PUBLIC HEALTH ASSESSMENT

FEED MATERIALS PRODUCTION CENTER (US DOE)
[a.k.a. FERNALD ENVIRONMENTAL MANAGEMENT PROJECT]
HAMILTON AND BUTLER COUNTIES, OHIO

POTENTIAL EXPOSURE PATHWAYS

Biota Pathway

Background

There are several farms and gardens near the Fernald site. These have operated before, during, and after the time the facility was active. Chemicals and radioactive contaminants released from the site to air, soil, and water have been deposited onto, or been incorporated into, plants, animals, or animal products (collectively known as *biota*) off site. For example, chemicals and radionuclides released to air may be deposited onto soil and pasture grass. Contaminants in soil and grass may be ingested by farm animals or taken up into the root systems of edible plants. These contaminants may then accumulate in the edible portions of the animals (i.e., flesh, milk, eggs) and plants and be consumed by humans. Ingestion of contaminated biota by nearby residents is a potential pathway for human exposure to contaminants from the Fernald site. ATSDR scientists evaluated this pathway for the site.

Environmental Data

The Fernald facility did not routinely collect all types of biota samples while the facility was in operation. They began sampling milk from dairy cows on farms located near the site in 1983 (DOE 1972 - 1999). Milk samples were collected from farms whose cows grazed on land adjacent to the site as well as another dairy farm located 22 miles west of the site. This second location was selected to represent background conditions. Most of these samples were analyzed for total uranium or uranium isotopes. From 1990 to 1994, the samples were occasionally analyzed for other radioactive contaminants, such as strontium 90; radium 226 and 228; and thorium 228, 230, and 232; however, the results were varied, especially for radium 228.

In June and August 1994, ATSDR was assisted by the EPA=s National Air and Radiation Environmental Laboratory (NAREL) and sampled milk from a dairy farm located on the southeast portion of the Fernald property. We also collected samples from a second dairy farm located 6 miles northwest of the site. All of the samples were analyzed for radioactive contaminants including uranium 234, 235, and 238; potassium 40; and lead 212. ATSDR prepared a Health Consultation discussing the findings of our sampling (ATSDR 1995a).

The facility began routinely collecting samples of produce (vegetables and fruit) from farms located within 2 miles of the site in 1988. They routinely sampled tomatoes, corn, soybeans, potatoes, onions, turnips, cabbage, lettuce, apples, pumpkins, and green beans. They also collected samples from several farms located 10 to 30 miles from the site; these samples were considered representative of background conditions (DOE 1972 - 1999).

In August 1994, ATSDR and EPA=s NAREL staff collected produce samples from local produce stands located near and downwind of the Fernald site, and from stands located upwind and far from the site (ATSDR 1996b). The samples of bell peppers, tomatoes, cabbage, corn, squash, onions, green beans, cucumbers, beets, and cantaloupe were analyzed for radioactive contaminants including uranium 234, 235, and 238; and potassium 40. ATSDR prepared a Health Consultation discussing the findings of the sampling (ATSDR 1996b).

The facility began sampling fish from the Great Miami River, upstream and downstream of the Fernald site, in 1984. They sampled a variety of freshwater fish species, including largemouth bass, longear sunfish, river carpsucker, long nose gar, gizzard shad, and channel catfish (DOE 1972 - 1999). The fish sampling results (including upstream samples) for 1988 were approximately two orders of magnitude higher than for years before 1988, or for 1989. Because these analytical results were not reproducible, we did not consider them representative of maximum concentrations under current conditions at the site.

Because biota sampling was not routinely conducted while the facility was in operation, contractors for CDC used various mathematical models to predict *past* concentrations of uranium and other radionuclides in biota near the Fernald site (Killough et al. 1998a, 1998b). The models incorporate site-specific data on several types of phenomenon, such as (1) deposition of uranium and radionuclides onto pasture grass, (2) uptake of radionuclides in soil by plants, (3) consumption of contaminated water and soil by pasture animals, and (4) accumulation of radionuclides in surface water into freshwater fish (Killough et al. 1998a, 1998b). They estimated concentrations of uranium and other radionuclides (thorium 228, 230, 231, 232, and 234; radium 224, 226, and 228; actinium 228; protactinium 234m and 234; and plutonium 239) in vegetables, meat (beef and poultry), fish in the Great Miami River, milk, and eggs.

