per decade.
- Overall PFAS levels differed by race, with Asian participants generally having the highest levels and Hispanic participants the lowest levels. The differences were less pronounced in CARE-2 than in CARE-LA. These patterns have been observed in national data as well and noted in published literature.

Phenols

- BPA, BP-3, and methyl paraben (MP) were detected in more than 65% of samples.
- Adjusted for age, levels of BP-3 were 36% higher in women than in men. BPA was also slightly higher in women (13%). Levels of MP were over three times higher in women than in men.
- MP and BPA levels increased with age. MP levels increased by 23% per decade, and BPA increased by 13% per decade.

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[6] The Program sets "levels of concern" (LOCs) based on guidance from federal and State programs. Participants with an arsenic, cadmium, lead, or mercury result above the LOC are contacted for one-on-one follow-up and additional exposure assessment. For more on LOCs, see page 16.

1-NP

- We measured two metabolites of 1-NP, 6-hydroxy-1-nitropyrene (6-OHNP) and 8-hydroxy-1-nitropyrene (8-OHNP). Both were found in over 86% of samples, indicating widespread exposure to diesel exhaust.
- Levels of 1-NP metabolites were not associated with demographic factors except for age. 8-OHNP levels declined by 12% with every year of age.

CARE-2 findings of near universal detections of metals and PFASs and the differential exposures in race/ethnic groups are consistent with prior Biomonitoring California studies. However, for chemicals such as 1-NP, little data for comparison exists; programs like Biomonitoring California are just starting to understand exposures to these chemicals.

Over time, tracking of chemical levels in Californians can be used to evaluate temporal trends and to compare levels between different demographic groups. Comparison between CARE regions as well as between California and national data will be available in the upcoming CARE Study report and the next legislative report.

Measuring Analytes in Maternal Archived Samples (MAMAS)

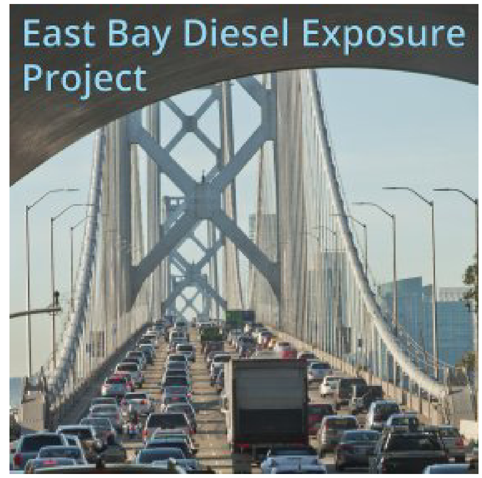
The MAMAS study analyzes maternal serum samples collected through CDPH's Genetic Disease Screening Program (GDSP). Samples obtained through routine prenatal screening are archived and made available to researchers through the California Biobank Program.

Biomonitoring California identified a subset of GDSP samples, collected from pregnant women across the state between 2012 - 2016, to analyze for levels of specific persistent chemicals (PFASs, PBDEs, PCBs, and OCPs). Only samples from singleton, healthy pregnancies were included in MAMAS. Samples were selected randomly to fulfill a sampling goal of equal numbers of samples by maternal race.

In the current reporting period, Biomonitoring California analyzed 292 samples for PFASs. Summary data will be added to the Biomonitoring California online results database.

East Bay Diesel Exposure Project (EBDEP)

EBDEP is a collaboration with the Center for Environmental Research and Children's Health at the University of California, Berkeley, and the University of Washington.



Measuring diesel exhaust exposures has been a key and ongoing priority of the SGP. To address this priority, the Program launched EBDEP in 2017 using one-time funding provided by the Legislature. EBDEP was designed to measure exposures to diesel exhaust and examine how exposures vary within families, between communities, and at different time points. Sample collection was completed during the previous reporting period.

EBDEP Activities (samples collected 2018-2019)

- Returned individual results, including 1-NP metabolites measured in urine and complementary data on 1-NP in house dust and indoor air samples, to 40 participating families.
- Presented initial EBDEP findings at the November 2019 SGP meeting and on the "Diesel Free by '33" webinar, sponsored by the Bay Area Air Quality Management District.
- Presented summary findings to EBDEP participants and other community members at a meeting of the West Oakland Community Steering Committee (established as part of implementing Assembly Bill 617 [AB 617]) and at a virtual community meeting for Richmond and San Pablo residents.
- Posted EBDEP summary results to the Biomonitoring California results database.
- Conducted additional analyses to examine important predictors of diesel exhaust exposures, such as traffic density, number of bus stops, and number of permitted diesel sources near participants' homes.

EBDEP Findings

- 1-NP metabolites were present in the urine of most participants (detection frequencies > 90%), indicating widespread exposure to diesel exhaust in EBDEP communities.
- Urinary 1-NP metabolite levels were generally higher during the fall and winter months.
- Levels of the 1-NP metabolite 6-OHNP were significantly higher in parents compared with their children.
- 1-NP metabolite concentrations measured in repeat urine samples from the same participants during one-week time periods showed high variability, which reflects the short half-lives of these chemicals in the body.

EBDEP summary results are available in the Biomonitoring California results database and in Appendix D. 1-NP levels measured in adult EBDEP participants were overall higher than levels measured in the CARE studies (LA County and Region 2), potentially due to EBDEP's focus on high-traffic areas. Comparisons for children are not available, due to a lack of comparable data.

EBDEP was conducted primarily in West Oakland and Richmond/San Pablo, which are communities heavily impacted by air pollution and other stressors like health inequities and high unemployment. Both of these communities, along with many others across the state, are now included in the Community Air Protection Program (CAPP), which was established by the California Air Resources Board (CARB) in 2018 to help fulfill the requirements of AB 617. EBDEP laid the groundwork for additional biomonitoring studies being planned for other AB 617 communities.

Additional Activities

Dissemination of Program Findings

Program information is disseminated to the public in several ways. The first priority is to provide results to study participants, including notification of elevated levels of chemicals and health education materials (see section below). Preliminary study findings, such as demographic, geographic, or temporal trends, are then released to stakeholders at public meetings and through the Program website. In coordination with the CDPH Office of Communications, the Program may share study findings through press releases and social media.

This Report to the Legislature will be posted to the CDPH and Biomonitoring California websites and shared with Program stakeholders via listserv and email.

Biomonitoring California staff and collaborators also participate in scientific conferences and publish study results in peer-reviewed journals. Appendix E lists journal publications and presentations by Biomonitoring California staff and collaborators that were produced during this reporting period.

Notification of Elevated Levels of Chemicals

The Program provides one-on-one follow-up for participants with an arsenic, cadmium, lead, or mercury result that exceeds the respective "level of concern" (LOC).

