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# Biomonitoring: The Chemicals Within Us

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Jane Chase lived next to a national wildlife sanctuary on Cape Cod for 50 years. She thought it was a healthy place to live, until she was diagnosed with two kinds of breast cancer. Then Jane and other women in her cancer support group began to wonder if their cancers "could have been sparked by something in the air, the water—or even their own homes."



**Biomonitoring finds chemicals in nearly everyone tested.**

Jane had an opportunity to take part in a study conducted by the Silent Spring Institute and Brown University. The study tested indoor air and dust samples from 120 homes in Cape Cod, and urine samples from their residents. It found many chemicals that are suspected of affecting human hormones. These chemicals can cause developmental, reproductive, and neurological problems and can increase the risk of certain cancers.

Researchers could not tell Jane if any of these chemicals contributed to her cancers. Nevertheless, she wanted to know which chemicals were found: "The more we know about what's in our environment, both indoors and outdoors, the more precautions we can take."

The links—from chemicals in our environment to health problems like cancer—are difficult to determine. Biomonitoring is one of the tools that help us research these links. Exploring the uses of biomonitoring, and its limitations, is the focus of this Perspectives issue.

> ***EWG tested 10 Americans, and found more than 200 synthetic industrial chemicals in their blood…. Their chemical exposures did not come from the air they breathed, the water they drank, or the food they ate. They were not exposed at work or at school [or from] personal care products or cleaning agents they used. How do we know? These 10 Americans were newborns. The chemicals we found in their umbilical cord blood crossed the placenta to contaminate the babies before birth.***
>
> —*Kenneth Cook, Environmental Working Group (EWG)*

*When there was an accidental mercury spill in a Massachusetts middle school in 2008, state public health officials used biomonitoring to test for mercury. They were able to identify those students and staff who needed special medical attention. The testing also helped allay the fears of those who were not exposed.*

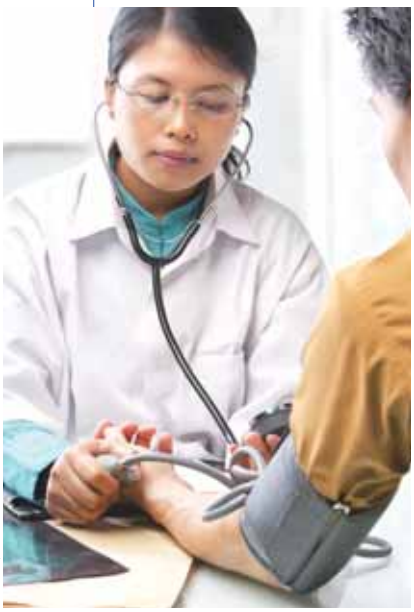
*—Scott Hendrick and Doug Farquhar, National Conference of State Legislatures*

## Chemicals and Health Risks

In addition to pesticides and prescription drugs, nearly 100,000 chemicals are registered for use in the US. Very few are adequately tested for safety before they are put into use. Many of these chemicals are pervasive, finding their way into our air, water, food, soil, and dust. They are in many products that people use daily, including food containers, furniture, electronics, and cosmetics.

There is growing evidence that chemical exposure is a significant risk factor for many chronic diseases. Researchers at the University of California, San Francisco and the Boston Medical Center documented 182 human diseases and health problems associated with chemical exposures (Collaborative on Health and the Environment database). The rising national rates of asthma, cancer, infertility, obesity, autism, and other diseases and developmental disorders add urgency to research on chemical exposure.

Young children and pregnant women are particularly vulnerable to these risks. Because young children's organs are developing, chemical exposures can have significant long-term effects. Because children are smaller than adults, their chemical levels may be higher relative to their weight. And the hand-to-mouth behavior of young children increases exposure.



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**Exposure to lead can cause high blood pressure, heart and kidney disease, and other health problems.**

Some chemicals, including lead and mercury, can cause brain damage and developmental problems in children. Some chemicals can increase the risk of developing chronic illnesses such as cancer or heart disease later in life. Endocrine-disrupting chemicals such as pesticides and flame retardants may cause developmental and reproductive problems.

