Implementation of the California Environmental Contaminant Biomonitoring Program: 2016-2017

Fifth Report to the California Legislature

BIOMONITORING CALIFORNIA

MEASURING CHEMICALS IN CALIFORNIANS

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

Gavin Newsom, Governor
State of California

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Executive Summary

Biomonitoring—the measurement of chemicals or their metabolites in a person's body—can provide an overall measure of human exposure to certain chemicals found in air, water, food, soil, dust, and consumer products. Biomonitoring helps us track the amounts and types of chemicals that get into people from all sources.

The California Environmental Contaminant Biomonitoring Program (the Program) was established through legislation in 2006 by Senate Bill 1379 (Perata and Ortiz, Chapter 599, Statutes of 2006) and codified in Health & Safety Code Sections 105440 et seq. Also known as Biomonitoring California, the Program is a collaborative effort involving the California Department of Public Health (CDPH) as the lead, the Office of Environmental Health Hazard Assessment (OEHHA), and the Department of Toxic Substances Control (DTSC). It receives technical advice and peer review from a Scientific Guidance Panel and input from the public.

A legislative report describing Biomonitoring California's findings is required every two years, beginning January 1, 2010 (H&SC Section 105459(a)). This is the fifth report, covering Biomonitoring California's activities and findings from January 2016 through December 2017.

Principal findings

The Fifth Report to the Legislature (2016-2017) provides updates on eight studies and public participation activities and contains findings from three of the eight studies: the Measuring Analytes in Maternal Archived Samples (MAMAS) Study, the Asian/Pacific Islander Community Exposures (ACE) Project, and the Biomonitoring Exposures Study (BEST). Three studies are new to this report:

1. The California Regional Exposure (CARE) Study will provide information on exposure to harmful metals and perfluoroalkyl and polyfluoroalkyl substances (PFASs) across the state.
2. The East Bay Diesel Exposure Project will measure chemicals associated with diesel exhaust in children and adults.
3. The ACE Project measured levels of selected metals and PFASs in two Asian/Pacific Islander communities in Northern California.

MAMAS Study Findings

Results from the first phase of the MAMAS study (MAMAS-1), which included 460 mothers from San Diego and Orange Counties, are now available. Samples were collected in 2012 and represent roughly equal proportions of White, Black, Hispanic, and Asian mothers. The Program measured persistent organic pollutants in the MAMAS-1 samples and found levels similar to national averages (calculated based on comparable adult participants from the National Health and Nutrition Examination Survey, or NHANES). Compared to the national average, MAMAS-1 participants have:

- Similar levels of perfluoroalkyl and polyfluoroalkyl substances (PFASs)
- Lower levels of the two most common PFASs (perfluorooctanoic acid [PFOA] and perfluorooctane sulfonate [PFOS])

- Lower levels of polybrominated diphenyl ethers (PBDEs); MAMAS levels were expected to be lower than national values (data from 2003-2004) because of decreasing exposures after California's ban of most PBDEs, which took effect in 2006
- Lower levels of PCBs and organochlorine pesticides (OCPs)

ACE Project Findings

Results for metals in blood have been evaluated for ACE 1 (the first phase of the ACE Project); results for metals in urine and PFASs in serum are still being analyzed. On average, ACE 1 participants had higher mercury, cadmium, and lead levels than the national adult average (based on the comparable NHANES population). ACE 1 participants also had mercury levels almost two times higher than the national adult Asian average. Based on preliminary analyses, various demographic, lifestyle, and dietary characteristics were associated with levels of blood metals:

- Participants who reported use of herbal remedies or products had higher mercury and lead levels than those who did not.
- Participants who ate fish more frequently, especially in the form of fish cake, paste, or balls, were found to have higher mercury levels than participants who ate fish less frequently.
- Immigrants living in the U.S. for 20 or fewer years had higher cadmium and lead levels than those born in the U.S.; no difference was seen for those living in the U.S. for more than 20 years.
- Older participants had higher cadmium levels than younger participants.
- Current smokers had nearly two times the levels of cadmium than participants who never smoked.
- Participants with lower educational attainment had higher cadmium and lead levels compared to those with higher educational attainment.
- Males had higher lead levels than females.

BEST Findings

Approximately 14% (30 out of 218) of the Expanded BEST population were found to have elevated inorganic arsenic levels.[1] Inorganic arsenic may harm the developing fetus and contribute to cardiovascular disease, and can increase cancer risk. The majority of participants with elevated inorganic arsenic (27 out of 30) elected to take a follow-up telephone survey to help determine potential sources of their exposures. Some of the results from this survey include:

- At least six participants lived or worked in areas where the average arsenic concentration in drinking water was greater than the drinking water standard of 10 parts per billion.
- Nearly all participants with elevated inorganic arsenic levels (25 out of 27) regularly consumed rice and rice-based products.
- Most participants with elevated inorganic arsenic levels (23 out of 27) regularly consumed fish or shellfish.

[1] Elevated arsenic, as indicated by urinary inorganic arsenic of 20 µg/l or greater

Recommendations

Since the Program's inception, Biomonitoring California has expanded its biomonitoring capability to nearly 200 chemicals or their metabolites across 14 chemical classes; launched eight Biomonitoring California projects; and conducted laboratory analyses for 14 projects led by external researchers. The California Regional Exposure (CARE) Study is poised to provide valuable information on statewide chemical surveillance information to policymakers and the public. Community studies, like the ACE Project, demonstrate the value of biomonitoring specific populations to identify disproportionately exposed groups, and can provide communities with objective measurements of environmental contaminants of concern.

Recommendations for Improving the Program

The following recommendations for improvement were developed with input from the Scientific Guidance Panel and community stakeholders and take into account Program activities and study findings to date.

1. Seek opportunities to work with community-based organizations, environmental justice groups, Tribes, and other stakeholders in Program implementation and targeted, community-based studies.
2. Maintain core laboratory capabilities and develop innovative laboratory methods to support the CARE Study and community-based studies.
3. Monitor for new and emerging chemicals of concern to track increases in exposures to these potential health threats and serve as an early warning system for chemical exposures in California.
4. Work toward a statewide representative sample by implementing the CARE Study to generate biomonitoring data that will:
    - Assist in the evaluation of the presence of harmful chemicals in Californians.
    - Establish trends in chemical exposures over time.
    - Support the evaluation of the State's innovative regulatory efforts, such as the Safer Consumer Products program, to reduce harmful chemical exposures.
5. Expand and improve results communication and health education for study participants, healthcare providers, community organizations, and the public.

Introduction

Californians experience widespread exposures to a multitude of chemicals, such as flame retardants, pesticides, heavy metals like mercury and arsenic, and substances used in manufacturing and consumer products (e.g., cosmetics and plastics), many of which pose health concerns. Recognizing that Californians' health can be improved by reducing exposures to harmful chemicals, the Legislature established the California Environmental Contaminant Biomonitoring Program (also known as Biomonitoring California), which is the first legislatively mandated, ongoing state biomonitoring program in the country.

Biomonitoring is the measurement of chemicals in human biological samples such as blood and urine. It can provide an overall measure of human exposure to certain chemicals from all sources, including air, water, food, soil, dust, and consumer products.

Biomonitoring is a proven scientific tool that can be used to demonstrate successes or failures of efforts to reduce chemical exposures. Results from biomonitoring studies play a key role in assessing the efficacy of measures to reduce specific chemical exposures, and in helping to inform efforts to identify and regulate chemicals of concern.

The primary goal of Biomonitoring California is to monitor, analyze, and report on specific environmental chemicals detected in blood, urine, and other biological specimens from a representative statewide sample of Californians. Measuring environmental chemicals in California residents will help answer such questions as:

- Which chemicals are in people's bodies, and how high are the levels?
- Are the levels of chemicals increasing or decreasing over time?
- Are there groups or subpopulations in California that have higher exposures to specific toxic chemicals?
- Do regulatory efforts, including bans or phase-outs of chemicals, actually reduce exposures?
- Do certain chemicals contribute to the development of chronic diseases or conditions?