Biomonitoring California's LOCs are adopted from other State and Federal agencies. LOCs for arsenic, cadmium, and mercury are based on guidance from the U.S. Environmental Protection Agency and U.S. Centers for Disease Control and Prevention (CDC); the LOC for lead was established by CDPH's Occupational Lead Poisoning Prevention Program (OLPPP).

Chemical	Measured in	Level of Concern for Adults
Arsenic (total)	Urine	≥ 50 micrograms (μg)/liter
Arsenic (inorganic)	Urine	≥ 20 μg/liter
Cadmium	Urine	>3 μg/g creatinine
Cadmium	Blood	≥ 5 μg/liter
Mercury	Urine	≥ 10 μg/liter
Mercury	Blood	≥ 5.8 μg/liter if pregnant or considering becoming pregnant; ≥ 10 μg/liter for all other adults
Lead	Blood	≥ 4.5 μg/deciliter

Of the 449 participants who were biomonitored for metals during this reporting period, about 9 percent had a result that exceeded the Program's LOC for one or more chemicals. Participants whose result(s) exceed the LOC(s) are provided with follow-up support. Follow-up includes a review of the participant's survey responses and a discussion with the participant about possible exposure sources and ways they might reduce their exposures. Follow-up for participants with elevated lead levels is conducted in coordination with OLPPP.

Providing Individual Results and Health Education

One of the founding principles of Biomonitoring California is that individuals have a right to know about the chemicals that have been detected in their own bodies. As required in the enabling legislation, individual results are always made available to study participants. Participants receive an introductory letter; study description; the participant's levels of measured chemicals, with study and NHANES[7] comparison values (when available); brief explanations of how to interpret the results; and chemical-specific fact sheets. The fact sheets include information on where the chemical is found, possible health concerns, and potential ways to reduce exposures. Materials are available in English, Spanish, and additional languages as needed.

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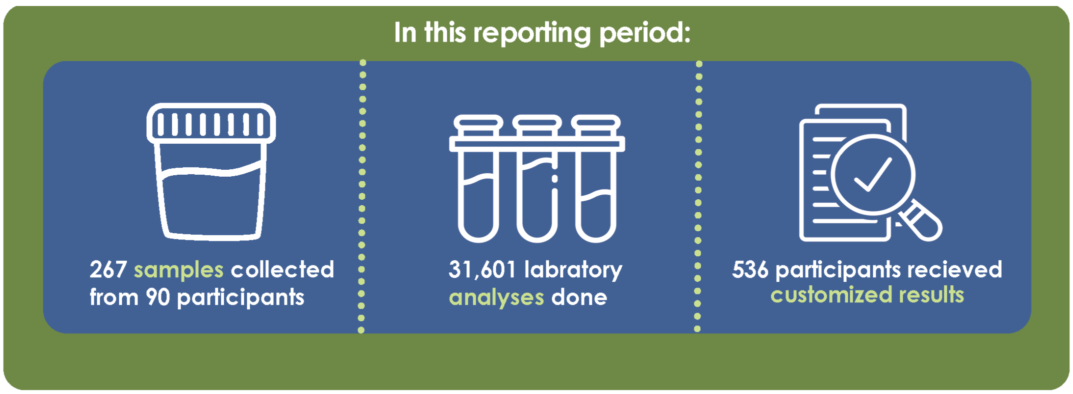
[7] National Health and Nutrition Examination Survey conducted by CDC. Samples from NHANES are analyzed for environmental chemicals as part of CDC's National Biomonitoring Program.

Over 99 percent of participants ask to receive their results; one of the factors that motivates participants to enroll in a biomonitoring study is to learn about their own chemical exposures. In the current reporting period, Biomonitoring California returned detailed results materials for 536 participants.[8]

The Program website provides further details on [communicating biomonitoring results](), including examples of the Program's results return materials.



Scientific Guidance Panel (SGP) and Chemical Selection

Scientific peer review of Biomonitoring California is provided by the SGP. OEHHA is responsible for convening and staffing the Panel and developing scientific documents and other materials to support the SGP's deliberations. The Panel consists of five members appointed by the Governor, two by the Speaker of the Assembly, and two by the Senate Rules Committee. SGP meetings are open to the public and are accessible via webcast or webinar.

The SGP provides formal recommendations on chemicals or chemical classes that should be biomonitored in California. The Panel also provides input on program priorities, study design and implementation, laboratory methods, and emerging scientific issues related to biomonitoring. The six SGP meetings held

[8] Results were not returned to individuals in the MAMAS study (n=292) because the identity of sample donors was not available to the Program.

during the current reporting period included routine Program updates and in-depth discussions of the following topics:

- **CARE Study findings,** including summary statistics and preliminary analyses of exposures by demographic groups (July 2019, March 2020, and July 2020)
- **Flame retardant exposures**, which included discussion of the Foam Replacement Environmental Exposure Study (FREES), described in the Sixth Report to the Legislature (July 2019)
- Initial results on **diesel exhaust exposures** from CARE-LA and EBDEP, and a discussion with CARB to explore **next steps for biomonitoring in AB 617 communities** (November 2019)
- Potential health effects of and human exposure to **quaternary ammonium compounds**, as part of the SGP's consideration of this class for inclusion on Biomonitoring California's lists of designated and priority chemicals (March 2020 and March 2021)
- **Non-targeted screening**, which included presentations from Biomonitoring California labs and national experts on how this technology could be used to assess exposure to current and emerging chemicals of concern (July 2020)
- **Surveillance study design**, with presentations from California Health Interview Survey staff and biomonitoring programs from other states about the challenges of conducting surveillance (November 2020)

For additional information, visit the SGP meeting page.

Public Involvement

Biomonitoring California is mandated to "provide opportunities for public participation and community capacity building" and to allow for "meaningful stakeholder input." The Program has several opportunities for public input:

- **Public access at SGP meetings**. Each SGP meeting is open to the public and includes an open public comment period. Individuals may share comments or ask questions in person or online. To address the COVID-19 emergency, the Governor authorized exemptions to certain requirements of the Bagley-Keene Open Meeting Act. This allowed the program to hold SGP meetings as webinars for the duration of this reporting period, starting in July 2020.

- **Online participation through Program email, listserv, and website**. The public can email the Program at any time with input and receive updates via the listserv, which had 1085 subscribers as of June 2021. Notes are sent to subscribers approximately twice each month with information on Program activities and highlighting new materials posted on the website, such as biomonitoring results.
- **Outreach to local health departments and community-based organizations**. Biomonitoring California staff routinely reach out to local health departments and community organizations during study planning and implementation and as part of disseminating results. Outreach may involve education on biomonitoring and environmental health issues; it also provides an opportunity for stakeholders to provide input on local issues and concerns.

More information on the range of public involvement efforts being carried out by Biomonitoring California can be found on the Program website.

