

Implementation of the California Environmental Contaminant Biomonitoring Program: 2014-2015

Fourth Report to the California Legislature



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



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Governor
State of California



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To obtain copies of the report

This report is available online at:

biomonitoring.ca.gov/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

Biomonitoring—the measurement of chemicals or their metabolites in a person’s body—provides an overall measure of human exposure to certain chemicals found in air, water, food, soil, dust, and consumer products. Biomonitoring helps public health officials and researchers better track the amounts and types of chemicals that get into people from all sources, and informs decision-makers and the public about potentially toxic chemical exposures that can affect the health of Californians.

Background

The California Environmental Contaminant Biomonitoring Program (the Program) was established through legislation in 2006 by Senate Bill (SB) 1379 (Perata and Ortiz) and codified in Health & Safety Code Sections 105440 et seq. Biomonitoring California 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 (SGP) and input from the public. For more information about Biomonitoring California, visit the Program website at biomonitoring.ca.gov.

The Program is required to submit progress reports every two years to the Legislature. This document is the fourth such report. The first three reports can be accessed online.¹ This report highlights Program accomplishments for the time period between January 1, 2014, and December 31, 2015.

Biomonitoring is an important public health function

Biomonitoring provides the only objective measure of chemical exposures, which may adversely affect the health of:

- The general population
- People living in communities impacted by particular industries or pollutants
- Vulnerable groups, such as pregnant women, children, or workers

Biomonitoring is a proven scientific tool that can demonstrate whether regulatory and public health efforts are reducing chemical exposures.

Biomonitoring also offers important information to inform and educate decision-makers and the public.

¹ www.biomonitoring.ca.gov/biomonitoring-california-reports

New Biomonitoring California Findings and Other Program Highlights

In establishing Biomonitoring California, the Legislature found that biomonitoring can “provide data that will help California scientists, researchers, public health personnel, and community members explore linkages between chemical exposures and health.” Biomonitoring California has focused to date on building laboratory capabilities, developing techniques to appropriately communicate results of individual tests to participants (as required by the statute), and engaging in a series of scientifically based targeted studies of vulnerable subpopulations that are described in the following sections. Where appropriate, results from the targeted studies have been compared with data from national surveys, providing valuable information about exposures in some California subpopulations.

Summary of Studies and Findings

As of December 31, 2015, Biomonitoring California initiated a total of five full project collaborations and 14 laboratory collaborations. Collectively, these studies include participants from a wide range of California populations. The studies measure a wide variety of chemicals with the potential for harming the health of Californians (see Table 1). Two of the five full project collaborations have been completed (see Appendix B). The following three studies occurred during the period covered by this report (January 1, 2014, to December 31, 2015):

The Measuring Analytes in Maternal Archived Samples (MAMAS) Study began in April 2014. MAMAS is a pilot study that measures metals, perfluorinated compounds (PFCs), and persistent organic pollutants (POPs) in archived maternal serum samples previously collected through the State’s Genetic Disease Screening Program. This study evaluated the use of archived specimens to build a statewide sample derived from pregnant women. For more information, please refer to page 12 of this report.

- Key finding from the MAMAS Study:
 - Perfluorinated chemicals (PFCs) levels measured in serum samples from pregnant women archived in 2012 are consistent with levels found in the US population.

The Biomonitoring Exposures Study (BEST) was initiated with a pilot in 2011, and later expanded to involve more than 450 adult residents of the Central Valley, with oversampling for Asians and Hispanics. For more information, please see page 12 of this report.

- Key findings from the BEST Study:
 - There are higher levels of arsenic in people living in the Central Valley compared to the general US population.

- Over 90% of participants had detectable levels of potentially toxic metals, including arsenic, cadmium, and mercury in their urine.
- Asian/Pacific Islanders generally had higher levels of mercury in their blood compared to other race and ethnic groups.
- Both Black and Asian/Pacific Islander participants had higher levels of cadmium in urine, compared to White participants.

The Foam Replacement Environmental Exposure Study (FREES) was launched in June 2015. FREES is a study designed to measure the effects of replacing or removing foam furniture on levels of flame retardants in participants' blood and urine samples. In parallel, collaborators at UC Davis are measuring changes in levels of these chemicals in participants' house dust. For more information, please see page 15 of this report.

Biomonitoring California is continuing to analyze information from these and other studies and will release additional findings as they become available. Summary results can be accessed at: biomonitoring.ca.gov/results. Highlights of Program findings to date are available at: biomonitoring.ca.gov/program-accomplishments.

Laboratory Capacity and Capabilities

Biomonitoring California's laboratories are collaborating with university researchers and other expert scientists to analyze samples collected for other studies (i.e., laboratory collaborations). For example, serum samples from thousands of female educators in the California Teachers Study (CTS) are being analyzed for persistent organic pollutants, including flame retardants, and persistent pesticides. The Program's analyses for CTS led to the key finding that race (non-white), lower socioeconomic status, and higher body weight were correlated with higher levels of some flame retardants.

Biomonitoring California has continued to expand its laboratory capability to analyze environmental chemicals in blood and urine samples and its capacity to detect these chemicals in larger numbers of people. Since the Program's inception, Biomonitoring California:

- Has developed the capability to measure over 160 distinct chemicals or their breakdown products in urine, serum, and whole blood.
- Obtained specimens from over 7,000 Californians.
- Conducted over 18,500 biomonitoring analyses for chemical pollutants, including metals, flame retardants, phthalates, PFCs, pesticides, bisphenol A, and others.

Communicating Results to Study Participants

Biomonitoring California is committed to its mandate to return biomonitoring results to study participants who request them. Results return materials were developed in coordination with

researchers from the University of California (UC), Berkeley, and reflect best practices for returning biomonitoring results to participants.

- To date, the vast majority of participants (96 %) recruited by Biomonitoring California into full project collaborations have indicated at enrollment that they would like to receive their results.
- Between 2012 and 2015, the Program provided specially designed packets that describe individual biomonitoring results to over 600 participants. The packets contain test results, fact sheets, and suggestions on ways to reduce exposures. Each participant has received multiple results packets, covering different types of analytes.
- As part of the BEST study, the Program collected participant feedback on the packets through surveys and interviews. Participant feedback on the packets has been positive.
- In August 2015, Program staff presented a webinar hosted by the Association of Public Health Laboratories (APHL) detailing Biomonitoring California's results communication approach. The webinar was well attended and demonstrated the Program's leadership in this area.
- A special session on best practices for biomonitoring results return was included on the November 2015 SGP meeting agenda.

Informing the Public and Supporting Other Programs

Biomonitoring California is required by state law to publicly release biomonitoring results, and has previously developed data summary reports for that purpose. To more effectively and quickly disseminate our findings, Biomonitoring California launched an online interactive results database in April 2014 (biomonitoring.ca.gov/results/explore). With this tool, users can view, print, and download summary biomonitoring results, customized by Biomonitoring California project, chemical group, or individual chemicals. This online database is an important element of the Program's strategy to keep the public informed of Biomonitoring California findings, and make study results easily accessible to other state, national, and international programs.

Program Priorities

Biomonitoring California identified the following priorities and opportunities for maintaining and improving the Program:

1. Statewide representative sampling

Biomonitoring a representative cross-section of the California population is a key statutory requirement that would provide important information about levels of environmental chemical exposures throughout the state, and remains the top priority of the Program.

2. Environmental justice

Conducting biomonitoring in the context of environmental justice is a guiding principle in the enabling legislation. One of the Program's top priorities moving forward is to continue to focus on environmental justice applications of biomonitoring.

3. Intervention studies (with an emphasis on consumer products)

Intervention studies provide important information on likely sources of biomonitored chemicals, by removing or replacing products known to contain the targeted chemicals. Biomonitoring California considers opportunities to measure chemical exposures from consumer products before and after an intervention. Information from consumer product biomonitoring studies can help support the efforts of California's Safer Consumer Products program.