Biomonitoring California's enabling legislation, Senate Bill 1379 (Perata and Ortiz, Chapter 599, Statutes of 2006), requires biennial reports to the Legislature. Specifically:

"By January 1, 2010, and every two years thereafter [Biomonitoring California] shall submit a report to the Legislature containing the findings of the program, and shall include in the report additional activities and recommendations for improving the program based upon activities and findings to date. Copies of the report shall be made available via appropriate media to the public within 30 calendar days following its submission to the Legislature."

This report is intended to inform the Legislature and the public of the status of the Program and includes information about its activities and findings for calendar years 2016 and 2017.

Background

Biomonitoring plays an important role in protecting public health. It is a tool to identify, measure, and report chemical exposures that may adversely affect the population's health. Biomonitoring provides important data that can help evaluate public health prevention and regulatory efforts in California. It can also identify highly exposed or vulnerable populations, such as communities impacted by a specific pollution source, or exposures of particular concern.

Biomonitoring California was established by Senate Bill (SB) 1379 (Perata and Ortiz, Chapter 599, Statutes of 2006). The legislative intent 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."

Biomonitoring California is a complex, multidisciplinary program developed and implemented collaboratively by the California Department of Public Health (CDPH), Office of Environmental Health Hazard Assessment (OEHHA), and Department of Toxic Substances Control (DTSC). This multidisciplinary collaboration contributes to the success of the program by bringing together expertise in analytical chemistry, toxicology, epidemiology, exposure science, and health education. Scientific peer review of Biomonitoring California activities is provided by the Scientific Guidance Panel (SGP), a panel of expert scientists appointed by the Governor and the Legislature from outside of state government. Biomonitoring California's roles and responsibilities are included in Appendix A. Information about Biomonitoring California funding is included in Appendix B.

Biomonitoring California Priority Areas

Biomonitoring California has established the following priorities to help guide Program activities.

1. Statewide representative sampling

Statewide representative sampling is the primary mandate of the enabling legislation and remains the top priority of the Program. Biomonitoring a representative cross-section of the California population provides important information about environmental chemical exposures throughout the state. Biomonitoring California has two active studies that provide statewide data: Measuring Analytes in Maternal Archived Samples (MAMAS) and the California Regional Exposure (CARE) Study.

2. Environmental justice

Conducting biomonitoring in the context of environmental justice is a guiding principle in the enabling legislation, and the Program prioritizes biomonitoring studies that adhere to environmental justice principles. The Asian/Pacific Islander Community Exposures (ACE) Project and the East Bay Diesel Exposure Project (EBDEP) are two examples of studies with an environmental justice focus. The Program

also conducted a series of stakeholder interviews with 84 environmental justice, community, and Tribal organizations to seek input on environmental exposure concerns and biomonitoring priorities across the state.

3. Consumer product studies

Chemicals from consumer products are ubiquitous in our environment. Biomonitoring California measures chemicals that are ingredients in commonly used consumer products in order to provide specific exposure information that can help inform DTSC's Safer Consumer Products program. The Foam Replacement Environmental Exposure Study (FREES) is an intervention study that assesses the differences in biomonitored flame retardant levels before and after household furnishings containing flame retardants are removed or replaced. The Pregnancy Environment and Lifestyle Study (PETALS), a collaboration with Kaiser Permanente, also explored exposures to consumer product chemicals and their potential health impact.

4. Chemicals of emerging concern

There are more than 40,000 chemicals currently in commerce in the United States, with new chemicals regularly coming into use every year.[2] One of the Program's priorities is monitoring for new and emerging chemicals of concern. The ability to detect increases in exposures to potential health threats will enable the Program to act as an early warning system for new chemical exposures in California. It will also support the State's regulatory efforts to reduce harmful chemical exposures. Additional investment in the Program's laboratories will be necessary to build and maintain a robust capability for detecting new and emerging chemicals. The Program is working to:

- Update existing methods to better reflect current use patterns (for example, the Program is working to update the phthalate metabolite method to include phthalates that are increasing in production and use)
- Use enhanced automation technology to streamline and expedite existing methods
- Use advanced screening technology to identify previously unidentified and unregulated chemicals of potential concern

Laboratory Capabilities

The two primary laboratories supporting Biomonitoring California are nationally recognized for their expertise in biomonitoring analytical methods. As of December 2017, the Program can measure 189 chemicals (see Figure 2).

- The Environmental Health Laboratory (EHL), a branch of CDPH, has primary responsibility within Biomonitoring California for developing and applying analytical methods to measure metals in blood, serum, and urine, and non-persistent organic chemicals, such as phthalates, phenols, and pesticides, in urine. EHL also oversees sample management and laboratory quality assurance for the Program.

[2] Toxic Substances Control Act (TSCA) Inventory, as implemented under The Frank R. Lautenberg Chemical Safety for the 21st Century Act.

- The Environmental Chemistry Laboratory (ECL), a division of the Department of Toxic Substances Control (DTSC), has primary responsibility for developing and applying analytical methods to measure persistent organic chemicals, such as polybrominated diphenyl ether (PBDE) flame retardants, polychlorinated biphenyls (PCBs), perfluoroalkyl and polyfluoroalkyl substances (PFASs), and organochlorine pesticides (OCPs), in serum. ECL is leading the Program's effort to broadly screen for and identify chemicals emerging as potential concerns for Californians' health.

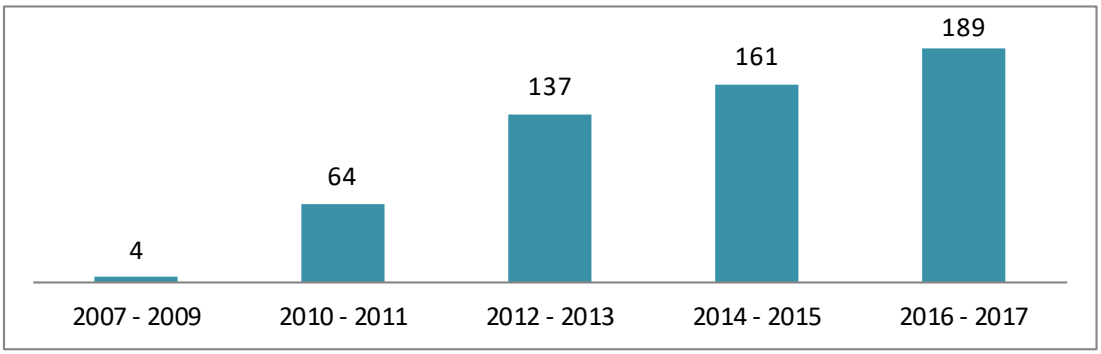

Figure 1: Number of Chemicals Analyzed by Biomonitoring California

Biomonitoring California's actual analytical capacity, or the number of specimens the lab can analyze in a given time period, is determined by staffing, instrumentation, and the availability of samples. During the two-year period covered by this report (January 1, 2016 through December 31, 2017), Biomonitoring California analyzed 3511 specimens from over 1500 individuals for toxic chemicals or their breakdown products, including heavy metals, flame retardants, and PFASs. The Program is considering several options to maximize Program efficiency:

- Biomonitoring a reduced number of chemicals
- Implementing sample management tracking tools to streamline sample receipt, storage, and management
- Automating laboratory methods to reduce time spent preparing and handling samples for analysis

Biomonitoring California Projects

Biomonitoring California has added three new studies[3] since the Fourth Report to the Legislature. For more information on Biomonitoring California studies, visit: www.biomonitoring.ca.gov/projects/archive.