Support for Other California Programs

Biomonitoring California is a critical component of the State's innovative regulatory and public health programs designed to reduce or prevent harmful chemical exposures. The Program produces valuable data that helps to identify and quantify chemical exposures across the state. Study results are shared to help inform and evaluate public health policies. Biomonitoring California findings are also used to support and inform other California programs, including the following.

- **The Safer Consumer Products (SCP) program**, operated by DTSC, was established to reduce toxic chemicals in the products that consumers buy and use. Biomonitoring California and SCP regularly collaborate to identify chemicals of emerging concern. The Program's priority chemicals are included in SCP's list of candidate chemicals.
- **The Community Air Protection Program** was established by CARB in response to AB 617. Targeted biomonitoring studies planned for AB 617

communities will complement ongoing air monitoring and help evaluate the effectiveness of strategies to reduce air pollution exposures.

- **The California State Water Resources Control Board** (SWRCB) protects the quality of the state's surface, ground, and drinking water. SWRCB requires measurement of PFASs in water sources near airports and municipal solid waste landfills, and from community water suppliers. It has also issued drinking water Notification Levels and Response Levels for specific PFASs. Biomonitoring California regularly confers with SWRCB on PFAS exposures. Biomonitoring California staff presented CARE Study data at an SWRCB technical seminar on PFASs to engender cross-department collaborations utilizing biomonitoring and drinking water measurements.
- **CalEnviroScreen,** a tool developed by OEHHA, uses environmental, health, and socioeconomic information to produce scores for every census tract in the state. The scores are mapped to help identify California communities with the highest pollution burdens and vulnerabilities. Information from Biomonitoring California studies, which directly measure chemical exposures, can be used to inform CalEnviroScreen scores.
- **Proposition 65**, formally known as the Safe Drinking Water and Toxic Enforcement Act of 1986, requires businesses to inform Californians if activities or products associated with the business can result in significant exposure to chemicals known to cause cancer, birth defects or other reproductive harm. Findings from Biomonitoring California studies are being used by researchers to help evaluate the impact of Proposition 65 on selected chemical exposures. OEHHA is the lead agency for implementation of Proposition 65.
- **The Occupational Lead Poisoning Prevention Program** (OLPPP), at CDPH, investigates and works to prevent lead poisoning cases linked to the workplace. Biomonitoring California collaborates with OLPPP to define and implement appropriate follow-up for study participants with elevated lead levels.

Complementary Studies and Support to External Partners

Biomonitoring California staff are involved in complementary studies related to chemical exposures, and also provide support and technical assistance to local agencies and researchers conducting biomonitoring and exposure assessments. Examples within the current reporting period include:

- **Maternal Cotinine and Autism Study.** CDPH's Environmental Health Laboratory (EHL) analyzed 201 maternal serum samples for cotinine, a metabolite of nicotine. Results will be used by CDPH to study the link between childhood neurological development and exposure to tobacco smoke.
- **Camp Fire Firefighter Study**. Biomonitoring California provided support to Commonweal and the San Francisco Firefighters Cancer Prevention Foundation in their investigation of chemical exposures in firefighters immediately following response to the Camp Fire of 2018. Program staff assisted with sample management, study logistics, and results return materials. EHL and DTSC's Environmental Chemistry Lab (ECL) conducted the laboratory analyses for metals, PBDEs, and PFASs. Results will be used by partners to inform health-protective measures for future wildfire responders.
- **Environmental Influences on Child Health Outcomes (ECHO).** This pediatric cohort study was initiated by National Institutes of Health (NIH) to study the relationship between prenatal chemical exposures, birth outcomes, and cognitive development in early childhood. ECL is a partner in a sub-study of ECHO, which is studying 1300 pregnant women from California and Illinois. During the reporting period, ECL measured PFASs in blood samples of 838 study participants.

Recommendations and Conclusions

Program priorities are shaped by our founding legislation and input from the Scientific Guidance Panel (SGP) and external stakeholders. At the July 2021 SGP meeting, recommendations for Program directions were discussed by the Panel for inclusion in this report. Dr. Megan Schwarzman, SGP Chair, and Dr. Penelope (Jenny) Quintana, SGP member, summarized the Panel's recommendations in an October 4, 2021 letter to the Program (see Appendix F). The recommendations of the Scientific Guidance Panel are listed below, along with paraphrased excerpts from the letter.

1. **Mitigate environmental health inequities**. The Program should conduct studies to identify disparities in exposure to environmental contaminants in environmental justice communities and populations, as a step toward addressing disproportionate harms. Examples of these studies include biomonitoring for pesticide exposures in farmworker communities or measuring diesel exposures in communities near high-traffic roadways or other sources of vehicular pollution, such as ports and distribution centers. Such studies can document disparities and inform targeted public health interventions.
2. **Design intervention studies to identify the impact of public policy and non-regulatory actions**.
   Intervention studies investigate questions specific to a particular public health or regulatory issue and can:
   - Assess changes in exposure to a particular pollutant following an intervention, such as a study evaluating the impact of air filtration.
   - Investigate the impact of consumer product changes, such as examining flame retardant exposures before and after the removal or replacement of foam-containing furniture.
   - Examine the impacts of state or regional policy, such as CARB clean diesel rules.
   - Help address community requests for action to reduce environmental harms.
3. **Evaluate exposures associated with climate change**. The Program should conduct studies that measure biomarkers of exposure to pollutants expected to increase with climate change. Examples include:
   - Chemicals associated with fires at the wildland-urban interface.
   - Pollutants in private water supplies that rural communities depend on and that tend to concentrate as water scarcity worsens.
   - Volatile, semi-volatile, or persistent organic compounds that could increase in concentrations with higher ambient temperatures.

4. **Use non-targeted analyses to identify industrial or commercial chemicals previously unrecognized as pollutants.** Non-targeted analysis (NTA) for chemicals in biological samples can identify previously unrecognized industrial or commercial compounds of potential concern for health. Instead of targeted testing for the presence of specific chemicals, which is the standard biomonitoring approach, NTA uses new techniques to screen for a much broader set of chemical contaminants in blood or urine. Biomonitoring California could apply NTA to proactively identify formerly undetected exposures in specific occupational groups (e.g., farmworkers and firefighters) or in high-risk groups (e.g., children from disproportionately polluted neighborhoods).
5. **Acknowledge the gap between what is feasible based on budget, and what would be required to meet the program's legislative mandate to conduct statewide surveillance.** In acknowledgement of the gap between the cost of statewide surveillance studies and the Program's allocation, Biomonitoring California should design smaller studies to assess inequities and link exposures and health; evaluate temporal trends and the effectiveness of public health regulatory programs; and address community concerns. The Panel also recommends additional resources to support effective statewide surveillance, which would include:
    - Designing and implementing recruitment to ensure that disadvantaged populations are well- represented.
    - Studying more regions of California simultaneously to generate statewide results and establish trends in various regions across comparable time periods.
    - Measuring a larger variety of chemicals in people, making efficient use of the Program infrastructure that already exists.