4. Chemicals of emerging concern

Biomonitoring California will continue to develop methods to identify new chemicals that pose potential health risks to Californians by:

- Expanding and automating methods to measure chemicals more quickly and accurately.
- Pioneering new laboratory methods to broadly screen for and identify new chemicals emerging as potential concerns for Californians' health.

5. Program Funding

Biomonitoring California receives baseline state funding of approximately \$2.2 million through five special funds. In addition, from September 2009 through August 2014, the Program received \$2.65 million annually for five years through a cooperative agreement from the Centers for Disease Control and Prevention (CDC). In September 2014, Biomonitoring California was awarded a second cooperative agreement from CDC at the maximum allowable amount of \$1.0 million annually for five years. To partially compensate for the reduction in federal funds, the 2014 Budget Act included state funds of \$700,000 per year for two years and four 2-year limited-term positions (two positions in DTSC and two in CDPH). The 2015 Budget Act included \$550,000 per year for two years and six 2-year limited-term positions for CDPH, and \$150,000 and two 2-year limited-term positions for DTSC.

Introduction

“Biomonitoring” refers to measuring chemicals in human biological samples, such as blood and urine. It can provide an overall measure of human exposure to certain chemicals found in air, water, food, soil, and consumer products. Biomonitoring can help assess the extent of chemical exposures from all sources, including the environment, consumer products, diet, and occupation.

Californians experience widespread exposures to a multitude of chemicals, including 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 serves an important public health function. It provides a measure of toxic or potentially toxic chemical exposures that may adversely affect the health of the general population; people living in communities impacted by particular industries/pollutants; and vulnerable sub-groups of the population, such as pregnant women and children. Biomonitoring is a proven scientific tool that can demonstrate whether regulatory and public health efforts are reducing 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.

Biomonitoring California was established by 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.”

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 has built capacity through targeted studies focused on exposures in vulnerable subpopulations in California. This strategy has allowed the Program to acquire essential laboratory equipment; train staff; develop methods to measure harmful chemicals, including emerging contaminants; and successfully pilot methods to communicate results to participants and the California public. Using this strategy, the Program has successfully leveraged state resources both by collaborating with other researchers and by acquiring supplemental extramural support through a cooperative agreement with the CDC. Having established sufficient capacity, Biomonitoring California is now planning to initiate the statewide survey (projected for 2018).

Program Priorities and Opportunities

Biomonitoring California has established a reputation for developing and using cutting-edge analytical methodologies and for setting high standards in reporting results to participants and the public. In order to continue to provide a high-quality state biomonitoring program and meet the needs of Californians, a series of facilitated planning meetings were convened with departmental managers and senior staff of Biomonitoring California. Several strategic areas were identified in order to prepare for the future, such as visioning, decision making, communication, and methods development.

These findings were shared with all Biomonitoring California staff and key managers in CDPH, OEHHA, and DTSC; the SGP; the public (via SGP meetings); and other stakeholders. The following key priorities and opportunities for maintaining and improving the Program were identified:

1. Statewide representative sampling

Biomonitoring a representative cross-section of the California population will provide important information about levels of environmental chemical exposures throughout the state, and this statutory mandate remains the top priority of the Program. The Program has continued to carry out targeted and community-based studies and analyses of archived samples to develop capacity for a statewide representative sample (these studies are described below and in Appendix A). These analyses provide important biomonitoring data that help inform public

health practice and policy in California. Targeted studies also add value by highlighting exposures in high-risk groups, such as: disadvantaged communities with specific exposure concerns; workers with potential exposures to chemicals not typically monitored in the workplace; and sensitive populations like pregnant women and infants. Targeted studies also contribute to the goal of understanding California's statewide burden of environmental exposure.

The Program continues to seek collaborations that allow access to samples that may provide a more representative cross-section of the California population while planning for a statewide sampling approach (projected for 2018).

2. Environmental justice

Conducting biomonitoring in the context of environmental justice is a guiding principle in the enabling legislation. One of the Program's top priorities moving forward is to continue to focus on environmental justice applications of biomonitoring. Below are two examples of new Program initiatives, which underscore this focus:

- Biomonitoring California is collaborating with the California Environmental Protection Agency's (CalEPA's) and OEHHA's California Communities Environmental Health Screening Tool (CalEnviroScreen) program. CalEnviroScreen is a screening methodology that can be used to help identify California communities that are disproportionately burdened by multiple sources of pollution (oehha.ca.gov/calenviroscreen). Data available through CalEnviroScreen, such as chemical levels in drinking water, can be used to interpret Biomonitoring California results in areas like the Central Valley.
- Biomonitoring California is working with San Francisco community groups to assess exposure to heavy metals and PFCs among Asian populations. The project will focus on low-income communities with strong cultural ties to fishing and fish consumption.

3. Intervention studies (with an emphasis on consumer products)

A public health intervention refers to a purposeful action to create, institute, and evaluate change in the context of improving health. In the case of biomonitoring, an intervention might include the removal, reduction, or replacement of potentially toxic chemicals or products containing these chemicals. Biomonitoring California has prioritized interventions focused on commonly used consumer products, in order to provide specific exposure information that can help inform the Safer Consumer Product program at DTSC. Below are some examples of intervention studies that Biomonitoring California has collaborated on:

- A study with the UC Davis to assess the changes in biomonitored flame retardant levels in participants after they remove or replace foam-containing furniture from their homes (see FREES description).

- A laboratory collaboration with UC Berkeley to analyze phthalates, triclosan, bisphenol A (BPA), parabens, benzophenone-3 (BP-3), and creatinine in urine samples from a population of teenage girls before and after a change to personal care and cosmetic products (see the Health and Environmental Research in Makeup of Salinas Adolescents [HERMOSA] study description).

Biomonitoring California will consider additional projects to measure chemical exposures from consumer products before and after an intervention as opportunities become available for such studies.

4. Chemicals of emerging concern

Biomonitoring California has prioritized the development of methods to identify new chemicals that pose potential harm to Californians by:

- Expanding and automating methods to quickly and accurately measure additional chemicals of public health interest.
- Pioneering new laboratory methods to broadly screen for and identify new chemicals emerging as potential concerns for Californians' health.

The Program continues to conduct activities to measure additional chemicals using its current methods, and expedite analytical throughput using enhanced automation, where possible. The Program has begun to explore methodologies for measuring previously unidentified chemicals that could pose health hazards, including:

- **Identifying unknown chemicals present in Californians.** The Program is developing methodologies to screen biological samples for previously unidentified chemicals of potential concern.
- **Fragrances, such as synthetic musks.** Fragrance chemicals are ubiquitous in personal care products, and exposures are likely to be widespread in Californians. These chemicals can pose a variety of health concerns. For example, synthetic musks are biologically active, potentially affecting the body's natural hormones.
- **Additional phthalates.** The Program is expanding our existing phthalates method to measure metabolites of additional phthalates that are increasing in use and exposure.
- **Newer flame retardants.** Biomonitoring California continues to track flame retardants that are replacing PBDEs and/or emerging as high-use chemicals. The Program will work to develop new methods to measure additional halogenated and organophosphate flame retardants.

5. Program funding

Biomonitoring California receives baseline state funding of approximately \$2.2 million through five special funds. In addition, from September 2009 through August 2014, the Program received \$2.65 million annually for five years through a cooperative agreement from CDC. When this initial funding cycle came to an end, CDC restructured its funding mechanism for the second cycle by lowering the award ceiling to allow for additional award recipients. Biomonitoring California was awarded the maximum allowable amount in this second funding cycle: \$1.0 million annually for five years starting September 2014.

