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ENVIRONMENTAL CONTAMINATION AND BREASTFEEDING IN KAZAKSTAN

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ACRONYMS

ADI	Acceptable Daily Intake
Cs	Cesium
DDE	2,2-bis(*p*-chlorophenyl)-1,1,1-trichloroethane
DDT	Dichlorodiphenyl trichloroethane
HCB	Hexachlorobenzene
HCH	Hexachlorocyclohexane
IAEA	International Atomic Energy Agency
I-TEQ	International Toxic Equivalent Quotient
PCB	Polychlorinated biphenyl
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
WHO	World Health Organization

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INTRODUCTION

Numerous reports have highlighted the profound health and economic consequences of environmental degradation in the former Soviet Union (1). In particular, the potential consequences for maternal and child health—and specifically for breastmilk contamination—have been of concern to health authorities and the international health community (2). The newly independent Republic of Kazakstan represents the broad range of environmental impacts and resultant health concerns emerging throughout the region. Kazakstan borders the Aral Sea, an internationally recognized ecological disaster area (3); is home to Semipalatinsk, the former Soviet nuclear testing site; and, has numerous plants for chemical synthesis, metal mining and milling, weapons manufacture, and petrochemical exploration and refineries. The present study, which analyzed breastmilk for dioxins, polychlorinated biphenyls (PCBs), chlorinated pesticides, toxic metals, and radionuclides, was undertaken to provide a scientific basis for the development of a national infant feeding policy in Kazakstan (4). This paper focuses on the infant feeding implications of breastmilk contamination; a parallel publication focuses on the assessment of exposures to chlorinated compounds in the same study population (5).

Environmental contaminants that pose the greatest threat are those which, in addition to being potent toxins with carcinogenic or endocrine disrupting properties, persist in the environment and accumulate at progressively higher concentrations in the food chain. Dioxins, PCBs, and chlorinated pesticides have these characteristics. Metals, although persistent, do not generally bioaccumulate significantly, with the exception of lead and mercury. In humans, these contaminants accumulate in adipose tissue primarily as a result of eating contaminated fish, meat, and dairy products (6). During lactation, maternal body fat — with residues of chlorinated contaminants accumulated since birth — is mobilized and incorporated into breastmilk. Breastfeeding is the main route of elimination of such contaminants.

Exposure to environmental contaminants through breastmilk poses a unique public health challenge because the health risks to the infant from such exposure can only be reduced by reducing breastfeeding, which also poses health risks (7). Breastfeeding has a strong protective effect on infant morbidity and mortality in both developing (8-10) and developed countries (11), because of both reduced exposure to environmental pathogens and the unique immunological properties of breastmilk (12). Comparing the risks of exposure to contaminants through breastmilk to the risks of not being breastfed, however, was not possible in Kazakstan because of the dearth of scientific information about environmental contamination in general, and about breastmilk contamination in particular (13).

POPULATION AND METHODS

Sampling sites were selected to provide a profile of high-risk exposures to possible contaminants. Samples were collected in two phases. Phase I focused on chlorinated contaminants and was conducted in seven sites in Central and Southern Kazakstan in 1994. Phase II focused on toxic metals and radionuclides and was conducted in eight sites in Central and Northern Kazakstan (including Semipalatinsk) in 1995. Because all of the contaminants under study are ubiquitous in the global environment, protocols for sample collection and analysis specified by the World Health Organization (WHO) (14) and WHO and the International Atomic Energy Agency (IAEA) (15) were used to ensure that study results would be directly comparable to international data. Following these protocols, clinic personnel contacted women who met the following selection criteria: 1) first lactation; 2) infant two to eight weeks of age for Phase I or two to twenty weeks of age for Phase II; and, 3) mother and infant apparently healthy. For Phase I, clinic personnel were asked to contact every woman who met the selection criteria; for Phase II they were asked to contact every other woman. In most clinics, all women who met this selection criteria participated and within-clinic selection bias was minimal. All women invited to participate signed a letter of informed consent, which to the authors knowledge was previously unknown in Kazakstan.

A total of 92 women were sampled in Phase I providing a total of 40 samples (seventeen individual and 23 pooled) for analyses of PCBs, dioxins, and furans and 101 samples for analysis of chlorinated pesticides. In Phase II, between twelve and seventeen samples per site were collected for a total of 115 samples. Breastmilk samples were pooled to create three pooled samples for radionuclide analysis per site.