Biomonitoring California is uniquely able to identify, quantify, and report on harmful chemicals present in the bodies of Californians. This information supports effective actions by the State to reduce specific chemical exposures and improve public health. Biomonitoring California studies have demonstrated widespread exposures to metals and PFASs. Additionally, studies help identify communities that are more highly exposed than others and help policy makers, public health leaders, and communities understand these disparities and advance environmental justice efforts across the state.

APPENDICES

Appendix A: Program Structure

Biomonitoring California is a multidisciplinary program developed and implemented collaboratively by the California Department of Public Health (CDPH), Office of Environmental Health Hazard Assessment (OEHHA), and the Department of Toxic Substances Control (DTSC). This multidisciplinary approach contributes to the success of the program by bringing together expertise in analytical chemistry, toxicology, epidemiology, exposure science, and health education. General departmental roles and responsibilities for Biomonitoring California are shown in Figure A1; however, staff members in all three departments frequently collaborate across activities.

Figure A1. Biomonitoring California Departmental Primary Roles and Responsibilities

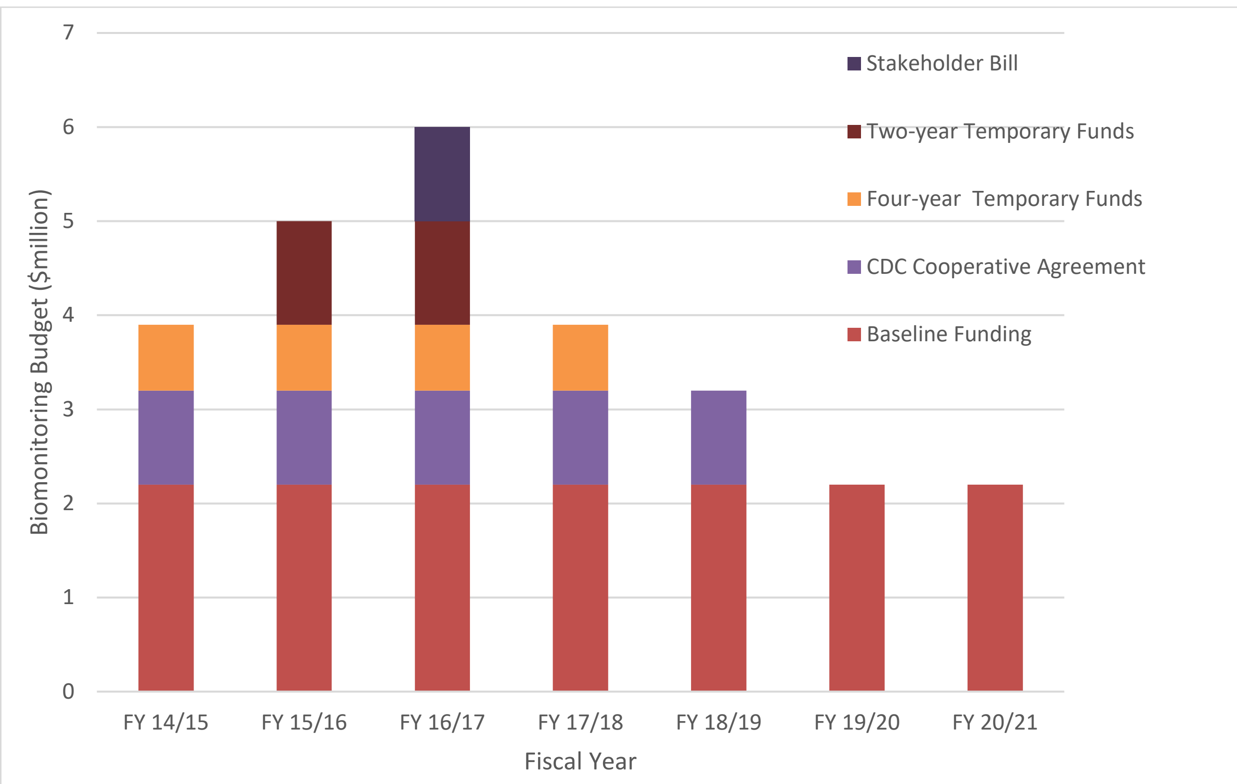
CDPH Environmental Health Investigations Branch	**CDPH** Environmental Health Laboratory	**OEHHA** Reproductive and Cancer Hazard Assessment Branch	**DTSC** Environmental Chemistry Laboratory
• Program lead; responsible for overall coordination of program components and partners • Liaison to National 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	• 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	• 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	• 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: Program Funding

Biomonitoring California has historically received $2.2 million in baseline State funding through five special funds, which have been supplemented by temporary State and federal funding[9] (see Figure B1 and Table B1). This funding supported the following projects in the current reporting period (July 2019 – June 2021):

- California Regional Exposure (CARE) Study
- Measuring Analytes in Maternal Archived Samples (MAMAS)
- East Bay Diesel Exposure Project (EBDEP)

Figure B1: Biomonitoring California Budget, FY2015-2021 (CDPH, OEHHA, and DTSC)



[9] Centers for Disease Control and Prevention Cooperative Agreement 5U88EH001148 (grant period: 2014-2019)

Baseline funding consists of five special funds: 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. Funding is ongoing.

Table B1: Biomonitoring California Budget (CDPH, OEHHA, and DTSC)

Funding/Source	Fiscal Year	Note
Baseline State funding: $2.2 million	n/a - baseline	• Split between CDPH, OEHHA, and DTSC • Supports 13.0 full-time positions
CDC Cooperative Agreement: $1.0 million	FFY 14/15 FFY 15/16 FFY 16/17 FFY 17/18 FFY 18/19	• Funds expired August 2019
State special funds (Four-year[10] augmentation): $700,000	FY 14/15 FFY 15/16 FFY 16/17 FY 17/18	• $350,000 and two 2-year limited-term positions for CDPH • $350,000 and two 2-year limited-term positions for DTSC • Funds expired June 2018
State special funds (2-year augmentation): $1.2 million	FY 15/16 FY 16/17	• $550,000 and six 2-year limited-term positions for CDPH • $600,000 and two 2-year limited-term positions for DTSC • Funds expired June 2017
Stakeholder bill (1-year augmentation): $1.0 million	FY 16/17	• Intended for environmental justice activities • New activities included the EBDEP, an expansion of the ACE Project, and environmental justice outreach • Funds expired June 2017

The State budget that was enacted on July 1, 2021 includes an additional $2 million annually to support the Program. The planned expansion of the Program enabled by this funding will be covered in the Eighth Report to the Legislature.

[10] Funds were initially approved for two years (FY 14/15 and FY 15/16) and were extended for an additional two years (FY 16/17 and FY 17/18)

Appendix C: Program Analytical Capabilities

Biomonitoring California laboratories can measure over 120 chemicals in blood, urine, and serum. A summary of chemical groups measured by Program laboratories is included in the table below. The Program's website provides additional information on these chemicals.