In 2014, the Budget Act included augmented state funds of \$700,000 per year for two years and four 2-year limited-term positions (two positions in DTSC and two in CDPH), and the 2015 Budget Act included \$550,000 and six 2-year limited-term positions for CDPH, and \$150,000 and two 2-year limited-term positions for DTSC.

Biomonitoring California Long-Term Goals

1. Measure human exposures to chemicals at the state and community level, using science-based surveys and methods.
2. Examine trends in chemical levels over time.
3. Help assess the effectiveness of:
 - Environmental regulations
 - Public and occupational health interventions
 - Efforts to improve the safety of consumer products

Biomonitoring California Studies

The enabling legislation directs the Program to conduct statewide and community-based biomonitoring studies contingent on funding (Health and Safety Code [H&SC] section 105441). To undertake such studies, Biomonitoring California has engaged in collaborations with other researchers and has obtained archived biological samples collected by other public health programs across California.

The Program's studies thus far include varied sets of California residents and workers with a focus on subpopulations that may be especially vulnerable or that may have greater chemical exposures, including pregnant women and residents of agricultural communities.

Results from Biomonitoring California studies are compared to national data collected by the CDC to determine whether the levels of contaminants in the California groups are higher, lower, or the same as in the nationwide population. In some cases, collaborating researchers are also

planning to follow study participants over time to assess potential associations between biomonitoring results and health outcomes. The Program's ongoing studies and collaborations are laying the groundwork for better characterizing chemical exposures in California's diverse population, including racial and ethnic groups underrepresented in national biomonitoring studies.

The Program has carried out two types of biomonitoring studies:

- **Full project collaboration:** These are studies designed by Biomonitoring California staff, often in collaboration with other researchers. Biomonitoring California is responsible in whole or in part for:
 1. Study design, sample collection, and collection of exposure data;
 2. Laboratory analyses of blood, urine, and/or serum samples;
 3. Returning detailed information on biomonitoring results to all participants who request to receive their results.
- **Laboratory collaboration:** These are studies designed by external researchers, with Biomonitoring California providing laboratory support. Biomonitoring California is responsible for laboratory analyses and may provide additional consultation upon request.

In the time since the third report to the Legislature (covering the period January 2013 through December 2014), the number of participants in Biomonitoring California projects has continued to increase. All full project collaborations and some lab collaborations were supported in part by CDC cooperative agreements 5U38EH000481 and 5U88EH001148. Collaborations with external partners allow the Program to leverage existing resources.

Full Project Collaborations

Three full project collaborations and the MAMAS statewide pilot study, which were conducted during 2014-2015, are discussed below. Results of these studies are posted in the Program's interactive database, biomonitoring.ca.gov/results, as they become available.

1. Measuring Analytes in Maternal Archived Samples (MAMAS)

The MAMAS pilot study analyzes maternal serum samples collected through CDPH's Genetic Disease Screening Program (GDSP). The MAMAS study has the potential to provide an excellent approximation of a statewide sample of pregnant women. Participation in the prenatal screening program is high (approximately 70% of pregnant women). Samples were selected to equally represent White, Black, Hispanic, and Asian mothers from across the state.

The MAMAS study differs from other full collaborations in two ways:

1. The study uses samples collected in the past by the CDPH GDSP, which obtains the samples through routine prenatal screening. Biomonitoring California identifies a subset of these samples to analyze for levels of specific chemicals (more detail below).
2. Samples are not associated with any personal identifiers, such as name and address. The Program cannot, therefore, return results to participants.

The first phase of the pilot study, MAMAS-1, analyzed 460 samples obtained from GDSP archives. Samples represented mothers from San Diego and Orange County who had undergone prenatal screening in 2012. Samples were analyzed for metals, perfluorinated chemicals (PFCs), and POPs, which include polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), and organochlorine pesticides (OCPs). MAMAS-1 found PFC levels were consistent with levels found in the overall US population. Data from this phase also indicated that the serum separator gel used by GDSP was contaminated with several metals. Because this makes quantifying metals in MAMAS samples infeasible, the decision was made to drop metals as an analytical panel and measure only PFCs and POPs (listed above).

A subsequent phase of the pilot study, MAMAS-2, extended sampling statewide to provide data on maternal exposures throughout California. By the end of 2015, 540 new samples were received from four geographic regions (Alameda and Contra Costa counties, San Bernardino and Riverside counties, Los Angeles County, and Northern California counties) representing mothers who had undergone prenatal screening in 2015. MAMAS-2 samples will be analyzed for POPs and PFCs.

The MAMAS pilot demonstrated the feasibility of using archived serum samples from GDSP for some biomonitoring analyses, but several limitations were identified:

- No exposure information and limited demographic information are available. Therefore, analysis of MAMAS samples can only indicate the level of chemical exposure in the population, and cannot identify potential sources.
- Each sample contains a very small volume of serum, which limits the number of analyses.
- Of the fourteen classes of chemicals listed in Table 1, only four (PFCs, PBDEs, PCBs, and OCPs) can be measured in serum samples from GDSP. The collection tubes used by GDSP are contaminated with metals, which prevents accurate analyses of metals in these serum samples. GDSP collection protocols are outside the control of Biomonitoring California.

Despite these challenges, the MAMAS study provides useful information on some chemicals across the state. Archived samples can be acquired quickly and easily, and are relatively inexpensive when compared to costs associated with sample collection in other biomonitoring

exposure studies. MAMAS samples can be used to assess emerging chemicals of concern and to monitor trends in chemicals over time.

2. Biomonitoring Exposures Study (BEST)

Biomonitoring California is collaborating with the Kaiser Permanente Division of Research, Research Program on Genes, Environment and Health to conduct the two-phase project known as the BEST. Kaiser Permanente membership in California's Central Valley is demographically similar to the entire population of northern California with respect to characteristics such as educational attainment and race/ethnicity, which are known to be important determinants of long-term health outcomes.

In Phase 1, or "Pilot BEST," Biomonitoring California measured environmental chemical exposures in 112 adult Kaiser Permanente members living in the Central Valley. Recruitment was based on achieving balanced distributions across characteristics of race/ethnicity, gender, and age. Pilot BEST laboratory analyses were completed in 2013, and all results were returned to participants in 2014. Summary data are posted on the Program website.

Pilot BEST participants were sent results return evaluation surveys, and about 40% completed them. Analyses show that 96% of the respondents were glad to have participated in Pilot BEST and were satisfied with the information they received.

In Phase 2, known as "Expanded BEST," environmental chemical exposures are being measured in an additional 341 adult Kaiser Permanente members in the Central Valley. Expanded BEST focused on recruiting Hispanics and Asian/Pacific Islanders and included provisions to enable participation by those who speak only Spanish. Questionnaires (in English and Spanish), medical information, and blood and urine samples have been collected;² analyses began in 2014.

Analyses are being conducted on laboratory results and questionnaire data from the two phases of BEST to better characterize potential exposure pathways for selected chemicals. The Program is examining results by demographic characteristics in order to better describe any differences among sub-populations. In-depth analyses are underway for metals, PFCs, and PBDEs in conjunction with exposure data from participant questionnaires. Additionally, Biomonitoring California is using CalEnviroScreen³ data on water contamination to investigate the potential contribution of arsenic in residential drinking water to arsenic exposure in BEST participants.

² Of the samples collected from 341 individual participants, 337 serum samples, 315 blood samples, and 274 urine samples could be analyzed.

³ California Communities Environmental Health Screening Tool

The status of BEST sample collection and data analyses as of the reporting period is summarized below:

- Exposure questionnaire data and biological samples were collected from 453 adult Kaiser Permanente members.
- Laboratory analyses for 119 chemicals or their metabolites were completed for Expanded BEST in the current reporting period, and result packets have been returned to participants for all these analyses.
- Participants in Expanded BEST who had elevated inorganic arsenic levels were offered retesting and a follow-up questionnaire to help identify additional potential sources of exposure.
- Data analyses comparing BEST results to national levels have been completed.
- Summary results for Pilot and Expanded BEST are posted on the Program's website.