## Biomonitoring Fills a Knowledge Gap

Biomonitoring measures the amount of a chemical or its breakdown products in blood, urine, hair, and other body fluids or tissues. It allows scientists to assess the chemicals that actually get into people from many sources. As technological advances allow more chemicals to be detected at lower levels, the use of biomonitoring is increasing.

Researchers can use biomonitoring data to strengthen the investigation of possible links between chemicals and disease:

- Combined with information from other sources, such as cancer and birth defect registries, biomonitoring is an important component of environmental health tracking—the ongoing monitoring of environmental exposures and related health hazards.
- Combined with studies of chemical toxicity, biomonitoring helps researchers identify the chemicals that are of greatest concern for human health.

Biomonitoring also provides important information for government programs responsible for protecting public health and regulating chemical emissions. It can tell us how well policies to reduce exposure are working. It can also identify disparities in exposure and help public health officials prioritize actions to reduce exposure.

**Scientists can test for hundreds of chemicals in blood and urine.**

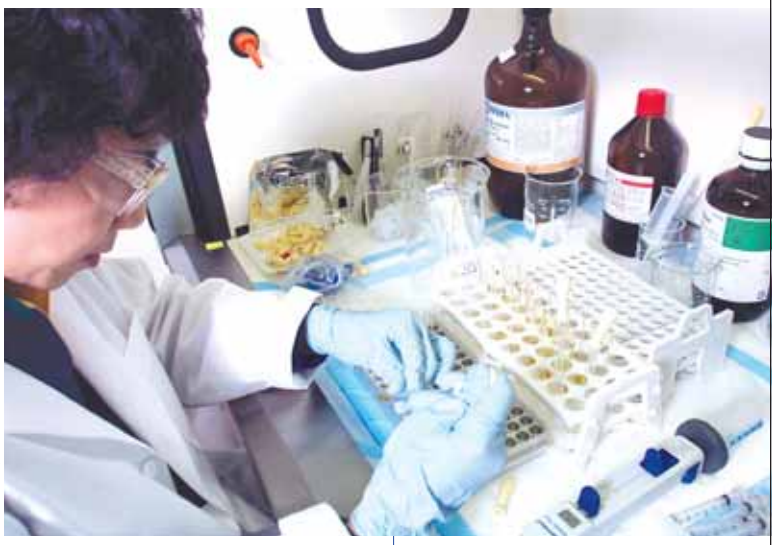

Photo courtesy of CDC

## Biomonitoring in the US

The largest biomonitoring program in the nation is conducted by the US Centers for Disease Control and Prevention (CDC) through the National Health and Nutrition Examination Survey (NHANES). The 2010 Fourth National Report on Human Exposure to Environmental Chemicals is the most comprehensive biomonitoring effort in the survey's 10-year history. It reported the results of 212 chemicals measured in the blood or urine of thousands of participants.

NHANES findings show that chemical exposures are widespread among Americans. The ubiquity of exposure and the ineffectiveness of existing US chemical policies have led to efforts to reform these policies. A primary focus of reform efforts is the Toxic Substances Control Act of 1976. Under this act, the burden is on government agencies to show that a chemical causes health problems. Often, chemicals are already in widespread use by the time such evidence is available.

Proposed federal legislation would hold manufacturers more accountable for the safety of chemicals. For example, draft legislation would require manufacturers to provide more data on chemicals and require the US Environmental Protection Agency to prioritize the regulation of chemicals to reduce exposures to chemicals of high concern.

### Common Sources of Chemical Exposures and Their Health Effects

| Chemical | Source | Health Effects |
|---|---|---|
| **Lead** | Peeling paint in older homes<br>Metal water pipes in old homes<br>Jobsites in painting, construction, battery recycling, and radiator repair<br>Consumer products (some old or imported pottery, toys, costume jewelry, art supplies, hair dyes) | Learning and behavior problems in children<br>Impaired thinking, reasoning and memory in adults<br>High blood pressure, heart disease<br>Kidney disease<br>Reproductive problems<br>Low birth weight |
| **Mercury** | Eating contaminated fish<br>Broken thermometers | Impaired nervous system<br>Learning disabilities |
| **Pesticides** | Bug and weed killers used in homes, yards, farming, and landscaping<br>Products to kill head lice<br>Products to kill fleas on pets<br>Termite and mosquito control | Cancer<br>Hormonal changes<br>Reproductive problems<br>Impaired nervous system<br>Kidney and liver damage |
| **Bisphenol-A (BPA)** | Some plastics<br>Linings of food containers and cans | Cancer<br>Reproductive problems<br>Hormonal changes |
| **Flame Retardants** | Foam in furniture, car seats, and carpet pads<br>Computers, televisions and other electronics | Reproductive problems<br>Learning, memory, and behavior problems<br>Hormonal changes |