Summary results for all Biomonitoring California studies are posted to the Program's interactive online database (www.biomonitoring.ca.gov/results) as they become available. New findings within the reporting period are included below.

[3] California Regional Exposure (CARE) Study, East Bay Diesel Exposure Project (EBDEP), and Asian/Pacific Islander Community Exposures (ACE) Project.

California Regional Exposure (CARE) Study

Status for 2016-2017: New study
Biomonitoring California (BC) Priority Area: Statewide representative sampling

The goal of the California Regional Exposure (CARE) Study is to measure and compare environmental chemicals in people across the state. This information will support efforts to reduce chemical exposures in Californians and improve public health. The CARE Study will measure levels of selected metals (e.g., arsenic, lead, mercury, and cadmium) in urine and/or blood, and levels of perfluoroalkyl and polyfluoroalkyl substances (PFASs) in serum.

The choice of these analytes was motivated by the widespread exposures occurring across the state, as well as the known health concerns. Metals are linked to a range of potential health effects, including cancer, cardiovascular disease, and toxicity to the developing infant and child. PFASs are used in a variety of consumer and industrial applications (e.g., fire-fighting foams, non-stick cookware, stain-repellent carpets and clothing, and grease-repellent food containers). They may affect the developing fetus and child, decrease fertility, interfere with the body's natural hormones and the immune system, and increase cancer risk. Additional chemicals of concern, such as pesticides and chemicals related to air quality, may be added as resources allow.

The CARE Study divides the state into eight different regions, based on geography, feasibility, population size, and perceived sense of community identity (based on available information). The CARE Study will be implemented in one region per year, and it will take approximately eight years to complete one round of surveillance across the state. After the CARE Study completes one cycle of statewide sampling, the Program will return to the first region, Los Angeles County (Table 2).

Table 1: Summary of CARE Study Regions and Timeline

Phase	Number of Participants	Collection Year	Representing
Region 1	300	2018	Los Angeles County
Region 2	300	2019	Inland Valley (Mono, Inyo, Imperial, Riverside, San Bernardino)
Region 3	300	2020*	Orange and San Diego counties
Region 4	300	2021*	Central Coast (Monterey, San Luis Obispo, Santa Barbara, Santa Cruz, Ventura)
Region 5	300	2022*	Central Valley (Fresno, Kern, Kings, Madera, Mariposa, Merced, San Benito, Stanislaus, Tulare)
Region 6	300	2023*	Gold Country (Alpine, Amador, Calaveras, El Dorado, Nevada, Placer, Sacramento, San Joaquin, Sierra, Sutter, Tuolumne, Yolo, Yuba)
Region 7	300	2024*	Bay Area (Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, Sonoma)
Region 8	300	2025*	Northern Counties (Butte, Colusa, Del Norte, Glenn, Humboldt, Lake, Lassen, Mendocino, Modoc, Plumas, Shasta, Siskiyou, Tehama, Trinity)
Region 1	300	2026*	Los Angeles County

*Timeline is projected and subject to change

Results from the first region will be difficult to compare to results from later regions, due to temporal trends in chemical exposures over the eight-year time span. However, data from each region, as well as collective data from regions sampled in close temporal proximity, will be a valuable source of baseline information on chemical exposures in Californians.

Los Angeles County was selected as the first region because it is home to 28% of the state's population and is ethnically, racially, and linguistically diverse. The Program worked with the Los Angeles County Department of Public Health and community-based organizations to recruit participants, and opened limited recruitment in December 2017 through the study website. The Program also mailed a recruitment postcard to a randomized set of households in Los Angeles County, inviting individuals to join the CARE Study. Potential participants will complete a short demographic survey, which will allow the Program to collect samples from 300 participants who reflect Los Angeles County demographics.

In the current reporting period, Biomonitoring California:

- Developed a CARE Study protocol, including activities, costs, and analysis of feasibility, benefits, and limitations
- Worked with subject matter experts, including the Program's Scientific Guidance Panel (SGP), to refine and improve the CARE Study protocol
- Identified eight geographic regions for the study and selected Los Angeles County as the first region
- Developed study tools, exposure surveys, and other materials, and received study approval from the Committee for the Protection of Human Subjects
- Conducted community outreach activities, including webinars, phone calls, and in-person meetings with community groups
- Developed an online participant tracking system using the Salesforce platform
- Initiated limited recruitment (December 2017)

The CARE Study is an efficient approach to achieving statewide biomonitoring surveillance over time. It has the potential to provide important information about chemical exposures in California. The study is designed to be easily scalable. This means that if additional resources become available, the Program will be able to biomonitor additional chemicals of concern and/or expand the CARE Study to biomonitor more than one region per year.

Measuring Analytes in Maternal Archived Samples (MAMAS)

Status for 2016-2017: Update to existing study
BC Priority Area: Statewide representative sampling

The MAMAS pilot study analyzes maternal serum samples collected through CDPH's Genetic Disease Screening Program (GDSP). This study was approved by the Committee for the Protection of Human Subjects, which is the State's Institutional Review Board (IRB). Samples are obtained through routine prenatal screening and are archived and made available to researchers through the California Biobank Program. The purpose of this pilot is to evaluate the feasibility of deriving a statewide sample from the Biobank. Because samples are banked on an ongoing basis, the Biobank may provide an opportunity to

examine chemical exposure trends over time. Biomonitoring California identified a subset of these samples to analyze for levels of specific persistent chemicals (PFASs, PBDEs, PCBs, and OCPs). Samples were selected to equally represent White, Black, Hispanic, and Asian mothers from across the state.

Table 2: Summary of MAMAS Sampling and Timeline

Phase	Number of Samples	Collection Year	Representing pregnant women from
MAMAS-1	460	2012	San Diego and Orange counties
MAMAS-2	540	2015	Alameda, Butte, Colusa, Contra Costa, Del Norte, Glenn, Humboldt, Lake, Lassen, Los Angeles, Mendocino, Modoc, Nevada, Placer, Plumas, Riverside, San Bernardino, Shasta, Sierra, Siskiyou, Sutter, Tehama, Trinity, and Yuba counties
MAMAS-3	300	2016	Imperial, Marin, Monterey, Napa, Sacramento, San Benito, San Francisco, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Solano, Sonoma, Ventura, and Yolo counties

In the current reporting period, Biomonitoring California analyzed 242 of the 540 MAMAS-2 samples for PFASs, PBDEs, PCBs, and OCPs, and analyses will continue in 2018. The Program also received a third set of samples (MAMAS-3).

The MAMAS pilot study provides useful information on exposure to a limited set of persistent chemicals (PFASs, PBDEs, PCBs, and OCPs), and has the potential to provide an approximation of a statewide sample of pregnant women. Participation in the prenatal screening program is currently high (approximately 70% of pregnant women). However, the MAMAS pilot falls short of a true statewide representative sample in several ways:

- Samples are limited to pregnant women who participate in the State's prenatal screening program.
- GDSP provides only serum samples, in very small amounts. This limits the number and variety of chemicals the Program can measure.
- No information on environmental exposures is collected from the women whose samples are analyzed, and the Program has no means to contact these participants. Therefore, the MAMAS pilot cannot identify sources of exposure, nor can the Program return biomonitoring results and health education materials to participants.

Given these disadvantages, the Program plans to continue to use GDSP samples in a limited manner to track trends in chemicals over time and across the state, and to monitor emerging chemicals of concern.