For Phase I, target chemicals included the seventeen 2,3,7,8-substituted dioxins and furans and the ten homologue groups of tetra- to octa-substituted dioxins and furans; selected tri- to deca-substituted PCBs, including the most toxic coplanar and mono-ortho PCBs; and, 23 commonly detected chlorinated pesticide residues, including the DDT (1,1-dichloro-2,2-bis (*p*-chlorophenyl)ethylene), chlordane, and hexachlorocyclohexane (HCH) families. Samples of whole milk were analyzed by high resolution gas chromatography-high resolution mass spectrometry. The lipid content of each sample was determined, and the contaminant levels were expressed on a fat-weight basis. Protocols for sample collection, handling, and analysis are described in detail elsewhere (5, 16-17).

For Phase II, the target metals were aluminum, antimony, arsenic, beryllium, cadmium, lead, mercury, nickel, thallium, and chromium. The target element for radioactivity analysis was cesium-137 (Cs-137). Metals were analyzed by inductively-coupled plasma mass spectrometry, inductively-coupled plasma atomic emission spectrometry, and/or neutron activation analysis; Cs-137 was detected by a high sensitivity and high resolution Ge detector with a detection limit of 0.1 Bq (2.8 pCi).

RESULTS

Maternal and infant characteristics for both Phase I and II are similar (Table 1).

Table 1: Reported maternal and infant characteristics

Characteristic	Phase I (n=92)	Phase II (n=115)
Mother		
Age (y)	22.4 ± 3.8[1]	23.7 ± 4.6
Education (y)	12.3 ± 2.0	12.8 ± 2.3
Height (cm)	162.7± 6.1	163.6 ± 6.4
Pre-pregnant weight (kg)	58.5 ± 8.0	56.0 ± 7.4
Weight at term (kg)	67.2 ± 8.7	66.7 ± 8.5
Body mass index	21.4 ± 2.6	21.8 ± 2.7
Infant		
Birthweight (g)	3282 ± 645	3270 ± 457
Low birthweight (%)	9.3	5.4

[1]Mean ± SD

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Chlorinated Compounds

The 40 samples analyzed for dioxins had a mean concentration of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), one of the potentially most carcinogenic dioxin congeners, of 13.6 pg/g fat (median 5.4 pg/g fat) (Table 2). Six samples were particularly high in TCDD (19.6 to 118.2 pg/g fat) and represent six of the eight samples collected from two cotton-growing districts in the south, near Uzbekistan. None of the other five sites showed similar high levels of this congener. The International Toxic Equivalent Quotient (I-TEQ) (18), a summary indicator of dioxin congeners and hence a better measure of potential risk, indicates a mean concentration of 20.1 pg/g fat (median 11.9 pg/g fat). However, the six samples with high concentrations of TCDD, had a mean I-TEQ of 70.0 pg/g fat. The mean concentration for the proposed PCB-TEQ for three coplanar PCBs (#77, 126, 169) (19) was 9.1 pg/g fat; all samples were less than in Europe (20), with the exception of one of the samples also high in TCDD that contained 44 pg/g fat.

Table 2: TCDD, I-TEQ, Total PCBs, and PCB-TEQ from breastmilk[1]

	TCDD (pg/g fat)			I-TEQ (pg/g fat)			PCB-TEQ (pg/g fat)		
	Median	Mean	Range	Median	Mean	Range	Median	Mean	Range
Total (n=40)	5.4	13.6	1.2-118.2	11.9	20.1	4.2-132.9	7.6	9.1	4.9-44.4
Individual (n=17)	6.7	17.1	1.3-118.2	12.7	23.8	4.2-127.3	9.4	11.3	4.1-44.4
Pooled (n=23)	5.2	11.3	2.6-117.1	11.0	17.8	4.7-132.9	7.6	8.1	4.9-12.8
High in TCDD (n=6)	35.5	57.8	19.6-118.2	51.5	70.0	27.8-132.9	6.7	12.6	4.9-44.4
European data[3]		1.4-4.5[4]			15-36[4] 5-53[5] 9-27[6]			0.8-16.1[6]	

[1]Breastmilk averaged 3.5% fat.
[2]Due to instrument malfunction, three PCB extracts were lost.
[3]Range of regional means.
[4]Reference 25.
[5]Reference 24.
[6]Reference 20.

The mean concentration of total PCBs is 410 ng/g fat, which is just below the range of mean concentrations of 420 to 1,200 ng/g fat recently reported in Europe (25). Concentrations of six PCB congeners (#28, 52, 101, 138, 153, 180), summed as an indicator of overall contamination, are in the range of < 100 to 350 ng/g fat, which again are on the low end of the range reported in other European countries (200 to 750 ng/g fat) and less than those recently reported in the Czech and Slovak Republics (> 1000 ng/g fat) (20).

Among the chlorinated pesticide residues, only α-, β-, and γ-HCH, hexachlorobenzene (HCB), DDE (2,2-bis(*p*-chlorophenyl)-1,1,1-trichloroethane), DDT were detected (Table 3). HCB was detected at concentrations similar to those in Europe, while β-HCH, DDE, and DDT were in excess of current European concentrations. Calculated daily intakes of dioxins, PCBs, β-HCH, and total DDT, based on breastmilk concentrations, are reported in Table 4.