Chemicals may be grouped in classes based on chemical structure or function. A class may be made up of thousands of different chemicals, not all of which can be measured using the same analytical method.

Chemical group	**Description of chemicals in the lab panel**
Environmental phenols	Environmental phenols have a wide variety of uses, such as in personal care and other consumer products, and share a common chemical structure. Environmental phenols currently measured by the Program in urine are bisphenol A (BPA); bisphenol F (BPF) and bisphenol S (BPS), which are used as replacements for BPA in some applications; the antimicrobials triclosan and triclocarban; benzophenone-3 (BP-3), a UV stabilizer used in sunscreens; and parabens, which are used as preservatives in personal care products and food. This group of chemicals may interfere with the body's natural hormones.
Herbicides	Biomonitoring California measures the herbicide 2,4-D in urine. 2,4-D is found in some home lawn products designed to kill weeds. There is concern that 2,4-D may interfere with the body's natural hormones and affect the developing fetus and may increase cancer risk.

Chemical group	Description of chemicals in the lab panel
Metals	Metals are used in many industries and are found in a variety of products. Biomonitoring California measures antimony, arsenic (total and specific forms), cadmium, cobalt, lead, manganese, mercury, molybdenum, thallium, and uranium. • Some forms of antimony may contribute to respiratory problems, affect the heart, and increase cancer risk. • Inorganic arsenic may harm the developing fetus, contribute to cardiovascular disease, and can increase cancer risk. The most prevalent form of arsenic in seafood is not considered to be a health concern. • Cadmium, lead, and mercury are toxic metals with established levels of concern that can cause a range of health effects, including harm to the developing infant and child, and increased cancer risk. • Cobalt is essential as part of vitamin B12, but in other forms can harm the heart, thyroid, and nervous system, and may increase cancer risk. • Manganese and molybdenum are essential nutrients that can be toxic at higher levels. • Thallium is a highly toxic metal that can harm many important processes in the body. • Uranium can cause kidney damage and increase cancer risk. Biomonitoring California measures metals in urine and/or blood.
Organochlorine pesticides (OCPs)	The OCPs measured by Biomonitoring California in serum are no longer used in the United States. Because OCPs last a long time in the environment, they can still be found in high-fat fish, meat, and dairy products. Examples of OCPs include DDT, which is still used in some other countries, and chlordane. OCPs may affect the developing fetus, may interfere with the body's natural hormones, and may increase cancer risk.

Chemical group	Description of chemicals in the lab panel
Organophosphate flame retardants (OPFRs)	As brominated flame retardants are phased out, organophosphate flame retardants have been entering the market in larger quantities. Some OPFRs may interfere with the body's natural hormones, decrease fertility, affect the developing fetus, and increase cancer risk. Biomonitoring California measures organophosphate flame retardant metabolites in urine.
Organophosphate (OP) pesticides	OP pesticides are used in commercial agriculture to control pests on fruit and vegetable crops. They are also used in home gardens, for flea control on pets, and in some no-pest strips. OP pesticides may affect the nervous system and may harm the developing fetus, possibly affecting later learning and behavior. Biomonitoring California measures OP pesticide metabolites in urine.
Perfluoroalkyl and polyfluoroalkyl substances (PFASs)	PFASs are used to make various products resistant to stains, grease, and water. Some example products that use PFASs include non-stick cookware, stain-repellent carpets and clothing, and grease-repellent food containers. PFASs may affect the developing fetus and child, decrease fertility, interfere with the body's natural hormones and the immune system, and increase cancer risk. There are thousands of PFAS chemicals in use. Biomonitoring California measures twelve PFASs in serum.
Polybrominated diphenyl ethers (PBDEs)	PBDE flame retardants were commonly added to polyurethane foam used in upholstered furniture and in some infant products. PBDEs were also used in electronics and insulation for cables and wires. U.S. production of penta- and octa-PBDEs ended by 2006. PBDEs have spread through the environment and break down slowly. Research studies have measured the world's highest levels of PBDEs in California residents. PBDEs may interfere with the body's natural hormones, may harm the developing fetus, and may decrease fertility. Biomonitoring California measures PBDEs in serum.

Chemical group	Description of chemicals in the lab panel
Polychlorinated biphenyls (PCBs)	PCBs were widely used to insulate electrical equipment and as plasticizers. PCBs were banned in the late 1970s but are still in some old equipment and products. They have spread through the environment and take a long time to break down. They are found in some high-fat fish and high-fat animal products, and in old caulk and old fluorescent light fixtures. Exposure to PCBs can affect the developing fetus and interfere with the body's natural hormones and may increase cancer risk. Biomonitoring California measures PCBs in serum.
Polycyclic aromatic hydrocarbons (PAHs)	PAHs occur naturally in petroleum products, such as gasoline and diesel, and are formed when these products are burned. PAHs are found in tobacco, wood, and wildfire smoke. They also form when foods are grilled, barbecued, or roasted. PAHs may contribute to respiratory problems, affect the developing fetus and the body's natural hormones, and increase cancer risk. Biomonitoring California measures PAH metabolites in urine.
Pyrethroid pesticides	Pyrethroid pesticides are common ingredients in pest control products for the home and garden. They are also used to control insects on commercial agricultural crops and livestock. Some pyrethroid pesticides may affect the developing fetus, interfere with the body's natural hormones, and increase cancer risk. Biomonitoring California measures pyrethroid pesticide metabolites in urine.

Appendix D: Summary Data from CARE and EBDEP

Data generated during this reporting period (July 2019- June 2021) are summarized below. This includes data from the California Regional Exposure Study – Region 2 (CARE-2) and the East Bay Diesel Exposure Project (EBDEP). 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.
- **Level of Detection (LOD)**: The lowest concentration of an analyte that can be reliably measured.

In some tables, the total number of samples does not match the number of total participants in the study since not all participants were able to provide both urine and blood samples.

Data for the other studies described in the Seventh Report as well as data from prior Biomonitoring California studies can be found on the Biomonitoring California website.

CARE 2 – Participant Demographics

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

[1] Number of participants may not sum to 359, and percentages may not sum to 100% because of missing data.

[2] From ACS 2019, using the 5-year estimates provided for smaller U.S. 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).