Preliminary findings from BEST include:

- Higher levels of arsenic were found in both the Pilot and Expanded BEST populations compared to the general US population.
- Metals with known serious health concerns, including arsenic, cadmium, mercury, and lead, were detected in all participants.
- Women in Expanded BEST had higher blood levels of cadmium compared to men, but lower levels of lead.
- Asian/Pacific Islanders in Expanded BEST generally had higher levels of mercury in their blood compared to other race/ethnic groups.
- Both Black and Asian/Pacific Islander participants had higher levels of cadmium in urine, compared to White participants.

Factors potentially contributing to these differences, including lifestyle, diet, and country of birth, are being investigated. For more information on Pilot and Expanded BEST, visit:

biomonitoring.ca.gov/projects/biomonitoring-exposures-study-best-1pilot and biomonitoring.ca.gov/projects/biomonitoring-exposures-study-best-2expanded.

3. Foam Replacement Environmental Exposure Study (FREES)

Biomonitoring California is collaborating with UC Davis on a study to assess the changes in flame retardant levels in serum (PBDEs) and urine (OPFRs) samples from participants after they remove or replace foam-containing household furnishings. Launched in June 2015, this small-scale intervention study will provide data on the levels of a wide range of flame retardants present in homes and household residents. Twenty-eight participants were recruited through December 2015.

As of December 31, 2015, FREES has:

- Recruited approximately 28 participants to the study and conducted initial exposure assessment.
- Started collection of exposure questionnaire data and samples from homes and household residents.

Laboratory Collaborations

The seven laboratory collaborations conducted during 2014-2015 are discussed below. As results become available, they are posted on the Program's website, biomonitoring.ca.gov/results. Descriptions of additional laboratory collaborations are included in Appendix B: Past Projects and Collaborations.

1. Health and Environmental Research in Makeup of Salinas Adolescents (HERMOSA) Study

The HERMOSA ("beautiful" in Spanish) Study is designed to investigate chemical exposures from personal care and cosmetic products in a small group of teenage girls. Biomonitoring California laboratories analyzed levels of phthalates, triclosan, BPA, parabens, BP-3, and creatinine in urine samples from participants. HERMOSA investigators chose these chemicals based on their potential to adversely affect the endocrine (hormonal) system. The study included an intervention in which participants were provided alternative personal care products not containing the chemicals tested for to determine whether this would reduce levels of these chemicals in their bodies.

The HERMOSA Study was conducted as a joint effort of researchers at the UC Berkeley; La Clinica de Salud del Valle de Salinas; and a team of youth researchers from the CHAMACOS (Center for the Health Assessment of Mothers and Children of Salinas) Youth Community Council. Funding for the study was provided by the California Breast Cancer Research Program.

Key findings include:

- Over 90% of the HERMOSA participants had detectable levels of triclosan, BP-3, methyl paraben, propyl paraben, and phthalates in their urine.
- Levels of phthalates, parabens, and BP-3 found in the HERMOSA study participants were slightly higher than levels found in the national population.⁴
- Girls who wore makeup more frequently were found to have higher paraben levels.

⁴ National levels were determined based on a comparable population of participants ages 14-18 from the 2011-2012 National Health and Nutrition Examination Survey (NHANES)

- The intervention (i.e., switching to alternative products for three days) substantially reduced urinary concentrations of some of the study chemicals. These reductions in chemical concentrations included monoethyl phthalate (27% reduction), BP-3 (36% reduction), methyl paraben (44% reduction), propyl paraben (45% reduction), and triclosan (36% reduction).

2. Pregnancy Environment and Lifestyle Study (PETALS)

Biomonitoring California laboratories measured BPA, triclosan, and BP-3 levels in urine samples from 300 pregnant women diagnosed with gestational diabetes mellitus (GDM) and 600 pregnant women who did not have GDM (controls). These chemicals may interfere with the body's natural hormones. PETALS aims to identify the contribution of the measured chemicals to the risk of GDM in expectant mothers. Two urine specimens from each of these 900 study subjects were analyzed for these chemicals, for a total of approximately 1,800 analyses. As of December 2015, the Program's laboratories had analyzed and reported 228 results.

3. Los Angeles Taxi Driver Study

This UC Los Angeles (UCLA) Environmental Health Sciences study is designed to measure polycyclic aromatic hydrocarbon (PAH) exposures in non-smoking taxi drivers from the Greater Los Angeles Area. PAHs are a known component of motor vehicle exhaust and may contribute to respiratory problems, affect the developing fetus and the body's natural hormones, and increase cancer risk. Taxi drivers were studied because of their frequent occupational exposure to PAHs. Biomonitoring California measured levels of PAHs in 232 samples from 22 taxi drivers collected before and after work shifts and from four individuals with low exposure to traffic.

The study found that median concentrations of 1-hydroxypyrene, a commonly used marker for total PAH exposure, were 125% higher than the US general population, and 50% higher than a group of UCLA students. UCLA conducted the data analysis. Results will be used to help evaluate the effectiveness of exposure mitigation strategies.

4. California Teachers Study

The California Teachers Study (CTS) is a large, multi-institutional, statewide cohort study conducted by the Cancer Prevention Institute of California, the City of Hope, the University of Southern California, and UC Irvine to study factors influencing women's health among active and retired female school teachers and administrators in California. In a sub-study focusing on links between chemical exposures and breast cancer, Biomonitoring California laboratories are analyzing levels of PFCs, PBDEs, and other POPs (PCBs and OCPs) in serum samples from women with breast cancer compared to women without breast cancer. Recruitment was completed in 2014. For more information about this study, visit biomonitoring.ca.gov/projects/california-teachers-study-cts. As of December 2015:

- Approximately 2,500 samples were transferred to Biomonitoring California laboratories, of which more than half have been analyzed for PFCs and one-fourth have been analyzed for other POPs (PCBs, PBDEs, and OCPs).
- The Program has posted results for a subset of CTS participants in our interactive database (biomonitoring.ca.gov/results). More results will be added as they become available.

Key findings include:

- As part of CTS, investigators examined predictors of flame retardant exposures. Certain characteristics were correlated with higher exposures for some flame retardants. Non-white, lower socioeconomic status, and heavier weight individuals were likely to have higher levels of flame retardants.
- Living close to solid waste disposal sites may be related to higher serum PBDE levels, including BDE-47 and BDE-100.

5. California Childhood Leukemia Study (CCLS)

The CCLS is a case-control study at UC Berkeley with over 3,000 enrolled families. In a small sub-study, Biomonitoring California analyzed 48 blood samples collected in 2006-2007 from mothers living in households with high levels of flame retardants (PBDEs) in dust. This effort was first reported on in the Third Report to the Legislature. The purpose of the collaboration is to examine a possible link between flame retardant exposure in the environment and childhood leukemia. Data are available on the Program website: biomonitoring.ca.gov/projects/california-childhood-leukemia-study-ccls.

6. Community Health Impacts from Mining Exposures Study (CHIMES)

CHIMES is a collaboration between the Sierra Streams Institute and the Cancer Prevention Institute of California. The study is an investigation into the human health consequences of residence in a mining-impacted community, and was designed with significant community involvement. A total of 60 women over the age of 21 who are residents of western Nevada County were recruited. Biomonitoring California provided laboratory and program support, including conducting analyses of levels of metals, including arsenic and cadmium; providing input on the results return approach and protocols for evaluating elevated levels of metals; and offering other consultation as needed. Partners in this collaboration analyzed biomonitoring results with questionnaire data to explore potential exposures to waste metals from mining. Statistical analyses are ongoing, and results will be released as they become available.