Results from MAMAS-1, which included 460 pregnant women from San Diego and Orange Counties, are now available. Samples were collected in 2012 and represent roughly equal proportions of White, Black, Hispanic, and Asian mothers. Approximately 29% of the MAMAS-1 population utilized Medi-Cal. Less than 20% of the sample population is under 25 years of age, and 15% of the population is over age 35. The Program measured PFASs, PBDEs, PCBs, and OCPs in the MAMAS-1 samples and found:

- Levels of PFASs in MAMAS-1 participants were generally consistent with 2011-2012 levels found in women of childbearing age in the national population.[4]
- MAMAS-1 participants had lower levels of the two most common PFASs (perfluorooctanoic acid [PFOA] and perfluorooctane sulfonate [PFOS]) compared to the national population.[4]
- Levels of PBDEs were lower in MAMAS-1 participants compared to the 2003-2004 national average and to levels reported in California adults sampled in 2008-2009. This pattern is not surprising, given the expected decreasing trends in PBDEs after California's ban of most of these chemicals.
- Levels of PCBs and OCPs were lower in MAMAS-1 participants compared to the national average.

The results of the first round of MAMAS analysis indicate that samples obtained through the California Biobank Program may serve as a useful indicator of population-level exposures for some chemical panels. However, the method of sample collection, available sample volume, and lack of participant and exposure data limit the utility of the Biobank as a source of samples for statewide biomonitoring.

East Bay Diesel Exposure Project

Status for 2016-2017: New study
BC Priority Area: Environmental justice

The East Bay Diesel Exposure Project (EBDEP) is a collaboration between Biomonitoring California and the University of California, Berkeley. Exposure to diesel exhaust is associated with serious health effects, including potential to exacerbate asthma and increase cancer risk. Mapping of pollutant sources suggests that levels of diesel exhaust and the subsequent health impacts vary between communities. Diesel exhaust was identified in 2009 by the Program's Scientific Guidance Panel as a priority for biomonitoring, and was again identified as a priority in 2017 by environmental justice organizations across the state (see section on Public Participation Activities, Environmental Justice Outreach).

EBDEP will biomonitor levels of diesel exhaust chemicals in residents in Alameda and Contra Costa counties. This project will measure individual exposures to diesel exhaust, and examine how those exposures vary within families, between communities, and over time. This information can be used to help evaluate the effectiveness of regulatory efforts to reduce diesel exhaust emissions. Participants will also be given information on actions they could take to reduce their exposures.

EBDEP will recruit adult participants with a child between the ages of 3-6. Biomonitoring California will work with community-based organizations, childcare centers, and clinics to recruit study participants.

Participants will provide exposure information about the home environment and daily activities, parent and child urine samples, and home dust and air samples. In order to understand exposures to diesel exhaust during different times of the year, EBDEP staff will revisit participants approximately four to six months after the first visit to collect additional exposure information and samples. All samples will be

[4] Comparison group of comparable female NHANES participants between the ages of 18 and 45. NHANES data for PBDEs, PCBs, and OCPs are available from 2003-2004; data for PFASs are available from 2011-2012.

analyzed for diesel exhaust chemicals at the University of Washington, one of the only laboratories in the world with the analytical capacity to measure diesel exhaust chemicals in human samples.

In the current reporting period, Biomonitoring California has:

- Set up an Inter-Agency Agreement with the University of California, Berkeley
- Developed study protocols and received study approval from the Committee for the Protection of Human Subjects and UC Berkeley's Institutional Review Board
- Conducted outreach activities and meetings with community groups
- Initiated participant recruitment (November 2017)

Asian/Pacific Islander Community Exposures (ACE) Project

Status for 2016-2017: New study
BC Priority Area: Environmental justice

Prior biomonitoring studies[5] have indicated that the Asian/Pacific Islander (API) community may have higher levels of certain chemicals, including metals and PFASs, compared to people from other ethnic or racial groups. Factors affecting levels of these chemicals could include dietary preferences, such as regular consumption of fish and rice, and the use of traditional remedies, such as some herbal medicines.

The Asian/Pacific Islander Community Exposures (ACE) Project measured levels of selected metals (arsenic, cadmium, lead, and mercury) in urine and/or blood, and levels of PFASs in serum. Information from the ACE Project will expand our understanding of chemical exposures in the API community, which makes up approximately 14% of the California population. The ACE Project will also help us begin to understand how exposure sources might differ between Asian sub-populations.

The ACE Project was implemented in two phases. The first phase of the project (ACE 1) was launched in 2016, in collaboration with APA Family Support Services. The Program recruited 100 Chinese adults who had lived in the San Francisco Bay area for at least one year. The second phase of the project (ACE 2) was launched in 2017, in collaboration with the Vietnamese Voluntary Foundation (VIVO). The Program recruited an additional 100 Vietnamese adults who had lived in the San Francisco Bay area for at least one year.

In the current reporting period, Biomonitoring California:

- Worked with APA Family Support Services on the initial ACE Project concept and established a new partnership with VIVO.
- Developed ACE Project protocols, translated materials into Chinese and Vietnamese, and received study approval from the Committee for the Protection of Human Subjects.
- Conducted outreach activities at community events throughout the San Francisco Bay Area.

[5] Including California's Biomonitoring Exposures Study (https://biomonitoring.ca.gov/projects/biomonitoring-exposures-study-best-2expanded) and the Centers for Disease Control and Prevention's National Report on Human Exposure to Environmental Chemicals (https://www.cdc.gov/exposurereport/index.html)

- Enrolled 100 Chinese (ACE 1) and 100 Vietnamese (ACE 2) adults, surveyed participants for information on potential sources of exposure, and obtained participants' blood and urine samples.
- Returned results to participants. Participants in ACE 1 have received results for both metals and PFASs. ACE 2 participants with elevated levels of potentially toxic metals have received their results. All remaining results will be returned in 2018.

ACE 1 results for metals in blood have been evaluated; evaluation of results for metals in urine and PFASs in serum are ongoing. On average, ACE 1 participants had higher mercury, cadmium, and lead levels than the national adult average.[6] ACE 1 participants also had mercury levels almost two times higher than the national adult Asian average.

Based on preliminary analysis, various demographic, lifestyle, and dietary characteristics were associated with levels of blood metals:

- Participants who reported use of herbal remedies or products had higher mercury and lead levels than those who did not.
- Participants who ate fish more frequently, especially in the form of fish cake, paste, or balls, were found to have higher mercury levels than participants who ate fish less frequently.
- Immigrants living in the U.S. for 20 or fewer years had higher cadmium and lead levels than those born in the U.S.; no difference was seen for those living in the U.S. for more than 20 years.
- Older participants had higher cadmium levels than younger participants.
- Current smokers had nearly two times the levels of cadmium than participants who never smoked.
- Participants with higher educational attainment had lower cadmium and lead levels compared to those with lower educational attainment.
- Females had lower lead levels than males.

Continued analyses of the data will be conducted in order to further identify associations between participant characteristics and levels of chemical exposures. In addition, the Program will continue to work with community partners to develop educational messages and methods that specifically focus on individuals who are more likely to be more highly exposed.

Biomonitoring Exposures Study (BEST)

Status for 2016-2017: Update to existing study
BC Priority Area: Statewide representative sampling

The Biomonitoring Exposures Study (BEST) has been described in prior reports to the Legislature. This study, a partnership with Kaiser Permanente Northern California Division of Research, was the first

[6] National averages are calculated based on comparable adult participants from the National Health and Nutrition Examination Survey (NHANES).

large-scale Biomonitoring California study. Samples were collected from 453 Central Valley residents in 2012 (Pilot BEST) and 2013 (Expanded BEST). In the current reporting period, Biomonitoring California:

- Retested 15 participants found to have elevated inorganic arsenic levels.
- Followed up with participants to provide additional health education information and conduct an exposure survey, to help identify potential sources of inorganic arsenic (e.g., diet, drinking water, occupation).
- Tested 218 samples for perchlorate and returned results to participants. Perchlorate is an ingredient in rocket fuel and explosives. Industrial uses of perchlorate have led to contamination of soil, groundwater, and drinking water in some areas of California. Perchlorate can interfere with thyroid activity; may affect the developing fetus and child; and may increase risk factors for heart disease.