***Nearly 600 girls in California and Ohio taking part in a study of pubertal development were tested for hormonally active chemicals, including PBDE flame retardants. Four of the PBDE chemicals were found in nearly all of the participants; these flame retardant levels were, on average, 35-40% higher in girls in California than in Ohio. The higher PBDE levels in California likely reflect differences in fire codes.***

*—Gayle Windham et al., CYGNET Study Team*

*The CHAMACOS study found one or more pesticides in over 78% of the women who participated. Six of the pesticides were present at levels significantly higher than the national averages.*

*—Rosemary Castorina et al., University of California, Berkeley*

## Biomonitoring California

The NHANES represents the overall US population, and cannot be used to generate state- or community-specific information. Increasingly, states are conducting their own biomonitoring studies and using CDC data for comparison.

In 2006, California established Biomonitoring California—the first statewide biomonitoring program in the nation. When fully implemented, this program will provide ongoing data obtained from representative samples of the state's residents. It will also provide information on the effectiveness of regulatory efforts to decrease people's exposure to specific chemicals.

In 2009, California was one of three states to receive funding from the CDC to enhance laboratory capacity for biomonitoring and refine methods before launching statewide programs.

State-level biomonitoring programs can focus on chemicals of special interest and monitor the effects of state laws and regulations. They can use their biomonitoring data to guide public health policies. States, compared with national agencies, can better identify and track exposure trends in specific populations—such as infants and children, pregnant women, workers in selected occupations, and communities with known chemical exposures.

Like programs in other states, Biomonitoring California is building its capacity by conducting pilot projects in selected communities and populations. These projects are developing and testing procedures and laboratory methods, and identifying potential exposure sources. They are also testing strategies for communicating results to study participants and other stakeholders.



**The drift from pesticide spray can affect farmworkers and residents. The CHAMACOS study found that prenatal exposure to pesticides may have health impacts in later years, including lower IQ.**

One example is the Chemicals In Our Bodies Project, which Biomonitoring California is conducting with researchers at the University of California, Berkeley and San Francisco. This project will study chemical exposures among two highly vulnerable populations—pregnant women and newborn infants.

Other California researchers are carrying out regional studies independent of Biomonitoring California. An example is the Center for Environmental Research & Children's Health at the University of California, Berkeley, which has been assessing the health of mothers and children through the CHAMACOS project. This project has been working with residents in the Salinas Valley for many years to study the effects of ongoing exposure to pesticides and other chemicals on the health of pregnant women and their children.

Community-based projects like these allow researchers to test hypotheses and study vulnerable groups. Such projects can complement and inform statewide and national studies. And they are often of great interest to affected communities, especially when results and prevention strategies are shared.

*Among women in the CHAMACOS study, over 70% currently request their biomonitoring results. Many women in the study also want their spouses present when they receive their results.*

## Biomonitoring and the Public

As biomonitoring expands, explaining it to a broad audience becomes critical. Biomonitoring California's mandate includes educating the general public—as well as study participants and policymakers. This raises many challenges:

**Explaining uncertainties.** There is still much to learn about the ways that chemicals get into the environment and people's bodies, their short- and long-term effects, and the complex causes of disease.

**Explaining new terms and complicated science.** Biomonitoring is a relatively new area of learning for the general public, full of scientific complexities and the technical jargon of toxicology, epidemiology, statistics, and other fields.

**Reducing misinterpretation.** People may misinterpret data, particularly when they feel a lack of control over exposure and uncertainty about possible health effects. For example, some scientists have been concerned that, without additional guidance, learning that there are chemicals in their breast milk might affect some mothers' decisions to breastfeed.[1]

**Providing appropriate advice.** "Safe" exposure levels have not been established for many chemicals and advice on reducing exposure is limited and controversial.