7. Combined Antioxidant and Preeclampsia Prediction Studies (CAPPS)

Biomonitoring California laboratories partnered with Stanford University to measure metals in archived serum samples from the National Institute of Child Health and Human Development

Maternal Fetal Medicine Unites Network specimen bank as part of CAPPs. Biomonitoring California analyzed samples from 75 preterm birth cases and 75 term births. Findings indicated that higher serum levels of heavy metals were not associated with spontaneous preterm birth.

Measuring Chemical Exposures

Biomonitoring California's two state laboratories are nationally recognized for their leadership and expertise in biomonitoring analytical methods. Each lab has unique areas of expertise to maximize analytical capabilities across the program.

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

The Environmental Chemistry Laboratory (ECL), a division of the DTSC, focuses on developing methods for and measuring **persistent** organic chemicals, such as flame retardants, PCBs, PFCs, and OCPs in serum, that bioaccumulate in people. ECL leads the Program's effort to broadly screen for and identify new chemicals emerging as potential concerns for Californians' health.

As of December 2015, the Program can measure 161 chemicals in 14 chemical groups, which include metals, pesticides, flame retardants, chemicals from personal care products and plastics, and other persistent pollutants such as PCBs. Chemicals that Biomonitoring California labs can measure are listed in Table 1. In 2015, Biomonitoring California added new analytical methods to measure OPFRs, which are replacement flame retardants for banned PBDEs in polyurethane foam and other materials; and chemicals that are structurally similar to BPA.

Figure 1 shows the rapid expansion of laboratory capability since the beginning of the Program in 2007 to 2013. In the First Report to the Legislature (2007-2009), laboratory capability included measurement of just three metals in blood and one pesticide in urine. By the Second Report (2010-2011), Biomonitoring California laboratories had the capability to measure more than 60 chemicals or their breakdown products in blood, urine, and serum. At the close of 2015, the Program was able to analyze 161 chemicals.

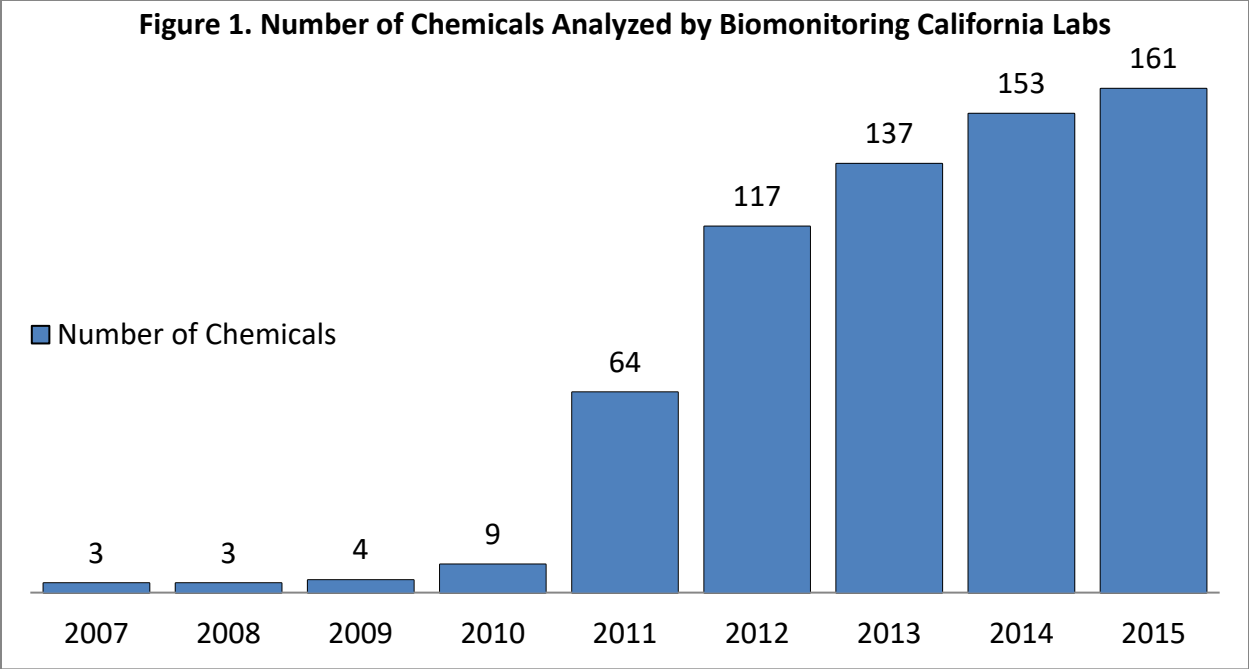


Table 1. Chemicals that Biomonitoring California Labs Can Measure

Chemical group	Description of chemicals in the lab panel
Organophosphate flame retardants	<p><i>New Method: Added 2015</i></p> <p>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, phosphate-based flame retardants have been entering the market in larger quantities. In 2015, Biomonitoring California initiated measuring organophosphate flame retardants in urine.</p>
Bisphenol-A analogs and substitutes	<p><i>New Method: Added 2015</i></p> <p>BPA is being voluntarily phased out of a number of consumer products because of 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 developed a new method to measure selected BPA analogs, some of which are BPA substitutes, in urine.</p>
Environmental phenols	<p>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, BP-3, and parabens. This group of chemicals may interfere with the body's natural hormones. Biomonitoring California measures environmental phenols in urine.</p>
Polybrominated diphenyl ethers and their metabolites (PBDEs and OH-BDEs)	<p>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. Scientists 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 hydroxy-PBDEs in serum.</p>

Chemical group	Description of chemicals in the lab panel
Metals	<p>Metals are used in many industries and found in a variety of products. Biomonitoring California measures arsenic (total and specific forms), cadmium, cobalt, lead, manganese, mercury, molybdenum, thallium, tungsten, and uranium.</p> <ul style="list-style-type: none"> • Some forms of arsenic (“inorganic arsenic”) may harm the developing fetus and contribute to cardiovascular disease, and can increase cancer risk, while other forms found in seafood are 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 cancer and toxicity to the developing infant and child. • Cobalt is essential as part of vitamin B12, but in other forms can increase cancer risk and harm the heart, thyroid, and nervous system. • Manganese and molybdenum are essential nutrients that can be toxic at higher exposure levels. • Thallium is a highly toxic metal that can harm many vital processes in the body. The health effects of tungsten are not well known, and its potential to affect the immune system or contribute to cancer risk is currently being studied. • Natural uranium is a weakly radioactive metal that can cause kidney damage and increase cancer risk. <p>Biomonitoring California measures metals in urine and/or blood (whole blood, plasma and serum).</p>
Perfluorinated chemicals (PFCs)	<p>PFCs are used to make various products resistant to oil, stains, grease, and water. Some example products that use PFCs include non-stick cookware, stain-repellent carpets and clothing, and grease-repellent food containers. There is concern that PFCs may affect the developing fetus and child, decrease fertility, interfere with the body’s natural hormones and the immune system, and increase cancer risk.</p> <p>Biomonitoring California measures PFCs in serum. The broader category of “perfluoroalkyl and polyfluoroalkyl substances (PFASs),” which includes PFCs, was added to the list of designated chemicals in 2015, and the Program is working to expand laboratory methods on this class of chemicals.</p>

Chemical group	Description of chemicals in the lab panel
Organochlorine pesticides (OCPs)	The OCPs measured by Biomonitoring California 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 Dichlorodiphenyltrichloroethane (DDT), which is still used in some other countries, and chlordane. OCPs may affect the developing fetus and interfere with the body's natural hormones, and may increase cancer risk. Biomonitoring California measures OCPs in serum.
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.
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 and interfere with the body's natural hormones, and may increase cancer risk. Biomonitoring California measures pyrethroid pesticide metabolites 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 is no longer used due to toxicity concerns. Biomonitoring California measures these herbicides in urine.
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 also 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.

