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National exposure measurements for decisions to protect public health from environmental exposures

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Abstract

Protecting public health from environmental exposures requires four steps: detection of exposures known or expected to cause disease, assessment of health risk from exposure, implementation of an exposure intervention, and assurance that the exposure intervention is effective. To prioritize efforts in these four areas one must consider the size of the population affected, the seriousness of health effects, and the availability of cost-effective exposure interventions. Population exposure data is critical to each of these steps for protecting health. Biomonitoring data for the US population is now available to assist public health scientists and physicians in preventing disease from environmental exposures, and it complements that available for levels of chemicals in environmental media. The Second National Report on Human Exposure to Environmental Chemicals provides for the US population serum, blood and urine levels for 116 environmental chemicals over the years 1999 and 2000, with separate analyses by age, sex, and race/ethnicity. This national exposure information identifies which chemicals get into Americans in measurable quantities; determines whether exposure levels are higher among population subgroups; determines how many Americans have levels of chemicals above recognized health threshold levels (for chemicals with such threshold levels); establishes reference ranges that define general population exposure so unusual exposures can be recognized; assesses the effectiveness of public health efforts to reduce population exposure to selected chemicals; and tracks over time trends in US population exposure. Blood lead measurements in the population were important in identifying lead in gasoline as a significant source of human lead exposure and documenting the reduction in blood lead levels in the population as a result of removing lead from gasoline and other products in the United States. Serum cotinine levels in the early 1990s found more widespread exposure to environmental tobacco smoke (ETS) in the United States than previously thought and additional measurements in 1999 and 2000 documented major declines in exposure to ETS as a result of public health actions in the 1990s.

A new biomonitoring assessment of the exposure of the US population will be released every 2 years as the "National Report on Human Exposure to Environmental Chemicals." These reports will include the current 116 chemicals and new chemicals added to monitor priority exposures of the population.
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Introduction

Public health scientists and physicians are challenged to protect populations from harmful exposures to

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environmental chemicals and to recognize exposures that are not of health concern. Prevention of environmental disease requires: (1) detection of exposures known or likely to cause disease, (2) assessment of health risk from exposure, (3) implementation of an exposure intervention, and (4) assurance that the exposure intervention has been effective. Exposure information for populations is critical to each of these disease prevention steps.

Public health must be careful to assure that large segments of the population are not subjected to adverse health effects from exposures to environmental chemicals. Additional priority should be given to exposures that cause more serious disease and are amenable to cost-effective interventions. Given the large number of chemicals to which the public is regularly exposed, public health needs reliable data to determine which chemicals are actually getting into people's bodies and at what concentrations or dose.

Measurement of the health-relevant dose of chemicals in people has been an area of major advance in the last two decades (Needham and Sexton, 2000; Pirkle et al., 1995; Mendelsohn et al., 1998; Sampson et al., 1994; Fishman et al., 2000). The dose of a chemical that reaches a target organ (biologically effective dose) is the most health-relevant exposure measurement. The obvious barriers to biopsies of human organ systems make this dose measurement rarely available. A second-best dose measurement for evaluating health significance is the level of the chemical or its metabolite measured in the more accessible human specimens of blood and urine (internal dose). Internal dose measurements are typically referred to as biological monitoring or biomonitoring. Advances in the last two decades in analytical chemistry methods to measure chemicals and their metabolites in blood and urine and in human toxicokinetics have made biomonitoring much more available and interpretable for assessment of internal dose exposures.

Biomonitoring exposure data for the US population

The scarcity of biomonitoring data for the US population and other populations potentially exposed prompted a major effort at CDC to develop the capability to fill this gap. Since about 1985, CDC has focused on developing analytical methods to measure environmental chemicals in human specimens—usually blood, serum, and urine but also saliva, hair, meconium, breast milk and tissues. These analytical methods start with only small amounts (usually 1 ml or less) of serum, blood, or urine and are able to measure multiple chemicals (usually more than seven chemicals per method) at low levels (typically parts-per-trillion levels but for dioxin and related compounds, the detection limits are in the mid-parts-per-quadrillion). All analytical methods for organic compounds use isotope dilution mass spectrometry with measurements made on either tandem quadruple mass spectrometers or high resolution (at 10,000 resolution) mass spectrometers. CDC can now measure more than 300 chemicals from four regular tubes of blood and a regular urine sample (www.cdc.gov/nceh/dls).

Exposure information for the US population requires a population survey. The only survey of the US population to collect blood or urine samples is CDC's National Health and Nutrition Examination Survey (NHANES), conducted by CDC's National Center for Health Statistics (NCHS) (detailed survey information is available at http://www.cdc.gov/nchs/nhanes). The survey design is a complex, stratified, multistage, probability-cluster design to select a representative sample of the civilian, non-institutionalized US population. Selected population groups are oversampled and special statistical techniques are required to obtain valid population estimates. Specific analytical guidelines and complete datasets are provided at the NCHS website referenced above.

The Division of Laboratory Sciences (DLS) of CDC's National Center for Environmental Health has obtained blood and urine specimens from participants in NHANES for analyses of environmental chemicals and their metabolites. A single blood and urine sample are obtained during the visit of the participant to the survey trailers. Participants come throughout the day. Blood lead measurements were made in NHANES II (1976–1980). Blood lead, blood cadmium, and serum cotinine were measured in NHANES III (1988–1994). A larger set of environmental chemicals were measured starting in 1999, when NHANES began sampling the US population every 2 years.

In January, 2003, DLS published the "Second National Report on Human Exposure to Environmental Chemicals," based on blood and urine samples from NHANES 1999–2000 (CDC, 2003). The "Second Report" is the most comprehensive assessment to date of the exposure of the US population to environmental chemicals. A total of 116 chemicals are in the "Second Report" including lead, cadmium, mercury, thallium, uranium, other metals, metabolites of organophosphate and carbamate insecticides, phthalates, cotinine, polycyclic aromatic hydrocarbons (PAHs), dioxins, furans, coplanar polychlorinated biphenyls (PCBs), non-coplanar PCBs, organochlorine pesticides, phytoestrogens, herbicides, pest repellants, and disinfectants. A few of these chemicals were measured on all participants, but most were measured on a randomly selected one-third or one-half subset of participants. Details are provided at www.cdc.gov/exposurereport.

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