As reported in the fourth report to the Legislature, Biomonitoring California found elevated levels of arsenic in the BEST population. Approximately 14% (30 out of 218) of the Expanded BEST population were found to have elevated inorganic arsenic levels.[7] Inorganic arsenic may harm the developing fetus and contribute to cardiovascular disease, and can increase cancer risk. The majority of participants with elevated inorganic arsenic levels (27 out of 30) elected to take a follow-up telephone survey to help determine potential sources of arsenic exposure. Some of the results from this survey include:

- At least six participants lived or worked in areas where the average arsenic concentration in drinking water was greater than the drinking water standard of 10 parts per billion.
- Nearly all participants with elevated inorganic arsenic levels (25 out of 27) regularly consumed rice and rice-based products.
- Most participants with elevated inorganic arsenic levels (23 out of 27) regularly consumed fish or shellfish.
- Other potential sources identified include beer, wine and/or sake, hijiki seaweed, and occupational exposures.

The Program offered optional retesting to all Expanded BEST participants with elevated inorganic arsenic levels to ascertain if levels remained elevated following health education, and 15 participants accepted. Retesting found that five of the 15 participants continued to have elevated inorganic arsenic levels. Three of the five participants opted for a third round of testing, and one of the three was found to be elevated.

Firefighter Occupational Exposures (FOX) Project

Status for 2016-2017: Update to existing study
BC Priority Area: Chemicals of emerging concern

The Firefighter Occupational Exposures (FOX) Project has been described in prior reports to the Legislature. The FOX Project, a partnership with the University of California, Irvine, looked at exposures

[7] Elevated arsenic, as indicated by urinary inorganic arsenic of 20 µg/l or greater

in firefighters from a Southern California county. Samples were collected from 101 firefighters in 2011 and 2012. At the time of enrollment, participants were given the option to donate their samples for future biomonitoring analyses.

In the current reporting period, Biomonitoring California measured organophosphate flame retardants (OPFRs) in the 83 FOX participants who donated their samples for future study. OPFRs are chemicals of emerging concern, used as substitutes for banned flame retardants (i.e., PBDEs), and have been entering the market in larger quantities. Scientists are still studying how OPFRs may affect health. Some OPFRs may interfere with the body's natural hormones, decrease fertility, affect the developing fetus, and increase cancer risk. Results are currently being analyzed.

Foam Replacement and Environmental Exposure Study (FREES)

Status for 2016-2017: Update to existing study
BC Priority Area: Consumer product studies

The Foam Replacement and Environmental Exposure Study (FREES) has been described in prior reports. FREES is an intervention study that measures flame retardant levels in serum (PBDEs) and urine (organophosphate flame retardants [OPFRs]) before and after household furnishings that contain flame retardants are removed or replaced. Biomonitoring 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; may decrease fertility; and may increase cancer risk. OPFRs are used as replacements for PBDEs in some applications and may interfere with the body's natural hormones; may decrease fertility; may affect the developing fetus; and may increase cancer risk.

There are 26 enrolled participants who have agreed to contribute blood, urine, and hand wipe samples approximately every six months over the course of two years (2016-2018). In the current reporting period, Biomonitoring California:

- Collected baseline, 6-month, and 12-month samples for all study participants
- Collected 18-month (final) samples for 15 of the 26 participants
- Returned baseline and 6-month results to participants. Results will be analyzed following all four rounds of testing.

Pregnancy Environment and Lifestyle Study (PETALS)

Status for 2016-2017: Update to existing laboratory collaboration[8]
BC Priority Area: Consumer product studies

The Pregnancy Environment and Lifestyle Study (PETALS) has been described in prior reports. Biomonitoring California laboratories determined levels of bisphenol A (BPA), triclosan, and benzophenone-3 (BP-3) in urine samples from 300 pregnant women diagnosed with gestational diabetes

[8] Laboratory collaborations are biomonitoring studies designed by external researchers who request laboratory support for their biomonitoring project. Biomonitoring California is responsible for laboratory analyses and may provide additional consultation upon request.

mellitus (GDM) and 600 pregnant women who did not have GDM. These chemicals may interfere with the body's natural hormones, and PETALS aims to identify their contribution to the risk of GDM in expectant mothers. Two urine specimens from each of the 900 study subjects were analyzed for these chemicals. In the current reporting period, the Program analyzed and reported 440 results.

Public Participation Activities

In addition to conducting biomonitoring studies, the Program is mandated to "provide opportunities for public participation and community capacity building" and to allow for "meaningful stakeholder input." Opportunities for public involvement and the Program's Public Involvement Plan, which provides an overview of the range of public involvement efforts being carried out by Biomonitoring California, can be found online at www.biomonitoring.ca.gov/public-involvement. In the current reporting period, Biomonitoring California has conducted the following public participation activities:

Environmental Justice Outreach

In 2016 and 2017, Biomonitoring California collected information from 84 organizations involved in environmental justice work across the state, via survey, webinar, and individual and group interviews. The purpose was to obtain community input on environmental chemical exposure concerns and biomonitoring priorities. Responses were analyzed, compiled, and presented to the Program. A wide range of recommendations were received, including:

- Measure additional chemicals of concern within each region of the CARE Study
- Use participatory research methods to involve community stakeholders in biomonitoring studies
- Provide education and resources to community-based organizations so they can support and educate community members
- Develop case studies of community studies to help explain the process and benefits of these studies
- Consider new results return opportunities, including lower-level literacy materials, and community-led meetings

Interviewees also recommended that Biomonitoring California maintain relationships with the environmental justice, community, and Tribal groups who were engaged in this process, and provide updates on the CARE Study and environmental justice activities through newsletters, meetings, or webinars. As a first step in implementing this recommendation, the Program held a roundtable discussion of its environmental justice activities at the Scientific Guidance Panel meeting on November 9, 2017. Guest discussants and attendees representing community and advocacy groups participated in the discussion, designed to identify how the Program can best advance environmental justice goals across the state.

Community Newsletter

A newsletter to disseminate biomonitoring information to a broader, non-scientific audience was initiated during the current reporting period. The first issue was released in spring 2017. It is envisioned that the Program will release 1-2 issues per year. Regular features will include news about current

biomonitoring studies, a focus on a particular chemical, and tips on how to reduce exposure. The first newsletter can be found at: https://biomonitoring.ca.gov/newsletter/vol-1-march-2017.

Program Website and Email List

The Program continues to expand and improve its website (www.biomonitoring.ca.gov) as an important tool for public outreach. During 2016-2017, the Program added content related to current activities, such as:

- New projects (ACE, CARE, FREES, PETALS)
- Updated lists of designated chemicals and priority chemicals
- Summary results (MAMAS, Pilot BEST)
- Scientific Guidance Panel meetings and new Panel members' biographies
- Fact sheets about chemicals being measured (e.g., cobalt, thallium, tungsten, uranium)
- Improved and updated lists of laboratory and Program publications

In addition, materials were developed that highlight the Program's top accomplishments during its first ten years. A new webpage template was designed to display the community newsletter in an electronic format.

Other ongoing public involvement activities include maintenance of an email list with 1025 active subscribers as of December 2017. Notes are sent to subscribers approximately twice per month, informing them of Program activities and new materials posted on the website, such as biomonitoring results.

Communicating Biomonitoring Results to Participants

The Program is required to return biomonitoring results to study participants who request them, even if the health implications of these results are scientifically uncertain. Biomonitoring California has a standard template to return biomonitoring results to study participants. This template includes a cover letter, a study description, individual results for environmental chemical levels with comparison values and text explanations, and chemical-specific fact sheets. Results return materials are currently available in English, Spanish, Chinese, and Vietnamese. Materials will be translated into additional languages for CARE Study participants, as needed. The Program also provides additional follow up for participants with elevated levels of mercury, lead, arsenic, or cadmium, as these metals are known to have harmful effects on health. Follow up for adult participants with elevated lead levels is conducted in coordination with CDPH's Occupational Lead Poisoning Prevention Program.