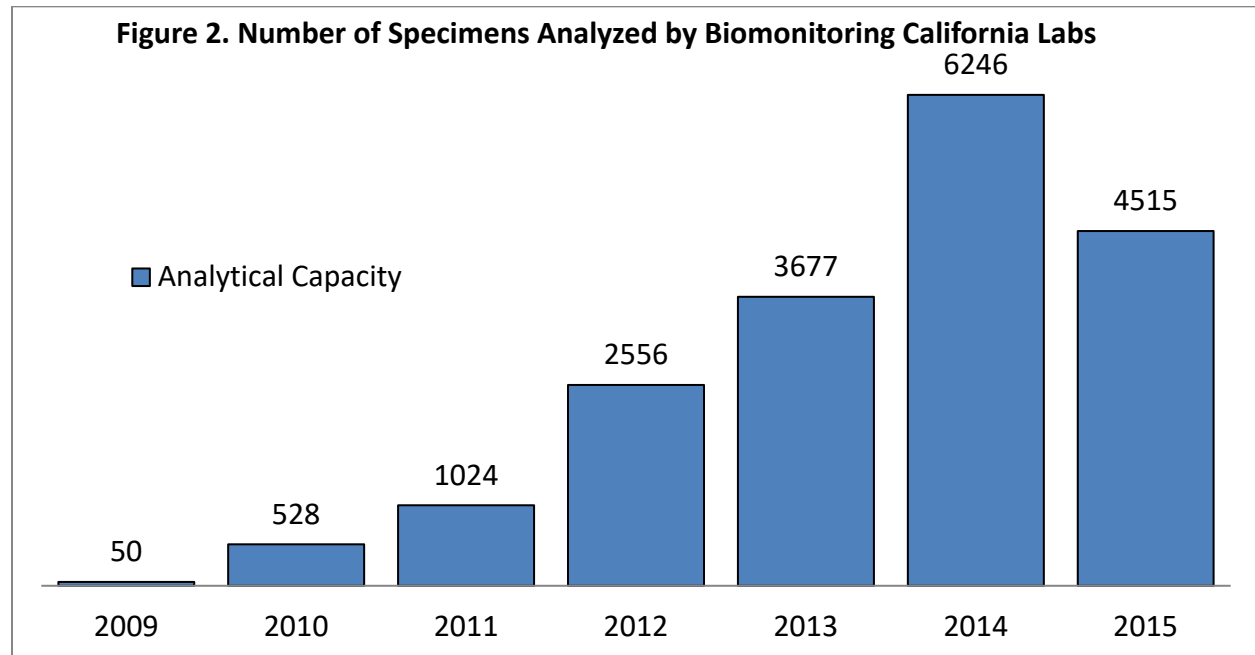
Chemical group	Description of chemicals in the lab panel
Phthalates	Phthalates are added to vinyl to make it soft and flexible. Vinyl products include shower curtains, flooring, and plastic tubing. Phthalates are also used in scented products, coatings like nail polish and paint, and a variety of other consumer products. Phthalates can interfere with the body's natural hormones and affect development and 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.
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.
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 may increase cancer risk. Biomonitoring California measures PAH metabolites in urine.

When the First Report to the Legislature was prepared, the Program had only begun to analyze specimens as part of the process of validating newly developed methods. As reported in the Second Report to the Legislature, the Program had rapidly expanded to conduct more than 1,500 analyses during 2010-2011 (Figure 2). The Program's analytical capacity⁵ saw unprecedented growth from 2012-2014 but then trended downward in 2015 when the first CDC cooperative agreement ended.

During the two-year period covered by this report (2014-2015), Biomonitoring California conducted more than 10,000 biomonitoring analyses for potentially toxic chemicals or their

⁵ Analytical capacity refers to the number of specimens the lab can analyze during a given time period. A single blood or urine sample may yield several specimens for analysis for different chemical classes

breakdown products, including heavy metals, flame retardants, phthalates, and pesticides. Overall, the larger relative number of analyses over these two years are due to the use of archived samples and limiting the analyses to only two panels (metals and PFCs), which allows for a faster turnaround time.



Outreach, Communication, and Public Participation Activities

H&SC Section 105451 directs Biomonitoring California to “provide opportunities for public participation and community capacity building” to allow for “meaningful stakeholder input” and to “develop a strategy and plan ... to establish the framework for integrating public participation in this program.” 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 biomonitoring.ca.gov/public-involvement.

Communicating Biomonitoring Results

A distinctive feature of the Program is the statutory requirement to return biomonitoring results to study participants who request them (H&SC Section 105443), even if the health implications of these results are scientifically uncertain. This poses a challenge for the Program to interpret biomonitoring results and convey their potential health implications to individuals, particularly when a particular chemical’s toxicity in humans has not been well studied.

To meet the results communication challenge, the Program has developed a standard template to return results to participants,⁶ offered in both English and Spanish. The template includes a cover letter, a project description page, individual results for chemical levels with comparison values and a text explanation, and chemical-specific fact sheets. The chemical-specific fact sheets, available online at biomonitoring.ca.gov/chemicals/fact-sheets, briefly summarize the sources of chemicals in the environment, possible health concerns, and possible ways to reduce exposure. Between 2012 and 2015, the Program provided results packets to the more than 600 participants who requested them. As part of the BEST study, the Program collected participant feedback on the packets through survey and interviews. Participant feedback on the packets has been positive.

In August 2015, Program staff gave a webinar hosted by the Association of Public Health Laboratories (APHL), detailing Biomonitoring California’s results communication approach. A special session on best practices for biomonitoring results return was held at the November 2015 SGP meeting (biomonitoring.ca.gov/events/biomonitoring-california-scientific-guidance-panel-meeting-november-2015).

⁶ biomonitoring.ca.gov/sites/default/files/downloads/Cover%20letter%20and%20Mock%20EBEST%20packet.pdf

Further details on the Program's efforts to effectively communicate biomonitoring results can be found in a new section of the website, available at:

biomonitoring.ca.gov/results/communicating-results.

Program Website

The Program continues to expand and improve the website (biomonitoring.ca.gov) as an important tool for public outreach. In April 2014, the Program launched an interactive results database that includes summary biomonitoring results from Biomonitoring California projects. The database is available online at biomonitoring.ca.gov/results/explore. Users can customize the display of the results from the database by choosing projects, chemical groups, or individual chemicals. The customized results can easily be printed or exported as a Microsoft Excel file. A glossary was added to define the terms used in the results database and elsewhere on the website. During 2015, the Program expanded the Spanish content on the website, with new translations of project pages, chemical pages, and chemical-specific fact sheets.

Other ongoing public involvement activities include maintenance of a listserv with 1076 active subscribers as of December 2015. 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. In 2015, the format for listserv notes was modified to optimize viewing on mobile devices.

Publications

The following scientific articles were published in 2014-2015. For more information, visit biomonitoring.ca.gov/biomonitoring-california-publications.

- Brown FR, Whitehead TP, Park J-S, Metayer C, and Petreas MX. Levels of non-polybrominated diphenyl ether brominated flame retardants in residential house dust samples and fire station dust samples in California. *Environmental Research* 2014; 135, 9–14.
- Dobraca D, Israel L, McNeel S, Voss R, Wang M, Gajek R, Park J-S, Harwani S, Barley F, She J, Das R. Biomonitoring in California firefighters: Metals and perfluorinated chemicals. *J Occup Environ Med*. Jan 2015; 57(1): 88–97.
- Fan R-F, Wang D-L, She J. Method development for the simultaneous analysis of trans, trans-muconic acid, 1, 2-dihydroxybenzene, S-phenylmercapturic acid and S-benzylmercapturic acid in human urine by liquid chromatography/tandem mass spectrometry. *Analytical Methods* 2015; 7, 573 – 580.
- Gavin QW, Ramage RT, Waldman JM, She J (2014). Development of HPLC-MS/MS method for the simultaneous determination of environmental phenols in human urine.

