

Biomonitoring: Measuring Environmental Chemicals in the Body

By *Davis Baltz, M.S.*

Biological monitoring (“biomonitoring”) is the direct measurement of chemicals in the body. Chemicals can be measured in many biospecimens, including blood, urine, hair, saliva, nail clippings, meconium, breast milk, and cord blood. Results are sometimes referred to as “body burden.”

Biomonitoring has been in the news frequently in recent months, in part because the field is advancing rapidly as laboratory techniques can detect chemicals in greater numbers and lower concentrations. Several illuminating studies show conclusively that exposure is widespread and virtually universal.

Biomonitoring is valuable for several reasons. It closes gaps in exposure data and establishes chemical exposure trends; identifies highly-exposed populations; expands biomedical, epidemiological, and behavioral public health research; helps assess whether regulations are working and helps set priorities for legislative and regulatory action; and informs first responses to emergencies.

Many, but not all, of the chemicals of concern are persistent, bioaccumulative and toxic (PBT) chemicals. They are persistent in the environment, bioaccumulate in the fatty tissue of wildlife and humans, biomagnify in the food chain, and are toxic in very small doses.

Recent Biomonitoring Studies

A Mt. Sinai School of Medicine study in January 2003 tested nine volunteers who had no history of occupational exposure to industrial chemicals or pesticides. (I was one of the nine people tested.)¹ An average of 91 chemicals was found per participant, including dioxins/furans, PCBs, metals, pesticides, phthalates and volatile organic compounds.

Since 2001, the Centers for Disease Control and Prevention (CDC) has published a National Reports on Human Exposure to Environmental Chemicals every two years, using data collected in the ongoing National Health and Nutrition Examination Survey. The first report in 2001 looked at 27 chemicals, while the second report in 2003 examined 116 chemicals. The third report, released in July of 2005, reported on 148 chemicals in 2,400 blood and urine samples in a cross section of Americans. Future reports will include longer lists (an estimated 310 chemicals in 2007 and 475 in 2009).

In the 2003 report, CDC found that the level of the metabolite of DDT (dichlorodiphenyltrichloroethane), which is DDE (dichlorodiphenyl-dichloroethylene) was three times higher in Mexican Americans than for non-Hispanic white or non-Hispanic black Americans.² DDE levels were clearly measurable in people aged

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12-19, despite the fact they were born after DDT was banned in the U.S. Another provocative finding was that children had twice the level of the organophosphate pesticide chlorpyrifos (Dursban®) than adults.

In CDC's recent 2005 report, it was reported that blood lead levels continue to decline as 1.6 percent of children had blood levels greater than 10 mcg/dl.³ In the 1970s, before lead was phased out of gasoline, 88.2 percent of children exceeded this threshold.

It was also reported that levels of the nicotine metabolite cotinine, associated with second hand tobacco smoke, continued to decline, although African Americans still have exposures twice as high as other groups. These data signal that efforts to reduce smoking in public places are effective in reducing exposure to a harmful chemical in the environment.

For mercury, 5.7 percent of women of childbearing age were within one order of magnitude of 58 mcg/liter, a concentration associated with neurodevelopmental effects in the fetus. The fetus and neonate are the most vulnerable to potentially life-long and irreversible impacts from exposure because their organ systems are still in development.

Two studies by the Environmental Working Group (EWG) have brought troubling data forward. In July 2005, EWG released its report on contamination of cord blood.⁴ The study examined ten cord blood samples from the American Red Cross chosen at random from babies born in August and September 2004. A total of 287 chemicals were found (of the 413 tested), with an average of 200 chemicals per sample, including pesticides, consumer product ingredients and wastes from burning coal, garbage and gasoline. If there was any doubt, this study shows conclusively that the placenta is not an impervious barrier that protects the developing child from environmental contaminants.

The second EWG study from September 2003 tested breast milk of nursing American women for brominated flame retardants.⁵ These chemicals are of high concern because their chemical structure is similar to PCBs. Found in every sample, the average level in first time mothers was 75 times higher than those obtained from testing in Europe, including the highest level ever measured in the U.S. of 1,078 ppb lipid.

Tips of the Iceberg?