In the current reporting period, Biomonitoring California returned results to over 500 participants. Of those study participants, over 20% required additional follow up due to elevated levels of toxic metals (lead, mercury, arsenic, and cadmium). The Program provided additional follow-up to over 120 participants with elevated levels of metals, offering information on common sources of exposure and guidance on how to reduce levels. Further details on the Program's efforts to effectively communicate biomonitoring results can be found at: www.biomonitoring.ca.gov/results/communicating-results.

Sharing Findings with the Public

Program information is disseminated to the public in a variety of ways. The first priority is to share results with study participants. Preliminary study findings (such as demographic, geographic, or temporal trends) are released to stakeholders at public meetings and through the Program website. In-depth analysis of the study data may result in publications for scientific audiences and informational materials for the general public. Reports to the Legislature are posted to the CDPH website and are shared with stakeholders via listserv and email.

In coordination with the CDPH Office of Public Affairs, the Program may share information and reports through press release and social media.

Conclusions and Recommendations

Since the Program's inception, Biomonitoring California has expanded its biomonitoring capability to 189 chemicals or their metabolites across 14 chemical classes; launched eight Biomonitoring California projects; and provided laboratory support to fourteen projects led by external researchers.

Through the CARE Study, Biomonitoring California is working toward a statewide representative sample. The plan for the CARE Study is both feasible and efficient, and the following compromises were made to the scope and duration of the study:

- Statewide sampling was initially designed in 2006 with randomized recruitment across the state every 2-3 years. Different approaches for randomized recruitment were rejected as too costly and were replaced with more efficient quota-based representative sampling.
- The samples will be collected over approximately eight years, moving region by region across the state. Results from the first region will be difficult to compare to those from later regions, however, because of temporal trends in chemical exposures over the eight-year time span.
- The study is designed to analyze a limited set of chemicals (metals and PFASs).

The CARE Study is poised to provide valuable information on statewide chemical exposures to policymakers and the public, and is designed to be easily scalable. If resources become available, the Program will be able to biomonitor additional chemicals of concern or reduce the length of time needed to sample all the regions in the state. Groups that participated in the Program's 2016-2017 environmental justice outreach activities have encouraged the Program to add other chemicals of concern, such as pesticides and chemicals related to air quality.

Community studies demonstrate the value of biomonitoring specific populations to identify disproportionately exposed groups. Studies like the ACE Project and the East Bay Diesel Exposure Project can provide communities with objective measurements of environmental contaminants of concern.

Recommendations for Improving the Program

The following recommendations for improvement were developed with input from the Scientific Guidance Panel and community stakeholders, and take into account Program activities and study findings to date.

1. Seek opportunities to work with community-based organizations, environmental justice groups, Tribes, and other stakeholders in Program implementation and targeted, community-based studies.
2. Maintain core laboratory capabilities and develop innovative laboratory methods to support the CARE Study and community-based studies.
3. Monitor for new and emerging chemicals of concern to track increases in exposures to these potential health threats and serve as an early warning system for chemical exposures in California.
4. Work toward a statewide representative sample by implementing the CARE Study to generate biomonitoring data that will:
    - Assist in the evaluation of the presence of harmful chemicals in Californians
    - Establish trends in chemical exposures over time
    - Support the evaluation of the State's innovative regulatory efforts, such as the Safer Consumer Products program, to reduce harmful chemical exposures.
5. Expand and improve results communication and health education for study participants, healthcare providers, community organizations, and the public.

Information and recommendations regarding program funding are available in Appendix B.

Appendix A: Program Structure

Biomonitoring California is a complex, multidisciplinary program developed and implemented collaboratively by the California Department of Public Health (CDPH), the Office of Environmental Health Hazard Assessment (OEHHA), and the Department of Toxic Substances Control (DTSC). This multidisciplinary collaboration contributes to the success of the program by bringing together expertise in analytical chemistry, toxicology, epidemiology, and health education. General roles and staff responsibilities for Biomonitoring California are shown in Figure A1 and listed below.

Figure A1. Biomonitoring California Departmental Roles and Lead Responsibilities

DTSC	**CDPH** (*Program Lead*)		**OEHHA**
Environmental Chemistry Laboratory Laboratory analyses of blood samples for biologically persistent chemicals Quality assurance and interpretation of laboratory data Broad screening to identify chemicals of emerging concern in California	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 and storage of blood and urine samples Broad screening to identify chemicals of emerging concern in California Management of analytical results and sample information using LIMS*	Environmental Health Investigations Branch Overall coordination of program components and partners Liaison/Principal Investigator on CDC Cooperative Agreement Design of statewide and community surveys Participant recruitment and sample collection Results communication to participants Management and analysis of epidemiologic data Generation of reports to the Legislature Dissemination of information to the public	Reproductive and Cancer Hazard Assessment Branch Scientific and administrative support of the SGP Evaluation of scientific information for chemical selection, choice of biomarkers, and interpretation of results Development of chemical fact sheets and protocols for evaluating elevated chemical levels Outreach to the public, including updates and improvements to the Program website

*LIMS = Laboratory Information Management System

CDPH is the lead entity, with primary responsibility for: (1) administering Biomonitoring California and coordinating the technical work of the three departments; (2) overall design of biomonitoring studies, including both statewide and community surveys, and submitting protocols for human subjects

committee review; (3) participant recruitment, sample collection, and data analysis; (4) receipt, storage, and analysis of blood and urine samples for metals and chemicals that are not biologically persistent; (5) quality assurance and interpretation of laboratory test results; (6) communication of test results to participants and dissemination of information to the public; (7) generation of the biennial reports to the Legislature; and (8) coordination of the CDC cooperative agreement.

OEHHA has primary responsibility for: (1) administering and supporting the Scientific Guidance Panel (SGP), which is described in greater detail below; (2) evaluating and summarizing scientific information for the SGP's deliberations on chemicals for biomonitoring; (3) evaluating and summarizing scientific information to interpret and return biomonitoring results to study participants; (4) collaborating with CDPH on study design and data analysis; and (5) conducting public outreach efforts, including through updates and improvements made to the Program's website: www.biomonitoring.ca.gov.

DTSC has primary responsibility for: (1) analysis of blood samples for biologically persistent chemicals; (2) quality assurance and interpretation of the laboratory's test results; and (3) exploring methodologies to identify new and emerging chemicals of concern, particularly those that have not yet been detected and could pose wide exposure concerns in the state. Additionally, staff from DTSC's Safer Consumer Products program help identify chemicals that may be a priority for monitoring based on potential for exposure through consumer products.

Staff members in all three departments collaborate on multiple activities, including program design, SGP meetings, and data analysis. For example, OEHHA and DTSC staff members contribute to the program design, for which CDPH is the lead. Similarly, OEHHA convenes the SGP and provides scientific support, while representatives from DTSC and CDPH provide scientific and other programmatic input to meeting content, as well as making presentations and responding to questions from the Panel. The three departments share responsibility for analyzing data collected by Biomonitoring California, focusing on different scientific issues so that analyses are not duplicative. Selected managers from the three departments also meet regularly ("Program Leads" meetings) to coordinate activities. Staff members from the three departments also constitute the Biomonitoring Interagency Group, which meets twice per month to share information.

Scientific Guidance Panel and Chemical Selection

As described in Senate Bill 1379 (Perata and Ortiz, Chapter 599, Statutes of 2006), scientific peer review of Biomonitoring California is provided by the Scientific Guidance Panel (SGP). The SGP's rigorous technical input provides a robust scientific underpinning for the Program. 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 nine members appointed by the Governor and the Legislature. More information on the SGP, including panelists' biographies, is available online at: www.biomonitoring.ca.gov/scientific-guidance-panel.