CARE Study participants were asked to indicate all racial or ethnic designations they identified with. In compliance with Assembly Bill (AB) 532 (Government Code section 8310.9), this information is presented in several ways:

- People who identify as a single ethnic or racial designation
- People who identify as multiple ethnic or racial designations
- People with a particular racial designation alone or in combination with other ethnic or racial designations

Participants who identified as a single race/ethnicity, not in combination with any other ethnic or racial designation	**CARE-2 Number** (Total n =359)[1]	**CARE-2 Percent (%)**
American Indian or Alaskan Native	4	1
Asian	22	6
Black or African American	16	4
Hispanic or Latino[2]	139	39
Native Hawaiian or Other Pacific Islander	0	0
White	131	37
Participants who identified as multiple ethnic or racial designations	**CARE-2 Number**	**CARE-2 Percent (%)**
Hispanic multiracial[2]	5	1
Hispanic and one race[2]	22	6
Non-Hispanic multiracial[3]	13	4
Participants who identified as any of these ethnic or racial designations, either alone or in combination	**CARE-2 Number**	**CARE-2 Percent (%)**
American Indian or Alaskan Native	11	3
Asian	27	8
Black or African American	26	7
Hispanic or Latino	166	46
Native Hawaiian or Other Pacific Islander	4	1
White	161	45

[1]Seven individuals in CARE-2 provided no race or ethnicity designations; therefore, numbers and percentages might not equal the total sample population.

[2]CARE Study participants were asked their race and ethnicity in a single question, without a separate question about Hispanic ethnicity. Therefore, it is possible for a participant to have indicated "Hispanic" alone and no racial category.

[3]Includes individuals who identified as mixed/biracial without indicating particular racial designations.

Metals Measured in Blood

Data are reported in µg/L with the exception of lead (µg/deciliter).

CARE-2

Summary results for levels of metals in blood (see units above) from 359 CARE-2 samples.

Chemical	Geometric mean	25th percentile	50th percentile	75th percentile	95th percentile	Detection frequency (%)
Cadmium	0.27	0.16	0.27	0.43	0.81	98.3
Lead	0.68	0.42	0.72	1.1	1.8	100
Manganese	10.2	8.2	10.2	12.7	16.4	100
Mercury	0.65	0.28	0.68	1.4	5.0	95.0

Metals Measured in Urine

Data are reported in micrograms per liter (µg/L) with the exception of cadmium (micrograms per gram creatinine).

California Regional Exposure Study – Region 2 (CARE-2)

Summary results for levels of metals in urine (see units above) from 357 CARE-2 samples.

Chemical	Geometric mean	25th percentile	50th percentile	75th percentile	95th percentile	Detection frequency (%)
Antimony	*	<LOD	<LOD	<LOD	0.17	17.6
Arsenic	6.0	2.7	6.2	11.9	49.2	100
Cadmium	0.24	0.14	0.24	0.41	0.91	95.0
Cobalt	0.19	0.10	0.19	0.39	1.2	94.1
Manganese	*	<LOD	<LOD	<LOD	0.31	19.0
Mercury	0.16	0.06	0.16	0.36	1.3	87.1
Molybdenum	30.9	15.5	34.4	64.3	140	100
Thallium	0.15	0.08	0.17	0.28	0.47	99.7
Uranium	*	<LOD	0.01	0.03	0.11	53.2

*This value cannot be calculated because the metal was not found in enough people (<65%).

Perfluoroalkyl and Polyfluoroalkyl Substances (PFASs) Measured in Serum

Data are reported in nanogram per milliliter (ng/mL).

CARE-2

Summary results for levels of PFASs in serum (ng/mL) from 358 CARE-2 samples.

Chemical	Geometric mean	25th percentile	50th percentile	75th percentile	95th percentile	Detection Frequency (%)
2-(N-Ethyl-perfluorooctane sulfonamido) acetic acid [Et-PFOSA-AcOH]	*	< LOD	< LOD	< LOD	0.05	19.3
2-(N-Methyl-perfluorooctane sulfonamido) acetic acid [Me-PFOSA-AcOH]	0.04	0.02	0.04	0.07	0.32	78.8
Perfluorobutane sulfonic acid (PFBuS)	*	< LOD	< LOD	< LOD	0.05	10.9
Perfluorodecanoic acid (PFDeA)	0.08	< LOD	0.08	0.13	0.29	65.9
Perfluorododecanoic acid (PFDoA)	*	< LOD	< LOD	< LOD	< LOD	0.3
Perfluoroheptanoic acid (PFHpA)	*	< LOD	< LOD	0.05	0.10	43.3
Perfluorohexane sulfonic acid (PFHxS)	0.78	0.46	0.84	1.6	3.8	99.7
Perfluorononanoic acid (PFNA)	0.21	0.12	0.23	0.35	0.79	92.2
Perfluorooctane sulfonamide (PFOSA)	*	< LOD	< LOD	< LOD	0.06	19.8
Perfluorooctane sulfonic acid (PFOS)	2.4	1.5	2.8	4.3	8.7	98.3
Perfluorooctanoic acid (PFOA)	0.98	0.67	1.1	1.7	2.7	98.6
Perfluoroundecanoic acid (PFUA)	*	< LOD	0.040	0.09	0.26	58.4

*This value cannot be calculated because the PFAS was not found in enough people (<65%).

Phenols Measured in Urine

California Regional Exposure Study – Region 2 (CARE-2)

Summary results for levels of phenols in urine (µg/L) from 151 CARE-2 samples

Chemical	Geometric mean	25th percentile	50th percentile	75th percentile	95th percentile	Detection Frequency (%)
Benzophenone-3	18.5	5.59	18.0	50.0	493	96.0
Bisphenol A (BPA)	0.50	< LOD	0.47	1.1	3.2	69.5
Bisphenol S (BPS)	*	< LOD	0.23	0.59	2.3	64.9
Ethyl paraben	*	< LOD	< LOD	2.0	69.7	35.8
Methyl paraben	15.3	3.11	12.6	79.4	535	94.0
Propyl paraben	*	< LOD	1.5	14.8	223	60.3
Triclocarban	*	< LOD	< LOD	< LOD	0.31	11.3
Triclosan	*	< LOD	< LOD	3.0	389	45.0

*This value cannot be calculated because the phenol was not found in enough people (<65%).

Diesel Exhaust Metabolites Measured in Urine

California Regional Exposure Study – Region 2 (CARE-2)

Summary results for levels of diesel exhaust metabolites in urine (pg/L) from CARE-2 participants. 142 samples were analyzed for 6-OHNP, and 155 samples were analyzed for 8-OHNP.

Chemical	Geometric mean	25th percentile	50th percentile	75th percentile	90th percentile	Detection frequency (%)
6-OHNP	150	83	150	300	960	88.7
8-OHNP	89	49	78	160	410	76.1

East Bay Diesel Exposure Project (EBDEP)

Summary results for levels of diesel exhaust metabolites in urine (pg/L) collected from adult participants. 38 samples were analyzed for 6-OHNP, and 40 samples were analyzed for 8-OHNP.

Chemical	Geometric mean	25th percentile	50th percentile	75th percentile	90th percentile	Detection frequency (%)
6-OHNP	240	130	240	540	1500	97.8
8-OHNP	150	82	160	290	730	94.7

Summary results for levels of diesel exhaust metabolites in urine (pg/L) collected from child participants (age 2-10 years). 40 samples were analyzed for 6-OHNP and 8-OHNP.