Information about risk is often difficult to explain and understand, and it is especially challenging for people with lower literacy and numeracy skills.

The average American reads between the 7th and 9th grade levels. Literacy levels are even lower among older adults, people with lower incomes, and those whose first language is not English. In addition, more than half of US adults have trouble with numeracy—the knowledge and skills required to understand and use basic mathematics.

An important goal for biomonitoring programs is to enhance "biomonitoring literacy" by providing participants and the lay public with transparent, accessible, useful, and comprehensive information while making scientific uncertainties clear.

## Reporting Participant Results

Because of the challenges listed above, many studies have not reported biomonitoring results to participants. However, many advocates and researchers maintain that participants have a right to know what is in their bodies. When participants have been given the choice, most have wanted to receive their results.

Biomonitoring California is required by law to give participants their results if they want them. Results must be provided in appropriate languages and formats.

Studies have found that participants can better understand their results when they have been well prepared beforehand. Such orientation should include an explanation of the purpose of the project. It should introduce the science and limitations of biomonitoring, and provide guidance to reduce misinterpretation. Participants should also be alerted that chemicals will be found in nearly everyone in the project.

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**Many study participants are concerned about protecting their children from exposure to harmful chemicals.**

[1] Some studies have shown that awareness of chemical exposures has not affected breastfeeding decisions. See Wu et al. in References.

Health Research for Action recently conducted focus groups with parents of girls enrolled in the Cohort Study of Young Girls' Nutrition, Environment, and Transitions (CYGNET) to determine their preferences for receiving their daughters' biomonitoring results. The CYGNET Study is examining how environmental, genetic, and other factors affect the timing of puberty. Early puberty is a risk factor for breast cancer. Parents wanted as much information as possible, even when the implications of their daughters' biomonitoring results were unknown. They wanted the results in written and graphic formats that were easy to read and understand.

In the Chemicals In Our Bodies project with pregnant women and their newborns, the authors are working with participants to develop and evaluate report-back materials. The process brings together experts in environmental health, risk communication, health literacy, and health education. The goal is to increase the understandability and relevance of the results, and to produce a model for use in future Biomonitoring California projects.

## Applying Health Literacy Best Practices

Research in the field of health literacy and health communication has created a set of best practices. The following practices can help us meet the challenges of explaining biomonitoring and reporting results.

**Assess audience knowledge, understanding, and needs.** Use focus groups and individual interviews to find out what people already know about the topic in question (their knowledge base), what they want to learn, and how they want to receive this information.

**Write at or below the average reading level of the audience.** Explain concepts clearly and minimize technical language.

**Supplement written materials with pictures and other visuals.** Simplify graphs and explain how to interpret them.

**Develop and test report-back materials with the intended audience.** Iteratively assess readability, usefulness, and appeal of materials through readability and usability tests. Readability tests use specialized software to determine the grade level of written materials. Usability tests involve structured one-on-one interviews with sample users to determine whether they can understand materials and act on the information.

**Supplement written materials with in-person communication.** Conduct one-on-one meetings to address participants' concerns. Host discussions between researchers and study participants to provide an opportunity for group learning. Convene community meetings to share overall results with interested members of the larger community, and brief policymakers and advocates on the findings.

**Evaluate the effectiveness and impact of education and outreach efforts.** Use focus groups, surveys, and interviews to evaluate the report-back process and improve future communication strategies and materials.

## Prescription for Change

There is increasing demand by policymakers and the public for concrete information on the health effects of environmental chemicals.