Table 3. Selected chlorinated pesticides from breastmilk[1,2]

	β-HCH (ng/g fat)			DDT (ng/g fat)			DDE		
	Median	Mean	Range	Median	Mean	Range	Median	Mean	Range
Total (n=101)	1670	2210	430-8610	230	295	75-1030	1500	1955	240-10540
Individual (n=77)	1815	2346	430-8610	240	307	75-1030	1536	2105	280-10540
Pooled (n=24)	1440	1748	750-4440	230	254	105-660	1500	1448	240-3180
European data									
1990-present		200[3]		not available				1000[3]	
1970-1980		280-2490[3]			260-4200[3]			1200-6700[3]	

[1]Non-detected: Heptachlor, Heptachlor epoxide, α-chlordane, gamma-chlordane, Dieldrin, Endrin aldehyde, Methoxychlor, Chlordecone, 2,4-DDD; Detected in limited samples: 2,4-DDT (n=12), 2,4-DDE (n=5), Aldrin (n=5), gamma-HCH (n=4), 4,4-DDD (n=4), Oxychlordane (n=2), Endosulfan-II (n=2), Mirex (n=1), and trans-Nonachlor (n=1).
[2]Breastmilk averaged 3.5% fat.
[3]Reference 6.

Metals and Radionuclides

Among the toxic elements, the median concentrations observed at each site were within the range of median concentrations in other countries reported by WHO/IAEA (15) and/or other sources of international data. None of the samples had Cs-137 present.

Table 4: Daily intake of selected chlorinated contaminants by breastfed infants[1]

	Exclusive	Partial
I-TEQ (pg/kg/d)	50 (18 - 558)	25 (8.8 - 279)
β-HCH (ng/kg/d)	7,014 (1,806 - 3,616)	3,507 (903 - 18,081)
Total DDT[2] (ng/kg/d)	7,266 (1,323 - 48,594)[3]	3,633 (662 - 24,297)

[1]Assuming an intake of 120 ml/kg/d for a fully breastfed infant and 60 ml/kg/d for a partially breastfed infant and a 3.5% fat content of breastmilk.
[2]Acceptable Daily Intake (ADI) for total DDT is 20,000 ng/kg/d (29).
[3]Median (range)

DISCUSSION

Despite widespread concerns about environmental contamination, the results of this study generally show concentrations of contaminants in breastmilk in Kazakstan similar to those found in Western Europe. PCBs were on the low end of European concentrations, many chlorinated pesticide residues commonly found in Europe were not detected, toxic metals were similar to international concentrations, and Cs-137 was not detected. However, the study did identify three important differences of potential concern. These include contamination with the most toxic dioxin congener, TCDD, in two sampling sites and generalized contamination with β-HCH and DDT. The localized high concentrations of TCDD are of particular concern as they are higher than previously documented, with the exception of breastmilk collected during the early 1970s in South Vietnam and recently analyzed (21).

Infant exposure to chlorinated compounds through breastfeeding is a function of the concentration of a particular contaminant in breastmilk and the volume of breastmilk consumed. Concentrations are highest in

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women breastfeeding for the first time, and for many contaminants, concentrations decrease over the course of lactation (6, 22). The volume of breastmilk ingested per day is generally high during the period of exclusive breastfeeding (defined as breastmilk as the sole source of food), when infants consume about 120 ml/kg/d, and gradually decreases as complementary foods are introduced. The exact volume depends on the specific infant feeding patterns and, in particular, on the durations of exclusive and partial breastfeeding. Representative data from Kazakstan show that although 96% of women initiate breastfeeding and breastfeed for a long period of time (median 13.9 mo), the duration of exclusive breastfeeding is short (median 0.4 mo) (23). Thus, even though infants are potentially exposed to contaminants in breastmilk over a long period of time, daily exposures are less than calculated for an exclusively breastfed infant because breastmilk is rarely their only source of food.

The median I-TEQ concentration in Kazakstan results in an intake of dioxins and furans of 50 pg/kg/d for an exclusively breastfed infant and 25 pg/kg/d for a partially breastfed infant (Table 4). These exposures are similar to exposures in Germany showing an intake of dioxins and furans of 71 pg/kg/d for an exclusively breastfed infant (24). After review of Western European concentrations of dioxins, a WHO/EURO expert group recommends continuation and promotion of breastfeeding (25). Of particular concern are the two districts with high breastmilk concentrations of TCDD as the median I-TEQ corresponds to a calculated intake of 216 and 108 pg/kg/d for an exclusively and partially breastfed infant, respectively. Additional research is needed to examine the relationship between TCDD exposure and infant and child development in these districts, particularly in light of recent reports suggesting possible adverse developmental outcomes associated with pre- and post-natal exposure (26-30).