The Panel met six times during 2016-2017, as required by law. Meeting materials, including agendas, presentations, scientific documents, other background materials, transcripts, and meeting summaries are also available on the Biomonitoring California website at: www.biomonitoring.ca.gov/meetings. The

meetings are open to the public and are available via webcast or webinar. The SGP agendas include ample time for public comment on each item, as well an open public comment period at the end of the meeting. Attendees participating in the meeting via the Internet can make comments via email (biomonitoring@oehha.ca.gov).

The SGP performs many functions that are critical to the success of Biomonitoring California. The SGP's major role is to review scientific and other materials and provide recommendations on chemicals or chemical classes that should be included in Biomonitoring California. The Panel provides feedback on the design and implementation of Program projects, suggestions on future projects, and advice to the laboratories. The SGP gives input on the content and format of results return materials, which are provided to study participants, and the Program's website. The Program also seeks input from the SGP on special topics, and invites outside experts for a richer discussion. Special topics during 2016-2017 included:

- 1-Nitropyrene as a biomarker for diesel exhaust exposure
- Considerations in pesticide biomonitoring, including challenges in measuring glyphosate
- Setting future priorities for Biomonitoring California, as part of marking the Program's 10th anniversary
- Perspectives from community and advocacy organizations on Biomonitoring California's activities, including the Program's recent environmental justice work

In 2016, the SGP reviewed preliminary screens of classes of pesticides and classes of chemicals used as UV stabilizers for possible future consideration as potential designated chemicals. In 2017, the SGP recommended that the class of "organophosphorus pesticides" be added to the list of designated chemicals, which is the entire pool of chemicals that can be considered for inclusion in Biomonitoring California projects. To access the current list of designated chemicals, visit: www.biomonitoring.ca.gov/chemicals/designated-chemicals.

Biomonitoring California recognized its 10th anniversary after the Scientific Guidance Panel meeting on March 8, 2017. The event highlighted the accomplishments of the Program to date. Several guest speakers were present, including former biomonitoring study participants, who spoke about their experiences; and prominent scientists in the field, who spoke about the significance and future of biomonitoring.

Appendix B: Program Funding

Biomonitoring California receives $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 (2016-2017):

- California Regional Exposure (CARE) Study
- Measuring Analytes in Maternal Archived Samples (MAMAS)
- Asian/Pacific Islander Community Exposures (ACE) Project
- Biomonitoring Exposures Study (BEST)
- Firefighter Occupational Exposures (FOX) Project
- Foam Replacement Environmental Exposure Study (FREES)
- Pregnancy Environment and Lifestyle Study (PETALS)
- East Bay Diesel Exposure Project

The one-year temporary augmentation in support of environmental justice activities in FY 2016-17 was used to support stakeholder interviews with 84 environmental justice, community, and Tribal organizations. The stakeholder interviews provided community input on environmental exposure concerns and biomonitoring priorities across the state. The East Bay Diesel Exposure Project and the ACE Project were also supported in part by this funding.

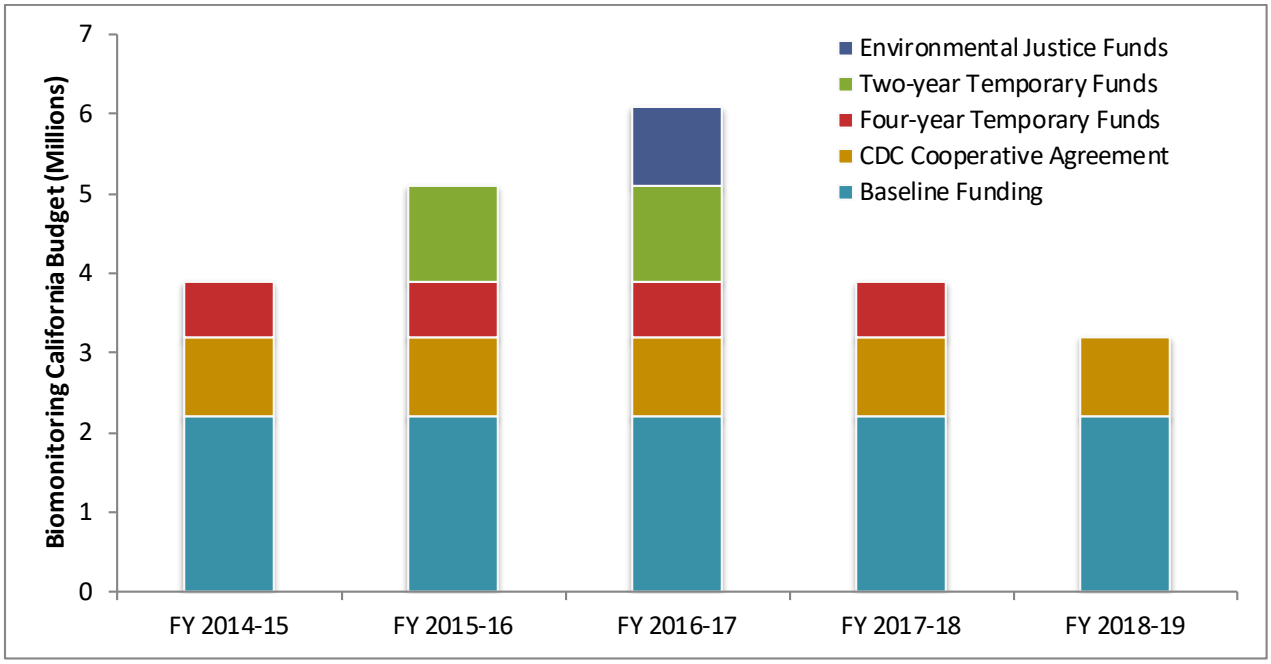

Figure B1: Biomonitoring California Budget, FY 2015-2019 (CDPH, OEHHA, and DTSC)

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

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

Funding	Fiscal Year	Note
$2.2 million	n/a - baseline	• Baseline State funding, split between CDPH, OEHHA, and DTSC • Supports 13.0 full-time positions
$1.0 million	FY 2015-FY 2019	• U.S. Centers for Disease Control and Prevention (CDC) cooperative agreement • Funds will expire August 2019
$700,000	FY 2015-FY 2018	• Four-year[10] temporary augmentation (State special funds) • $550,000 and two 2-year limited-term positions for CDPH • $150,000 and two 2-year limited-term positions for DTSC • Funds will expire June 2018
$700,000	FY 2016-FY 2017	• Two-year temporary augmentation (State special funds) • $550,000 and six 2-year limited-term positions for CDPH • $150,000 and two 2-year limited-term positions for DTSC • Funds expired June 2017
$1.0 million	FY 2017	• One-year temporary augmentation (State general fund) for environmental justice activities • New activities included the East Bay Diesel Exposure Project, an expansion of the Asian/Pacific Islander Community Exposures (ACE) Project, and environmental justice outreach) • Funds expired June 2017

The original proposed statewide survey as envisioned in the legislation was projected to cost nearly $10 million (in 2006 dollars). While the Program continues to pursue additional federal resources to meet the full extent of its complex laboratory and programmatic mandates, Biomonitoring California works within existing resources by limiting the scope of its studies and by reducing the quantity and types of laboratory testing. For example, during the planning phase of the CARE Study, the Program:

- Rejected costly randomized participant sampling in favor of more efficient quota-based sampling
- Reduced the pace of sample collection across the state, which improved the feasibility of sample collection; however, the slower pace of sampling may make it harder to detect trends in chemical exposures over time.
- Limited the set of analytes to metals and PFASs. Additional chemicals of concern, including pesticides and chemicals related to air quality, may be added as resources allow.