Intern J Environ Anal Chem 94(2):168-182 doi: 10.1080/03067319.2013.814123 Epub: 09 Jul 2013.

- Guo W, Nelson D, Hurley S, Reynolds P, Guo T, Wang M, Park J-S, Petreas M. Pilot study to assess effects of collection tube types and processing delay on measurements of persistent organic pollutants and lipids in human serum. *Chemosphere* 2014; 116:75-82.
- Park J-S, Voss RW, McNeel S, Wu N, Guo T, Wang Y, Israel L, Das R, Petreas M. High exposure of California firefighters to polybrominated diphenyl ethers. *Environ. Sci. Technol.*, 2015 Mar 3; 49(5):2948-58. doi: 10.1021/es5055918. Epub 2015 Feb 18.
- Petropoulou SSE, Duong W, Petreas M, Park J-S. 2014. Fast liquid chromatographic-mass spectrometric method using mix-mode phase chromatography and solid phase extraction for the determination of 12 mono-hydroxylated brominated diphenyl ethers in human serum. *Journal of Chromatography* 2014; A 138-147.
- Sen I, Zou W, Alvaran J, Nguyen L, Gajek R, She J. Validation of a simple and robust method for arsenic speciation in human urine using HPLC-ICP-MS. *J AOAC International* 2015; in press.
- Whitehead TP, Crispo-Smith S, Park JS, Petreas MX, Rappaport SM, Metayer C. 2015. Concentrations of persistent organic pollutants in California women's serum and residential dust. *Environmental Research* 2015; 136:57-66.
- Zota AR, Linderholm L, Park J-S, Petreas M, Guo T, Privalsky ML, Zoeller RT, Woodruff TJ. Correction to: A temporal comparison of PBDEs, OH-PBDEs, PCBs, and OH-PCBs in the serum of second trimester pregnant women recruited from San Francisco General Hospital, California. *Environ. Sci. Technol.* 2014; 48. 2512–2513.

Collaboration

The Program's partners and collaborators include community groups, scientists, and other State of California departments. Collaborating organizations include:

- APA Family Support Services
- Breast Cancer Fund
- Cancer Prevention Institute of California
- California Conference of Local Health Officers
- DTSC, California's Green Chemistry Initiative Program
- Centers for Disease Control and Prevention
- Center for Environmental Research and Children's Health
- CDPH, California Environmental Health Tracking Program
- CDPH, Childhood Lead Poisoning Prevention Branch
- CDPH, Genetic Disease Screening Program
- CDPH, Occupational Health Branch

- Child Health and Development Studies
- Environmental Working Group
- Green Science Policy Institute
- Kaiser Permanente Division of Research
- Lao Seri Association – Laotian Community Services
- Natural Resources Defense Counsel
- OEHHA, CalEnviroScreen Program
- Sierra Streams Institute
- Silent Spring Institute
- Stanford University
- UC Berkeley
- UC Davis
- UC Irvine
- UCLA
- UCSF
- Vietnamese Family Services
- Zero Breast Cancer

Conclusions

Biomonitoring California has been building laboratory capabilities and capacity and other elements of a robust state biomonitoring program since the Program’s inception. This effort has begun to generate data that helps assess the effectiveness of current public health and chemical policy in California. Examples of important findings made possible by Biomonitoring California’s efforts include:

Pilot and Expanded BEST

- Higher levels of arsenic were found in both the Pilot and Expanded BEST populations compared to the general US population.

Expanded BEST

- Arsenic and cadmium (measured in urine) and lead (measured in blood) were detected in 100% of the samples analyzed; mercury was detected in the blood of 99.7% of the samples.
- Women had higher blood levels of cadmium compared to men, but lower levels of lead.

- Asian/Pacific Islanders generally had higher levels of mercury in their blood compared to other race/ethnic groups.
- Both Black and Asian/Pacific Islander participants had higher levels of cadmium in urine, compared to White participants.

Factors potentially contributing to these differences, including lifestyle, diet, and country of birth, are being investigated.

MAMAS Study

- PFC levels measured in archived samples from pregnant women in 2012 are consistent with levels found in the US population.
- Archived serum samples collected through the State prenatal screening program provide a feasible and efficient means of biomonitoring a limited set of chemicals in a statewide sample of pregnant women.

Since 2006, the Program's inception, Biomonitoring California has:

- Expanded the biomonitoring capability of the CDPH and DTSC laboratories to measure over 160 chemicals or their metabolites, across 14 chemical classes.
- Dramatically increased capacity for chemical analyses to at least 4000 per year.
- Launched five full project collaborations and participated in fourteen laboratory collaborations.
- Launched the first major study using archived samples, which approximates a statewide representative sample. Although limited to pregnant women who participate in the State's prenatal screening program, the MAMAS study offers opportunities to measure exposures across different regions of the state.
- Fulfilled the mandate to return individual biomonitoring results in an understandable way to participants upon their request.
- Launched a new online interactive results database to quickly provide public access to study results as they become available.

Biomonitoring as Public Health Practice

Biomonitoring is an important public health function. It provides a measure of potentially toxic chemical exposures that may adversely affect the health of the general population; people living in communities impacted by particular industries/pollutants; and in vulnerable sub-groups, such as pregnant women, children, and workers.

Biomonitoring California's analyses provide important data that can help evaluate prevention activities in California. The Program's studies also identify highly exposed or vulnerable

populations such as: disadvantaged communities with specific exposure concerns; workers with potential exposures to chemicals not typically monitored in the workplace; and sensitive populations like pregnant women and infants.

Biomonitoring California has achieved its status as a recognized national leader among state biomonitoring programs by leveraging state and federal resources and building key partnerships around the state.

For more information, contact:

Environmental Health Investigations Branch
California Department of Public Health
850 Marina Bay Parkway, Building P-3
Richmond, CA 94804
510-620-3620

This report is available online at biomonitoring.ca.gov/biomonitoring-california-reports.

Appendix A: Program Structure

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 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, and epidemiology. General roles and staff responsibilities for Biomonitoring California are listed below and shown in Figure A1.

Figure A1. Biomonitoring California Departmental Roles and Lead Responsibilities

DTSC Environmental Chemistry Laboratory	CDPH Environmental Health Laboratory	CDPH Environmental Health Investigations Branch	OEHHA Reproductive and Cancer Hazard Assessment Branch
<ul style="list-style-type: none"> • Laboratory analyses of blood samples for persistent chemicals that accumulate in people • Quality assurance and interpretation of laboratory data • Broad screening to identify new chemicals of emerging concern in California 	<ul style="list-style-type: none"> • Laboratory analyses of blood samples for metals and urine samples for metals and <u>non-persistent</u> chemicals • Quality assurance and interpretation of laboratory data • Processing and long-term storage of blood and urine samples • Broad screening to identify new non-persistent chemicals of concern in California • Management of analytical results and sample information using Laboratory Information Management System 	<ul style="list-style-type: none"> • 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 	<ul style="list-style-type: none"> • 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 and protocols for evaluating elevated levels • Outreach to the public, including updates and improvements to the Program website

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 the laboratory's test results; (6) communication of test results to participants and dissemination of information to the public; (7) generation of the biennial reports; and (8) coordination of the CDC cooperative agreement

OEHHA has primary responsibility for: (1) administering and supporting the SGP; (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 test 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: 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, including those not yet identified.

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 and senior scientists 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 mandated in SB 1379 (H&SC Sections 105448 and 105449), 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 Biomonitoring California. 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: biomonitoring.ca.gov/scientific-guidance-panel.