Concentrations of β-HCH (2210 ng/g fat) greatly exceed the current median concentration for Europe (200 ng/g fat) (6), but are similar to recently reported concentrations for Russia (31). Similarly high concentrations were detected in France (1,000 to 2,000 ng/g fat) and Japan (650 to 4,780 ng/g fat) in the early 1970s, and in India and China (1,000 to 19,000 ng/g fat) in the 1980s (6). The median concentration of β-HCH corresponds to a calculated intake of 7,014 ng/kg/d for an exclusively breastfed infant and 3,507 ng/kg/d for a partially breastfed infant (Table 4). The infant feeding implications of these β-HCH exposures are unclear, as WHO has not set Acceptable Daily Intakes (ADIs) for this pesticide, and recommendations regarding breastfeeding in light of this pesticide exposure have not been made. Because a criterion for entry to the study was that the mother and infant were "apparently healthy," there is no evidence of acute toxic effects associated with present concentrations. Similar concentrations have been observed historically in Europe and Asia and adverse effects associated with breastfeeding have not been reported, although there is one report of a positive association between the residue level of β-HCH in breast adipose tissue and risks of breast cancer (32).

The mean concentration total DDT (sum of DDT and DDE) is twice current background concentrations in Europe (16) but is similar to historical concentrations. Total DDT concentrations in Kazakstan correspond to a calculated intake by an exclusively and partially breastfed infant of 7,266 and 3,633 ng/kg/d, respectively. For an exclusively breastfed infant, this is less than half of the ADI of 20,000 ng/kg/d (33).

Failure to detect Cs-137 in the breastmilk samples that included the former Soviet nuclear test site of Semipalatinsk is consistent with a recent IAEA report showing negligible levels of radionuclides in the area (34). The limit of detection used in this study to detect Cs-137 was considerably more stringent than in studies that found detectable concentrations of Cs-137 following the nuclear accident at Chernobyl and nonetheless endorsed breastfeeding (35-37).

Based in part on the results of this study, the Ministry of Health of Kazakstan is promoting breastfeeding. However, another legacy of widespread environmental contamination in the former Soviet Union is that of misinformation and mistrust. It is hoped that the results of this study will be effective in counteracting widespread concerns about breastmilk contamination in Kazakstan, as well as help foster a more scientific approach to address similar concerns throughout the region.

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WELLSTART INTERNATIONAL

Wellstart International is a private, nonprofit organization dedicated to the promotion of healthy families through the global promotion of breastfeeding. With a tradition of building on existing resources, Wellstart works cooperatively with individuals, institutions, and governments to expand and support the expertise necessary for establishing and sustaining optimal infant feeding practices worldwide.

Wellstart has been involved in numerous global breastfeeding initiatives including the Innocenti Declaration, the World Summit for Children, and the Baby Friendly Hospital Initiative. Programs are carried out both internationally and within the United States.

International Programs

Wellstart's *Lactation Management Education (LME) Program*, funded through USAID/Office of Nutrition, provides comprehensive education, with ongoing material and field support services, to multidisciplinary teams of leading health professionals. With Wellstart's assistance, an extensive network of Associates from more than 40 countries is in turn providing training and support within their own institutions and regions, as well as developing appropriate in-country model teaching, service, and resource centers.

Wellstart's *Expanded Promotion of Breastfeeding (EPB) Program*, funded through USAID/Office of Health, broadens the scope of global breastfeeding promotion by working to overcome barriers to breastfeeding at all levels (policy, institutional, community, and individual). Efforts include assistance with national assessments, policy development, social marketing including the development and testing of communication strategies and materials, and community outreach including primary care training and support group development. Additionally, program-supported research expands biomedical, social, and programmatic knowledge about breastfeeding.

National Programs

Nineteen multidisciplinary teams from across the U.S. have participated in Wellstart's lactation management education programs designed specifically for the needs of domestic participants. In collaboration with universities across the country, Wellstart has developed and field-tested a comprehensive guide for the integration of lactation management education into schools of medicine, nursing and nutrition. With funding through the MCH Bureau of the U.S. Department of Health and Human Services, the NIH, and other agencies, Wellstart also provides workshops, conferences and consultation on programmatic, policy and clinical issues for healthcare professionals from a variety of settings, e.g. Public Health, WIC, Native American. At the San Diego facility, activities also include clinical and educational services for local families.

Wellstart International is a designated World Health Organization Collaborating Center on Breastfeeding Promotion and Protection, with Particular Emphasis on Lactation Management Education.

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