Table 19 presents the maximum past and current uranium concentrations of uranium in biota off site of the Fernald facility. Several sources of environmental data are represented in this table (DOE 1972 - 1999; Killough et al. 1998a, 1998b; ATSDR 1995a, 1996b).

Table 20 presents the maximum current radioactive contaminant concentrations in biota off site of the Fernald facility. Not all types of biota were sampled each year, and not all types of biota were analyzed for every radionuclide. The data presented in this table are the maximum concentrations reported from several different sources (DOE 1972 - 1999; ATSDR 1995a, 1996b).

Table 19. Estimated and measured maximum past and current uranium concentrations in biota off site of the Fernald facility

Maximum Past Uranium Concentrations (in units of µg/kg, or ppb, for vegetables, meat, eggs, and fish; in µg/L, or ppb, for milk)				
Vegetables*	**Meat**	**Milk**	**Eggs**	**Fish**
189	12	48	3	865
Maximum Current Uranium Concentrations (in units of µg/kg, or ppb, for vegetables, meat, eggs, and fish; in µg/L, or ppb, for milk)				
Vegetables*	**Meat**	**Milk**	**Eggs**	**Fish**
1,079 ± 168	ND (< 36)	16 ± 2.2	NS	122

Key

µg/kg = micrograms per kilogram

µg/L = micrograms per liter

NS = not sampled

ND = not detected (lower limit of analytical detection)

ppb = parts per billion

* Uranium concentrations in vegetables are reported as an average concentration in tomatoes, peppers, potatoes, carrots, beets, onions, radish, soybean, cabbage, eggplant, green beans, pumpkins/squash, lima beans, turnips, and corn.

Source: Killough et al. 1998a, 1998b (for past uranium concentrations); and DOE 1972B1999; ATSDR 1995a, 1996b (for current concentrations).

Table 20. Measured maximum current radioactive contaminant concentrations in biota off site of the Fernald facility in pCi/g (Bq/g) for vegetables, meat, and fish; pCi/L (Bq/L) for milk

Radionuclide	**Vegetables***	**Meat**	**MilkH**	**Fish**
Total Uranium	0.72 ± 0.12 (0.027 ± 0.004)	- - - - -	11 ± 1.5 (0.407 ± 0.056)	0.082 (0.003)
Uranium 234	NA	< 0.01 (0.000)	1.9± 0.6 (0.070 ± 0.022)	NA
Uranium 235/236	NA	< 0.01 (0.000)	< 0.44 (< 0.016)	NA
Uranium 238	NA	< 0.004 (0.000)	1.7 ± 0.55 (0.063 ± 0.020)	NA

Thorium 228	NA	< 0.01 (0.000)	2.6 ± 1.2 (0.10 ± 0.04)	NA
Thorium 230	NA	< 0.03 (<0.001)	0.6 ± 0.5 (0.02 ± 0.02)	NA
Thorium 232	NA	< 0.01 (0.000)	< 1.2 (< 0.044)	NA
Radium 226	NA	< 0.03(<0.001)	0.9 ± 0.3 (0.03 ± 0.01)	NA
Radium 228	NA	NA	4.9 ± 3.6 (0.18 ± 0.13)	NA
Protactinium 234	NA	NA	900 ± 675 (33.33 ± 25)	NA
Strontium 90	NA	0.00 (0.000)	1.1 ± 0.7 (0.04 ± 0.03)	NA
Cesium 137	NA	< 0.02 (< 0.001)	< 10 (< 0.417)	NA
Plutonium 238	NA	< 0.004 (0.000)	NA	NA
Plutonium 239	NA	< 0.003 (0.000)	NA	NA

Key
pCi/g = picocuries per gram
Bq/g = becquerels per gram
pCi/L = picocuries per liter
Bq/L = becquerels per liter
NA = not analyzed for

* Concentrations in vegetables are reported as the averages of the maximum concentrations in tomatoes, peppers, potatoes, carrots, beets, onions, radishes, soybeans, cabbage, eggplant, green beans, pumpkins/squash, lima beans, turnips, and corn.

