Medical Toxicology and Public Health—Update on Research and Activities at the Centers for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry

Environmental Exposures among Arctic Populations: The Maternal Organics Monitoring Study in Alaska

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Abstract Evidence suggests that in-utero exposure to environmental chemicals, such as persistent organic pollutants (POPs), heavy metals, and radionuclides, that might bioaccumulate in the mother may increase a newborn's risk of adverse developmental, neurological, and immunologic effects. Chemical contamination of bodies of water and strong ocean currents worldwide can drive these chemicals from lower latitudes to Arctic waters where they accumulate in common traditional subsistence foods. In response to concerns of the people from Alaska of the effects of bio-accumulated chemicals on their children, the Maternal Organics Monitoring Study(MOMS) was developed. The objective of the study was to assess the risks and benefits associated with the population's subsistence diet. Data analysis of biological samples at the CDC's NCEH laboratory and maternal questionnaires is ongoing. Results will be provided to Alaska Native communities to help support public health actions and inform future interventions and research.

Keywords Arctic populations · Persistent organic pollutants · Subsistence diet · In-utero toxicity · The maternal organics monitoring study

The following is an update on research and activities in which clinical toxicologists are actively involved at CDC/ATSDR. The *Journal of Medical Toxicology* periodically will highlight some of these activities to illustrate the growing relationship between clinical toxicology and public health.

Note: The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention or the Agency for Toxic Substances and Disease Registry.

Evidence suggests that in-utero exposure to environmental chemicals, such as persistent organic pollutants (POPs), heavy metals, and radionuclides, that might bio-accumulate in the mother may increase a newborn's risk of adverse developmental, neurological, and immunologic effects [1]. POPs are resistant to degradation, can travel long distances via air or ocean currents, can bio-accumulate, and have the potential for human health effects [2]. They represent a wide variety of different chemicals including but not limited to pesticides, perfluorocarbons (PFC), polychlorinated biphenyls (PCB), polyaromatic hydrocarbons (PAHs), and dioxins [3]. There are numerous studies in the medical literature suggesting that mothers' exposures to these agents, heavy metals, and radionuclides are associated with adverse health effects in the developing fetus and their children.

There is a large body of evidence suggesting that POPs can have adverse reproductive and developmental outcomes. In a study of 89 women with repeated miscarriages, 20 % had elevated levels of at least one PFC [4]. The same study found significant associations between increasing PFC blood

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concentrations and immunological and hormonal changes [4]. The North Carolina Breast Milk and Formula Project investigated the effects of prenatal exposure to background levels of PCBs and the organochlorine pesticide, dichlorodiphenyl dichloroethene (DDE) via maternal breast milk. The authors reported that children with higher in-utero PCB and DDE exposure exhibited adverse neurologic findings, such as hyporeflexia and hypotonicity [5, 6]. The Lake Michigan/Maternal Infant Cohort Study reported both developmental disorders and cognitive deficits in the offspring of mothers who were exposed via fish consumption to PCBs and related compounds for at least 6 years before and during pregnancy [7–10]. A recent re-examination of 212 children from that study indicated neurodevelopmental deficits identified in infancy and early childhood still persist at age 11 years [11]. Other studies indicate that maternal serum PCB levels during pregnancy are positively associated with the number and type of infectious illnesses which occurred in infants during the first 4 months of life [12, 13]. Inuit mothers who had elevated levels of PCBs and dioxins in their breast milk had infants with decreased CD4+ (helper) to CD8+ (cytotoxic) T cell ratio at 6 to 12 months of age [14].

Adverse outcomes in pregnant women and children with exposures to heavy metals are well-described. Elevated lead levels in pregnant women are associated with gestational hypertension, low birth weight, impaired neurodevelopment, infertility, spontaneous abortions, and fetal/neonatal death [15]. In one study using the Bayley Scales of Infant Development, each 1 µg/dL increase in umbilical cord blood lead was associated with a reduction of 0.6 points in the mental development index scores of infants at age 3 months, with similar results at age 6 months [16]. Prenatal mercury exposure may also have health effects in children. For example, an evaluation of 917 Faroe Island children found subtle neuropsychological dysfunction in those aged 7 years who had any prenatal methylmercury exposure [17].