The Panel met six times during 2014-2015, 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: 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 as an open public comment period at the end of the meeting. Attendees participating in the meeting via the Internet are able to 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. These are referred to as "designated chemicals," which is the entire pool of chemicals that can be considered for inclusion in Biomonitoring California projects (biomonitoring.ca.gov/chemicals/designated-chemicals). The SGP can also recommend chemicals as priorities for biomonitoring in the state (biomonitoring.ca.gov/chemicals/priority-chemicals). The Panel provides feedback on the design and implementation of Program projects, as well as advice to the laboratories. The SGP gives input on results return materials for participants, website development, and future Program activities. The Program also seeks input from the SGP on special topics, and invites outside experts for a richer discussion. Special topics during 2014-2015 included best practices for biomarker collection, analysis, and interpretation; approaches for biomonitoring exposures to diesel exhaust; and how best to apply biomonitoring in efforts to improve the safety of consumer products.

Chemical selection activities in 2014-2015 included consideration by the SGP of various metals and two chemical classes as designated or priority chemicals, based on criteria related to exposure, health concerns and feasibility. At the March 2014 SGP meeting, the Panel recommended that chromium be added to the list of designated chemicals. The Panel also named antimony, beryllium, cobalt, manganese, molybdenum, thallium, tungsten, and uranium as priority metals for biomonitoring. In 2015, the Panel recommended two classes of chemicals for addition to the list of designated chemicals and also as priorities for biomonitoring in California: perfluoroalkyl and polyfluoroalkyl substances (PFASs) and ortho-phthalates.

Appendix B: Past Projects and Collaborations

Completed Projects:

The **Maternal and Infant Environmental Exposure Project (MIEEP)**, a study of 92 pregnant mothers and their infants in San Francisco, is complete, with scientific publications in development. MIEEP, also known as the Chemicals in our Bodies Project, was a collaborative study involving Biomonitoring California, the UC San Francisco (UCSF) Program on Reproductive Health and the Environment (PRHE), and the UC Berkeley (UCB) School of Public Health. This study was partially supported by the CDC cooperative agreement. Biomonitoring California measured environmental chemical exposures in 65 mother-infant pairs and an additional 27 pregnant women. English- and Spanish-speaking pregnant women were recruited at San Francisco General Hospital (SFGH) in 2010-2011. Urine samples and questionnaire information were collected in the third trimester of pregnancy, and maternal and umbilical cord blood samples were collected at delivery. This study was completed in 2013. For more information on this study, visit biomonitoring.ca.gov/projects/maternal-and-infant-environmental-exposure-project-mieep.

Among the major accomplishments of MIEEP were the following:

- Blood and urine samples from mothers were analyzed for 92 chemicals. Samples from infant cord blood were tested for 59 chemicals.
- Mothers received their results in 2012 and 2013, and were offered suggestions in English and Spanish on how to reduce exposures.
- Infant cord blood was found to contain up to 50 of the 59 chemicals that were biomonitored. Certain chemicals, including flame retardants, were found at higher levels in infants than in their mothers.
- Results from MIEEP suggest that levels of certain flame retardants banned in California in 2006 (Assembly Bill [AB] 302, Chan, 2003 & AB 2587, Chan, 2004) are declining in the population, providing support for California's public health policies.
- The Program identified a family with significantly elevated mercury levels in 2011. The pregnant mother had been using foreign-made skin-lightening creams adulterated with mercury. This led to a public health alert to medical providers and a subsequent follow-up study within CDPH to analyze skin-lightening products for mercury and other harmful contaminants.

Biomonitoring California, along with UCSF and UCB collaborators, will continue to evaluate MIEEP results for associations between chemical exposures and future health outcomes.

The **Firefighter Occupational Exposures (FOX) Study** of 101 firefighters in Southern California, is complete with regard to the original proposed work. The Program is planning to measure OP flame retardants in archived FOX urine samples. Firefighters are exposed to toxic chemicals in their work environment more frequently and at higher levels than the general population. The FOX study was

conducted in partnership with the UC Irvine's (UCI) Center for Occupational and Environmental Health and a Southern California Fire Authority. It was partially supported by the CDC cooperative agreement. During the course of this study, completed in 2013, Biomonitoring California collected questionnaire information from 101 firefighters in Southern California, and tested their blood and urine samples. The protocols and procedures developed in this pilot study will serve as a basis for subsequent biomonitoring efforts in occupational groups. For more information on the FOX Project, visit biomonitoring.ca.gov/projects/firefighter-occupational-exposures-fox-project.

Among the study's major accomplishments were the following:

- Blood and urine samples were analyzed for more than 80 distinct chemicals. All participants who requested their individual results received them in 2012 and 2013. (New results from OP flame retardant analyses will also be returned to participants who previously requested their individual results and donated their samples for further study).
- Firefighters' urine levels of BP-3 were significantly higher than the levels reported for the general population. BP-3, a chemical used as a sunblock in lotions and cosmetics and as an ultraviolet-light stabilizer in plastic surface coatings, may interfere with the activity of essential hormones (estrogen and testosterone). A manuscript describing these findings has been submitted.
- Very high levels of polybrominated diphenyl ether (PBDE) flame retardants were measured in all firefighters, particularly those with classifications consistent with front-line firefighting activities. Use of personal protection (such as a self-contained breathing apparatus) during firefighting and salvage operations, and proper cleaning and maintenance of firefighting gear were associated with lower serum PBDE levels, pointing to the efficacy of health and safety procedures.
- As part of a larger study on contaminants in house dust, dust samples were collected from several fire stations. Dust was analyzed for some of the same chemicals biomonitoring in firefighters. Levels of PBDEs (and in particular, decaBDE) in fire station dust were much higher than in dust similarly collected from hundreds of California homes.

Completed Laboratory Collaborations

The following six laboratory collaborations have been completed. For more information and description of these collaborations, visit the links to the Program's website for the specific projects below:

1. Center for the Health Assessment of Mothers and Children of Salinas. The Program analyzed phthalates in urine samples from 5-year-old children living in an agricultural community in the Salinas Valley (biomonitoring.ca.gov/projects/center-health-assessment-mothers-and-children-salinas-chamacos).
2. Cohort of Young Girls' Nutrition, Environment, and Transitions. The Program analyzed 500 blood samples for metals for a study of teenagers and young girls in the San Francisco Bay Area

biomonitoring.ca.gov/projects/cohort-young-girls-nutrition-environment-and-transitions-cygnet).

3. Markers of Autism Risk in Babies – Learning Early Signs. The Program analyzed phthalates in urine samples from pregnant women who already have an autistic child (biomonitoring.ca.gov/projects/markers-autism-risk-babies-learning-early-signs-marbles).
4. Pesticide Drift 2 Study. The Program analyzed urine samples from adults and children for pesticides for a study of individuals living in a rural agricultural community in Tulare County (biomonitoring.ca.gov/projects/pesticide-drift-2-study).
5. UCSF Studies 1 and 2 of Second-Trimester Pregnant Women. UCSF collected samples from women seeking care at SFGH in 2008-09 (n = 25 pregnant women) and 2011-12 (n = 36 pregnant women). Biomonitoring California analyzed blood samples for PFCs and other persistent organic pollutants, including PCBs, OCPs, PBDEs, and hydroxy-PCBs and hydroxy-PBDEs. For more information on this study, visit biomonitoring.ca.gov/projects/ucsf-studies-second-trimester-pregnant-women.
6. Women’s Health and the Environment (collaboration with UC Irvine). Women’s Health and the Environment (WHE) is being conducted by researchers at the UCI Center for Occupational and Environmental Health. Biomonitoring California analyzed 150 samples for creatinine and PAHs. The purpose of this collaboration is to examine a possible link between environmental contaminants and ovarian dysfunction, which is a major cause of infertility. For more information on this study, visit biomonitoring.ca.gov/projects/womens-health-and-environment-whe.