Chemical	Geometric mean	25th percentile	50th percentile	75th percentile	90th percentile	Detection frequency (%)
6-OHNP	150	63	170	330	1100	94.2
8-OHNP	130	61	130	260	740	95.2

Appendix E: Publications and Presentations

The Program has collaborated on the following papers, July 2019 – June 2021:

Eick S, Enright E, Geiger S, Dzwilewski K, DeMicco E, Smith S, Park J-S, Aguiar A, Woodruff T, Morello-Frosch R, Schantz S. (2021) Associations of maternal stress, prenatal exposure to per- and polyfluoroalkyl substances (PFAS), and demographic risk factors with birth outcomes and offspring neurodevelopment: An overview of the ECHO.CA.IL prospective birth cohorts. Int J. Environ. 18: 742. (January 2021)

Eick SM, Goin DE, Cushing L, DeMicco E, Park J-S, Wang Y, Smith S, Padula AM, Woodruff TJ, Morello-Frosch R. (2021) Mixture effects of prenatal exposure to per- and polyfluoroalkyl substances and polybrominated diphenyl ethers on maternal and newborn telomere length. Environ Health. 20(1):76. (June 2021)

Eick SM, Hom EKT, Izano MA, Cushing LJ, Wang Y, Smith SC, Gao S, Park J-S, Padula AM, DeMicco E, Valeri L, Woodruff TJ, Morello-Frosch R. (2020) Associations between prenatal maternal exposure to per- and polyfluoroalkyl substances (PFAS) and polybrominated diphenyl ethers (PBDEs) and birth outcomes among pregnant women in San Francisco. Environ Health. 19(1):100. (September 2020)

Gill R, Hurley S, Brown FR, Tarrant DH, Dhaliwal J, Sarala R, Park, J-S, Patton, S, Petreas, M (2020). Polybrominated diphenyl ether and organophosphate flame retardants in Canadian fire station dust. Chemosphere 253. (August 2020)

Lee E, Kinninger A, Ursin G, Tseng C, Hurley S, Wang M, Wang Y, Park JS, Petreas M, Deapen D, Reynolds P (2020). Serum levels of commonly detected persistent organic pollutants and per- and polyfluroalkyl substances (PFASs) and mammographic density in postmenopausal women. Int J Environ Res and Public Health 17(2):606. (January 2020)

Mehta SS, James-Todd T, Applebaum KM, Bellavia A, Coleman-Phox K, Adler N, Laraia B, Epel E, Parry P, Wang M, Park J-S, Zota A. (2021)Persistent organic

pollutants and maternal glycemic outcomes in a diverse pregnancy cohort of overweight women. Environ Res. 193:110551 (February 2021)

Sánchez-Soberón F, Sutton R, Sedlak M, Yee D, Schuhmacher M, Park J-S. (2020) Multi-box mass balance model of PFOA and PFOS in different regions of San Francisco Bay. Chemosphere. 252:126454. (August 2020)

Varshavsky J, Sen S, Robinson JF, Park J-S, Smith SC, Frankenfield J, Morello-Frosch R, Fisher SJ, Woodruff TJ. (2020) Racial/ethnic and geographic differences in polybrominated diphenyl ether (PBDE) levels across maternal, placental, and fetal tissues during mid-gestation. Nature-Scientific Report. 10(1):12247. (July 2020)

Varshavsky JR, Robinson JF, Zhou Y, Puckett KA, Kwan E, Buarpung S, Aburajab R, Gaw SL, Sen S, Gao S, Smith SC, Park J-S, Zakharevich I, Gerona RR, Fisher SJ, Woodruff TJ. (2021) Organophosphate flame retardants, highly fluorinated chemicals, and biomarkers of placental development and disease during mid-gestation. Toxicol Science. 181(2):215-228. (May 2021)

Wang A, Abrahamsson D, Ting J, Wang M, Morello-Frosch R, Park J-S, Marina S, Woodruff TJ. (2021) Suspect screening, prioritization and confirmation of environmental chemicals in maternal-newborn pairs from San Francisco. Environ Sci & Technol. 55(8):5037-5049. (March 2021)

Presentations by Program Staff

Attfield, K. Update on Bomonitoring California’s PFAS Biomonitoring. PFAS Technical Forum, State Water Resources Control Board. Dec 4, 2019

Attfield, K. California Regional Exposure Study: Los Angeles County. South Coast Air Quality Management District. Sept 9, 2019

Attfield, K. Highlights of surveillance issues in biomonitoring studies. State Biomonitoring & Environmental Public Health Tracking Community of Practice Call. February 11, 2021

Attfield, K. Biomonitoring of PFASs in California in surveillance and community-focused studies. International Society of Exposure Science Annual Meeting. September 21, 2020

Attfield, K. Foam Replacement Environmental Exposure Study (FREES): Biomonitoring Results. Biomonitoring Scientific Guidance Panel Meeting July 25, 2019.

Baehner, L. Assessing Exposure in the Asian Pacific Islander Community Exposure Project. September 20, 2020

Park, J-S. DTSC Laboratory Activities on PFAS: Biomonitoring Data and Results from Drinking Water Monitoring. Presented as an invited speaker at UC Berkeley Superfund Workshop. December 13, 2019

Wu, N. Biomonitoring California Program Updates. [July 2019, November 2019, March 2020, July 2020, November 2020, March 2021]

Additional information on Biomonitoring California publications and presentations can be found on the Program website.

Appendix F: Recommendations from the Scientific Guidance Panel

October 4, 2021

Tomás Aragón, MD, DrPH
Director, California Department of Public Health
By electronic correspondence to: tomas.aragon@cdph.ca.gov

Dear Dr. Aragón,

We are writing on behalf of the Scientific Guidance Panel (SGP) for the California Environmental Contaminant Biomonitoring Program (Biomonitoring California) with our recommendations for guiding the current and future efforts of the Program. Since its establishment by legislation (Senate Bill 1379, Perata and Ortiz, Chapter 599, Statutes of 2006), the SGP has met three times yearly to review progress and advise the program.

During our service on the panel, we have been deeply impressed with the significant impact of Biomonitoring California on the understanding of chemical exposures in California. In its first ten years, the program grew into a nationally recognized biomonitoring program with laboratory capability for measuring nearly 200 chemicals. The program has conducted over 20 biomonitoring studies with more than 40 collaborators, measuring chemicals in more than 7,500 Californians. In the process, the program detected elevated chemical exposures in at-risk populations and pioneered methods for returning results to participants, educating and empowering people to make decisions that could reduce chemical exposures. Biomonitoring California's studies have also identified emerging chemicals of concern—providing early warning of new environmental hazards—and have demonstrated the effectiveness of public health approaches that reduce chemical exposures.