The CARE Study is a cost-efficient approach to achieving statewide biomonitoring surveillance over time, and it has the potential to provide important information about chemical exposures in California. If additional resources become available, the Program will be able to include additional chemicals of

[10] Funds were initially approved for two years (FY 2015-FY 2016) and were extended for an additional two years (FY 2017-FY 2018)

concern and/or increase the pace of sample collection across the state. Looking forward, the Program is also working to increase analytical efficiency. Options include:

- Reducing the number of chemicals available for biomonitoring by one-third (from 189 to approximately 126 chemicals or their metabolites). This limits the Program's capability to biomonitor for important chemicals, including those most useful to local and state public health programs and emergency response.
- Implementing new sample management tracking tools to streamline sample receipt, storage, and management.
- Automating laboratory methods to reduce time spent preparing and handling samples for analysis.

Biomonitoring California cannot readily increase the number of chemicals measured given current instrumentation and Program resources. As laboratory instruments age, the Program will face growing difficulties maintaining existing biomonitoring capabilities. In anticipation of these challenges, the Program is prioritizing robust analytical methods and flexible studies with the greatest likelihood of fulfilling our mission to measure chemicals in a representative sample of Californians; establish trends over time; and assess the effectiveness of public health efforts and regulatory programs (Perata and Ortiz, Chapter 599, Statutes of 2006).

Appendix C: Chemicals that Biomonitoring California Labs Can Measure

Chemical group	Description of chemicals in the lab panel
Bisphenol A (BPA) analogs and substitutes	Manufacturers are removing BPA from a number of consumer products because of public concern over its potential effects on the endocrine system and action of hormones. However, chemicals with similar structures, such as bisphenol S (BPS), are still used in products and show similar biological activity as BPA, including potential hormonal effects. Biomonitoring California measures selected BPA analogs, some of which are BPA substitutes, in urine.
Environmental phenols	Environmental phenols have a wide variety of uses, such as in personal care and other consumer products. These chemicals share a common chemical structure. Some examples of environmental phenols are BPA, triclosan, benzophenone-3 (BP-3), and parabens. This group of chemicals may interfere with the body's natural hormones. Biomonitoring California measures environmental phenols in urine.
Herbicides	Herbicides measured by Biomonitoring California include 2,4-D and 2,4,5-T. 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. 2,4,5-T was used in the past to control weeds but was banned due to toxicity concerns. Biomonitoring California measures these herbicides in urine.
Metals	Metals are used in many industries and are found in a variety of products. Biomonitoring California measures a number of known toxic metals, including arsenic (total and specific forms), cadmium, lead, and mercury. Cadmium, lead, and mercury have established levels of health concern, and can cause a range of effects, including harm to the developing infant and child, and increased cancer risk. Some forms of arsenic ("inorganic arsenic") may harm the developing fetus and may contribute to cardiovascular disease, and can increase cancer risk, while other forms found in seafood are not considered to be a health concern. Biomonitoring California's expanded metals panel includes antimony, cobalt, manganese, molybdenum, and uranium. The Program measures metals in urine and/or blood (whole blood, plasma, and serum).
Organochlorine pesticides (OCPs)	The OCPs measured by Biomonitoring California were banned 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. Biomonitoring California measures OCPs in serum.

Chemical group	Description of chemicals in the lab panel
Organophosphate flame retardants (OPFRs)	Because of the historically high levels of flame retardants in Californians, the Program has made it a priority to measure banned flame retardants (i.e., PBDEs) and their substitutes to evaluate the effectiveness of new policies and interventions. 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. OP pesticides 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.
Perchlorate	Perchlorate is an ingredient in rocket fuel and explosives. It also occurs naturally in dry regions, such as in the Southwestern United States. Industrial uses of perchlorate have led to contamination of soil, groundwater, and drinking water in some areas of California. Perchlorate lasts a long time in the environment and can accumulate in various crops. Perchlorate can interfere with the thyroid gland's ability to use iodide, which can decrease the production of thyroid hormones. Perchlorate may affect the developing fetus and child and may increase risk factors for heart disease. Biomonitoring California measures perchlorate in urine.
Perfluoroalkyl and polyfluoroalkyl substances (PFASs)	PFASs are used to make various products resistant to oil, stains, grease, and water. Some example products that use PFASs include non-stick cookware, stain-repellent carpets and clothing, and grease-repellent food containers. There is concern that 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. Biomonitoring California measures PFASs in serum.
Phthalates	Phthalates are added to vinyl to make it soft and flexible. Vinyl products include shower curtains, flooring, and plastic tubing. Phthalates are also used in scented products, coatings like nail polish and paint, and a variety of other consumer products. Phthalates can interfere with the body's natural hormones, affect the developing fetus, infants, and children, and decrease fertility, and some phthalates may increase cancer risk. The male reproductive system is especially sensitive to phthalate exposure during development. Biomonitoring California measures phthalate metabolites in urine.

Chemical group	Description of chemicals in the lab panel
Polybrominated diphenyl ethers and their metabolites (PBDEs and OH-BDEs)	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. US 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 and OH-BDEs in serum.
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 and wood 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: Publications

The following papers were published in 2016-2017:

- Guo W, Huen K, Park J-S, Petreas M, Crispo-Smith S, Block G, Holland N. Vitamin C intervention may lower the levels of persistent organic pollutants in blood of healthy women – A pilot study, Food Chem Toxicol, 92: 197 – 204, 2016 (PMID: 2709010)
- Harley KG, Kogut K, Madrigal DS, Cardenas M, Vera IA, Meza-Alfaro G, She J, Gavin Q, Zahedi R, Bradman A, Eskenazi B, Parra KL (2016). Reducing phthalate, paraben, and phenol exposure from personal care products in adolescent girls: Findings from the HERMOSA intervention study. Environ Health Perspect DOI: 10.1289/ehp.1510514. Epub: 2016 March 7.
- Hurley S, Goldberg D, Nelson DO, Guo W, Wang Y, Baek HG, Park JS, Petreas M, Bernstein L, Anton-Culver H, Reynolds P. Temporal Evaluation of Polybrominated Diphenyl Ether (PBDE) Serum Levels in Middle-Aged and Older California Women, 2011-2015. Environ Sci Technol.51(8):4697-4704, 2017 (PMID: 28304169)
- Hurley S, Goldberg D, Wang M, Park JS, Petreas M, Bernstein L, Anton-Culver H, Nelson DO, Reynolds P. Time Trends in Per- and Polyfluoroalkyl Substances (PFASs) in California Women: Declining Serum Levels, 2011-2015. Environ Sci Technol 52(1): 277-287, 2017. (PMID: 29198103)
- Hurley S, Houtz E, Goldberg D, Wang M, Park J-S, Nelson DO, Reynolds P, Bernstein L, Anton-Culver H, Horn-Ross P, Petreas M (2016). Preliminary associations between the detection of perfluoroalkyl acids (PFAAs) in drinking water and serum concentrations in a sample of California women. Environ Sci Technol Lett 3(7):264–269. DOI: 10.1021/acs.estlett.6b00154. Epub: 2016 June 6.
- Kezios K, Gu Y, Liu X, Cirillo P, Tarrant D, Petreas M, Park JS, Cohn B, Factor-Litvak P. Hydroxylated polychlorinated biphenyl metabolites (OH-PCBs), maternal smoking and size at birth. Reprod Toxicol 71:166-175, 2017 (PMID: 28314564)
- Krowech G, Hoover S, Plummer L, Sandy M, Zeise L, Solomon G (2016). Identifying chemical groups for biomonitoring. Environ Health Perspect 124(12): A219-226. DOI:10.1289/EHP537. Epub: 2016 December 1.
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