Laboratory protocols to detect chemicals in the body only exist for approximately 500 chemicals. By contrast, during these past 60 years, more than 80,000 new synthetic chemicals have been developed and disseminated worldwide, with some 2,000 new chemicals added each year. Chemicals undergo very little scrutiny before approval for use. Of the 62,000 of these chemicals that were in existence when the Toxic Substances Control Act (TSCA) was enacted in the U.S. in 1977, only 2 percent have been fully examined by the Environmental Protection Agency. Of the 18,000

introduced into commerce since that time, no health data have been provided to EPA for 85 percent.⁶

Absence of information is not the same as absence of harm. Of greatest concern are the 2,800 high-production chemicals produced in volumes of more than 1 million pounds per year. These compounds are widely dispersed in homes, schools, communities, consumer products and the environment. The field of biomonitoring is developing against the backdrop that emerging scientific literature shows increasing links between chemicals in the environment and health endpoints.⁷

The new science is important because it is challenging our views of traditional toxicology and the maxim that “the dose makes the poison.” In fact, peer-reviewed studies are showing that low dose effects can appear and cause harm at levels below the previously identified No Observed Adverse Effect Level (NOAEL). Advances in biomonitoring technology are making some of these observations possible.

The chemical bisphenol A (BPA) is in the forefront of interest because of low dose studies. BPA is used to manufacture polycarbonate plastic, and global production now exceeds 6.4 billion pounds per year. It readily leaches from water bottles, metal food can linings and dental sealants, and is found in virtually everyone tested.

Earlier this year, Environmental Health Perspectives published a literature review of 115 BPA studies, of which 94 reported significant low dose effects.⁸ Thirty-one studies with animals reported effects below the predicted “safe” or reference dose of 50 mcg/kg/day.

Timing of Exposure

In addition to low dose, it is increasingly apparent that the timing of exposure can be a critical variable in the impact of chemical exposure, particularly *in utero*. For example, a single exposure to the anti-androgen flutamide caused hypospadias in over 50 percent of rat fetuses exposed on gestational day 17, but none on day 16 and less than 10 percent on day 18.⁹ This research shows that windows of vulnerability during fetal development for specific impacts can be extremely narrow. Current epidemiology would have difficulty detecting these effects.

However, epidemiologists are starting to use biomonitoring data to develop and test new hypotheses for human effects. For example, boys exposed in the womb were at higher risk for anti-androgenic effects of phthalate exposure on the developing male reproductive tract.¹⁰ The study tested seven parent phthalate compounds. Metabolites of three of them were correlated to smaller ano-genital index (AGI) measurements than normal. In addition, boys exposed to multiple phthalates simultaneously were also more likely to have smaller AGI measurements, including a greater likelihood to experience incomplete testicular descent. In fact, levels of phthalates associated with the observed AGI reductions are found in 25 percent of American women. The study builds on animal research about the “phthalate syndrome” showing a cluster of effects

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including demasculinization of the male reproductive tract, an increase in cryptorchidism, and, in adulthood, lowered sperm counts and testicular tumors.

One take-home message from the new science is that a new paradigm is needed to assess risk. The dose no longer always makes the poison, as timing of exposure can be critical. Biomonitoring demonstrates that exposure to multiple chemicals is a fact, yet understanding the effects of mixtures is extremely complicated and poorly understood. Traditional risk assessment looks at only one chemical at a time, and asks the question, "How much harm is allowable?" We need a more precautionary model that asks a fundamentally different question, "How little harm is possible?"

European REACH Policy

We have a promising example in Europe as the REACH (Registration, Evaluation, and Authorization of Chemicals) policy reform proposals move forward. REACH is the most far-reaching piece of environmental legislation in Europe in 30 years. In short-hand, REACH can be stated in the phrase: "no data, no market." Chemical manufacturers will be required to provide basic toxicological and exposure data about chemicals produced or sold in Europe. Companies wanting to use the most dangerous chemicals must seek permission for their continued use and possibly replace them with safer alternatives.¹¹ REACH proposals extend to imported chemicals which means that U.S. manufacturers will be subject to the new guidelines once they are finalized.

Summary

There are five key messages to be gleaned from new biomonitoring data.

- Biomonitoring is the ultimate proof that we are exposed to multiple chemicals that don't belong in our bodies.
- Everyone on earth is exposed.
- There is a growing body of literature linking health impacts with environmental exposures.
- Most chemicals are untested before being marketed.
- We need a more precautionary approach to chemicals management that at the least requires testing data of chemicals before they are introduced into commerce and the wider environment.

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