At the most recent meeting in July, 2021, the SGP developed recommendations for the coming year to accompany the program's seventh report to the Legislature. To frame these recommendations, we note that the initial intent of the legislation was to create a comprehensive program to regularly test a representative sample of Californians for an extensive suite of known and emerging synthetic chemicals and pollutants. This type of surveillance study can provide valuable information, detecting significant exposures and assessing impacts of public health policy. This program has not yet been funded at the level needed to meet this mandate. In the current absence of such funding, the SGP recommendations are intended to make the best use of limited resources.

The following five recommendations emerged from the full panel's discussion:

1. Mitigate environmental health inequities;
2. Design intervention studies to identify the impact of public policy and non-regulatory actions;
3. Evaluate exposures associated with climate change;
4. Use non-targeted analyses to identify industrial or commercial chemicals previously unrecognized as pollutants;
5. Acknowledge the gap between what is feasible based on budget, and what would be required to meet the program's legislative mandate to conduct statewide surveillance.

We would like to briefly expand on each of these recommendations.

(1) The program should conduct studies to identify disparities in exposure to chemicals and pollutants in environmental justice communities and populations, as a first step toward addressing disproportionate harms. Studies designed to provide data on environmental health inequities could include biomonitoring for pesticide exposures in farmworker communities, or for diesel exhaust exposures in relation to distance from high-traffic roadways or other sources of particulate pollution, such as ports and distribution centers. Such studies can document disparities and inform targeted public health interventions. When they are representative, they can also provide a baseline for evaluating the effects of state and local policies.

(2) Intervention studies are often smaller studies that investigate questions specific to a particular public health or regulatory issue. They can help address health inequities (recommendation #1) by involving communities that are disproportionately affected by environmental contamination. This type of small-size but high-impact intervention studies can:

- Assess changes in exposure to a particular pollutant following intervention, such as in a currently planned study evaluating the impact of air filtration in a Central Valley community;
- Investigate the impact of consumer product changes. For example, the Foam Replacement Environmental Exposure Study (FREES) measures participants' flame retardant exposure before and after the removal or replacement of foam-containing furniture. The study includes residents of low-income housing;
- Examine the impacts of state or regional policy, such as CARB clean diesel rules.

Finally, these types of studies address community requests for action. Members of affected communities understandably and repeatedly call for agencies to go beyond data gathering and take action to reduce harms. Intervention studies contribute to both efforts simultaneously.

(3) The program should conduct studies that incorporate biomarkers of exposure to pollutants that are expected to increase with climate change, such as:

- Chemicals associated with fires at the wildland-urban interface;
- Pollutants in the private water supplies that rural communities depend on and that tend to concentrate as water scarcity worsens;
- Volatile or semi-volatile or persistent organic compounds whose concentrations rise with higher ambient temperatures.

Linking this recommendation with points (1) and (2) above, intervention studies can assess positive effects of infrastructure on exposure disparities, such as the presence of tree cover in mitigating exposure to air pollution, diversifying the community-level solutions to exposure disparities.

(4) Non-targeted analyses of chemical compounds conducted on biological samples can identify industrial or commercial chemicals and their byproducts and metabolites that were previously unrecognized pollutants. A majority of environmental chemical analysis is targeted, that is, biological samples are tested for a set of specific, known chemicals, and the concentration of those chemicals in the samples is compared to population-wide exposure data. Instead of testing for the presence of

specific chemicals, non-targeted analyses use new techniques such as gas chromatography coupled with time-of-flight mass spectrometry to detect and report-out a wide variety of chemicals present in biological samples.

One of the most valuable contributions that Biomonitoring California can make is to use non-targeted analysis to proactively identify health-relevant exposures in specific occupational groups, such as farmworkers and firefighters, or in high-risk groups, such as children from disproportionately polluted neighborhoods.

(5) Finally, in acknowledgement of the gap between the cost of statewide surveillance studies and the program's allocation, we recommend that Biomonitoring California design smaller studies that address other key elements of the program's mission, including generating data that assesses inequities and links exposures and health; evaluating temporal trends and the effectiveness of public health regulatory programs; and addressing community concerns.

We recognize that it is not within the purview of program staff to address budget issues, however the SGP has previously expressed concern that without additional funding Biomonitoring California could not fully meet its legislative mandate. SB 1379 directs the State to establish a biomonitoring program that, "will assist in the evaluation of the presence of toxic chemicals in *a representative sample of Californians* [emphasis added]," among other priorities. Although the Program launched the California Regional Exposure (CARE) Study as a surveillance project to measure and compare environmental chemicals in people in eight regions encompassing the entire state, the total resources allocated to the program have been insufficient to study a truly representative sample of Californians. Limited funding stretched the study's timeline over decades, making it impossible to compare results from different regions. Furthermore, each time funding decreases, the program risks losing lab personnel with specific analytical expertise with the result that the program can lose the ability to analyze particular panels of chemicals, irrespective of their public health significance.

The most efficient way to fulfill the original legislative vision of statewide surveillance is to expand the reach of the CARE Study. We are buoyed by the recent investment the State has made in biomonitoring in the form of a $2 million budget augmentation for FY 2021-22. This augmentation will enable Biomonitoring California to hire additional staff, fund studies that have been limited by budget shortfalls and focus efforts on surveillance studies that can track trends in chemical exposures. However, while this budget augmentation is a step in the right direction, it will not on its own close the funding gap that keeps CARE from being truly representative. The study was initially expected to cost $10-12 millon per year (2007 dollars), significantly more than even the newly augmented program annual budget of $4.5 millon. With sufficient funding, the CARE study could:

- Devote sufficient resources for recruitment to ensure that disadvantaged populations are well-represented. Recruiting from California's marginalized communities is resource-intensive but prevents study populations from skewing toward wealthier and more highly educated groups.
- Increase sampling to simultaneously study more regions of California, ensuring that results are relevant to the whole state, and establishing time-trends that are comparable across the state.
- Expand chemical analyses—current measurements are limited to metals and some perfluoroalkyl and polyfluoroalkyl substances (PFASs). Sufficient funding would let the program routinely measure a larger variety of chemicals in people, making efficient use of the study infrastructure that already exists. This would also enable the program to evaluate exposures relevant to high-prevalence diseases, such as breast cancer, which was among the founding rational for Biomonitoring California.

On behalf of the SGP, we reiterate our admiration for the extensive accomplishments of Biomonitoring California, particularly given the limitations based on available resources. We are grateful for the leadership of CDPH alongside the other state agencies charged with implementing this critical program, and we are pleased to offer our ongoing assistance.

Sincerely,

Megan Schwarzman, MD, MPH
Chair, Scientific Guidance Panel for Biomonitoring California

Penelope J.E. Quintana, PhD, MPH
Member, Scientific Guidance Panel for Biomonitoring California