Of concern specifically in the Arctic is radionuclide contamination. The main source of external exposure in the Arctic is global fallout and mainly due to ^{137}Cs , ^{90}Sr , ^{131}I , ^{226}Ra , ^{95}Zr , ^{106}Ru , ^{54}Mn , and ^{95}Nb . These radionuclides were found in subsistence foods consumed by the Arctic population [18, 19]. The main health effects from radionuclides extend from their ability to emit ionizing radiation and cause cancer. The Arctic population may be receiving 2–10 mSv/year through dietary sources. That is approximately 1–5 times the dose received from background sources of radiation such as cosmic radiation, the soil and rocks in the earth, other living things, and consumed food. It is estimated that people in the Arctic exclusively consuming subsistence foods have a 12.5 % higher cancer rate [19]. A study of women near the Techa River, Russia, with ^{90}Sr contamination from dumping of nuclear waste showed increased accumulation in the skeleton of pregnant and lactating women. The authors noted that

increased radionuclide accumulation leads to increased radiation doses and the associated risk of cancer [20]. In another study of the population from the same region, a higher incidence of stillbirths, miscarriages, early neonatal mortality, and lethal developmental defects were found when compared with an unexposed population nearby [21].

Chemical contamination of bodies of water and strong ocean currents worldwide can drive POPs, heavy metals, and radionuclides from lower latitudes to Arctic waters where they accumulate in common traditional foods [1]. As a result, women in Arctic regions may be at greater risk of exposure to all of the chemicals mentioned above. Fish and marine mammals, which bio-accumulate and bio-magnify environmental pollutants, comprise the traditional arctic subsistence diet. Thus, contaminant levels of arctic inhabitants who rely on traditional diets can be 10 to 20 times greater than in inhabitants from most temperate regions [1]. Because several of these contaminants move from mother to fetus through the umbilical cord [1], contaminant measures in the mother's blood give an indication of the child's exposure. The growing fetus and the newborn child may be particularly sensitive to the toxic effects of many of these contaminants as described above.

In response to concerns of the people from Alaska of the effects of bio-accumulated chemicals on their children, the Maternal Organics Monitoring Study (MOMS) was developed by the Alaska Native Tribal Health Consortium (ANTHC) as an interagency biomonitoring program to study Alaska Native mothers consuming a subsistence diet and their newborn infants. The collaboration has evolved since its start in 1999 to include the National Center for Environmental Health (NCEH) of the Centers for Disease Control and Prevention (CDC), Yukon Kuskokwim Health Corporation (YKHC), the CDC Arctic Investigation Program in Anchorage, Environmental Protection Agency (EPA) Office of Tribal and International Activities, the EPA National Center for Environmental Research and the Center for Disease Control, and the Indian Health Service.

The objective of the study was to assess the risks and benefits associated with the population's subsistence diet. Serum and urine samples from Yupik Alaska Native (population served by the YKHC) pregnant women enrolled in this study were collected during their first prenatal visit. Umbilical cord blood samples were collected from their infants at delivery. Samples were analyzed for POPs such as perfluorocarbons (PFCs), phthalates, polychlorinated biphenyls (PCBs), pesticides, as well as heavy metals (arsenic, cadmium, mercury, and lead), phytoestrogens, cytokines, micronutrients, selenium, fatty acids (FAs), lipids, and radionuclides. Laboratory analyses of biological samples were performed at CDC's NCEH laboratory. Data from a maternal questionnaire to assess environmental and dietary exposures were also collected.

Some of the work has been completed and published [1]. Data analysis is ongoing. Epidemiologists, medical toxicologists, and statisticians at CDC are assisting with laboratory and data analysis.

Commentary

The Maternal and Infant Monitoring Study is an interagency biomonitoring program developed to study the possible health effects of persistent bio-accumulated chemicals, including POPs, heavy metals, and radionuclides, on Alaska native mothers and their children. Similar studies are looking at other Arctic populations in Canada, Denmark, Greenland, Finland, Iceland, Norway, and Sweden. Thus far, studies in the Arctic indicate that the overall benefits of a subsistence diet outweigh the risks from exposure to environmental pollutants [1].

Future areas of exploration for this study will be to evaluate the geographic distribution of POPs; assess maternal PFCs, lipids, and fatty acids; study a possible relationship between maternal hypertension and POP concentrations; and study the relationship between the physical condition of newborns and their POP concentrations. Results will be provided to Alaska Native communities to help support public health actions, such as interventions to reduce exposures while encouraging a traditional diet.

Compliance with Ethical Standards

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Conflict of Interest No conflict of interest to disclose.

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