Biomonitoring helps scientists and public health officials learn about the levels of chemicals and the patterns of exposure. As a society, we need

### Revising Text for People with Average Literacy

**The paragraph below is representative of a larger document that tested at a high reading level:**

*The presence of an environmental chemical in people's blood or urine does not mean that it will cause effects or disease. The toxicity of a chemical is related to its dose or concentration, in addition to a person's individual susceptibility. Small amounts may be of no health consequence, whereas larger amounts may cause adverse health effects.*

**Shortening sentences, explaining difficult concepts, and using more common words, results in a paragraph written at a 7th to 9th grade reading level:**

*Having certain chemicals in your blood or urine does not mean that the chemicals will cause a disease or another problem. Some chemicals are toxic. This means that they can cause health problems. Small amounts of these chemicals may not effect your health, but larger amounts might cause problems. Some people are more sensitive to certain chemicals than other people. They are more likely to be harmed.*


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**Getting input from participants about what they want to know will help them understand their biomonitoring results.**

this information in order to assess and prevent health risks. Our task is formidable: to study hundreds of chemicals in diverse populations with varied patterns of exposure. To achieve this goal, the authors recommend the following actions:

1. **Build biomonitoring infrastructure.**
   - Expand laboratory testing, analysis, and storage capacities.
   - Pilot study protocols in a variety of communities and populations to test and refine sampling methods.
   - Develop ongoing collaboration among public health scientists in state biomonitoring and disease surveillance programs, disease registries, environmental agencies, academic institutions, and nongovernmental organizations.
   - Develop research-based standards for report-back materials and their language and cultural adaptations.
2. **Disseminate basic information and results to researchers, study participants, policymakers, and the public.**
   - Conduct formative research to find out what people know and want to know about chemical exposure.
   - Involve participants in the development of biomonitoring study design and communication strategies.
   - Use the principles of health literacy and clear communication to develop, test, and evaluate communication materials.
   - Share findings of biomonitoring projects with state, academic, and nongovernmental organizations, health care providers, and community groups.
3. **Secure resources.**
   - Develop stable funding for biomonitoring programs. In some states, successful public health and environmental regulatory programs (such as lead abatement and hazardous waste disposal) are funded through small fees.
   - Identify extramural sources to supplement limited public funding. Both governmental and private funds are needed for targeted studies of vulnerable populations, for report-back efforts with affected communities, and for program evaluation.

## Conclusion

There is growing concern that chemical exposures pose risks to health. Chemicals have been linked to increases in developmental problems and chronic illness. These problems can increase health care costs.

Biomonitoring is an essential public health tool. Used with other scientific methodologies, it can help us assess risks from chemical exposures, measure associations with chronic diseases, and understand and prevent adverse health effects. It can provide important data for public health programs, environmental regulatory agencies, and health advocacy organizations.

Helping people understand the uses and limitations of biomonitoring—"biomonitoring literacy"—will strengthen future projects.

When people are better informed, they are more likely to take steps to protect their own and their family's health. And they are more likely to support policies that regulate the use of harmful chemicals and reduce chemical exposures before the public's health is compromised.

***Using strategies to adapt … resources more closely to the needs of population subgroups can improve outcomes. These design principles include matching readability more closely to users' literacy levels and using 'clear communication' formatting criteria, incorporating culturally relevant concepts and graphics, and adapting rather than literally translating material into other languages.***

*—Neuhauser et al., University of California, Berkeley*

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## To Learn More

Biomonitoring California: http://biomonitoring.ca.gov

US Centers for Disease Control and Prevention (CDC), National Biomonitoring Program: http://www.cdc.gov/biomonitoring

National Research Council report, *Human Biomonitoring for Environmental Chemicals*: http://www.nap.edu/catalog.php?record_id=11700

Environmental Health Investigations Branch, California Department of Public Health, Biomonitoring: http://www.ehib.org/topic.jsp?topic_key=101

Commonweal Biomonitoring Resource Center: http://www.commonweal.org/programs/brc/index.html

Center for Environmental Research & Children's Health, UC Berkeley (CHAMACOS Project): http://cerch.org/research-programs/chamacos/

Silent Spring Institute: http://www.silentspring.org

Environmental Working Group: http://www.ewg.org/health

Pollution in People: http://pollutioninpeople.org

References for this article are available on pp. 9-10 of the online version posted at: http://healthresearchforaction.org/perspectives/biomonitoring.pdf

## About Health Research for Action

Health Research for Action is located in the UC Berkeley School of Public Health. Our mission is to conduct research and translate findings from that research into policies, resources, and programs that reduce health disparities and create healthier, more empowered communities. All of our work is conducted in partnership with the people living in these communities.

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