[H] Due to limited data on radionuclide (other than uranium) concentrations in milk samples, we used average maximums of each for current years for our calculations.

Estimated Exposure Doses

ATSDR scientists evaluated *past*, *current*, and *potential future* exposure to *chemicals* in biota off site of the Fernald facility. Uranium was the only chemical evaluated for this pathway, because ATSDR has no information indicating that other chemicals are present in biota near the facility.

ATSDR scientists also evaluated *current* and *potential future* exposure to *radioactive* contaminants in biota off site of the Fernald facility. From 1989 through 1955, total uranium concentrations were analyzed in produce, milk (discontinued in March 1995), and fish. Other radionuclides evaluated in milk sampled from 1990 through 1994 were strontium 90, radium 226 and 228; thorium 228, 230, and 232; and protactinium 234. Collectively, we refer to all radionuclides evaluated for this pathway as "radioactive contaminants."

ATSDR scientists assumed that ingestion is the only route of exposure to chemicals and radioactive materials in biota. In estimating doses for biota pathways, ATSDR evaluated two *hypothetical* exposure scenarios. The first scenario assumes exposure to a young child, 1 to 6 years old, weighing 13 kilograms, who consumes from 50% to 100% of a daily diet of vegetables, meat, eggs, and milk from farms and gardens near the site, and consumes 50% of a daily diet of fish from the Great Miami River (EPA 1999; Killough et al. 1998b).

The second hypothetical exposure scenario assumes exposure to an adult, weighing 70 kg, who consumes from 50% to 100% of a daily diet of vegetables, meat, eggs, and milk from farms and gardens near the site, and consumes 50% of a daily diet of fish from the Great Miami River (EPA 1999; Killough et al. 1998b).

ATSDR=s assumptions about ingestion rates and percent of biota consumed by residents from areas near the site for the hypothetical exposure scenarios (described above) are presented in Table 21 (below).

Table 21. Age-specific ingestion rates and percent of biota consumed by Fernald residents for two hypothetical exposure scenarios for the biota pathway

Scenario	**Total Ingestion Rates* (in units of kg/day for vegetables, meat, eggs, and fish; and L/day for milk)**					Percent of Diet from Area Near Fernald Site*	
	Vegetables	**Meat**	**Milk**	**Eggs**	**Fish**	**Vegetables, Meat, Fish**	**Milk, Eggs**
Scenario #1: child	0.2	0.05	0.36	0.01	0.01	50	100
Scenario #2: adult	0.3	0.08	0.24	0.03	0.02	50	100

Key
kg/day = kilograms per day
L/day = liters per day

Notes
For Scenario #1, the age-specific ingestion rates represent an average of rates for males and females in three age categories (0B1, 1B4, and 5B9 years old).
For Scenario #2, the age-specific ingestion rates represent an average of rates for males and females in six age categories (15B19, 20B24, 25B29, 30B39, 40B59, and ≥ 60 years old).

* Total ingestion rates do not account for the fact that only 50% of the total amount of vegetables, meat, and fish are consumed under the hypothetical exposure scenarios.

Source: Killough et al. 1998b; EPA 1999

Chemicals

ATSDR scientists calculated two types of exposure doses for exposure to chemical uranium in biota. These are a *body dose* and a *dose to the kidney*. The kidney is the target organ for ingested uranium.

The chemical effects of uranium result *only* after the uranium is absorbed into the bloodstream from the gastrointestinal tract (following ingestion) and transported (distributed) to the kidney. In estimating *dose to the kidney*, ATSDR scientists assumed that 5% of the uranium in ingested biota is absorbed into the blood. This is a *conservative* assumption, because data from human ingestion studies and pharmacokinetic models indicate that maximum absorption of uranium from the gastrointestinal tract (e.g., stomach, small intestine) ranges from 2% to 4% for the soluble forms of uranium (ATSDR 1999b; ICRP 1995a).

Gastrointestinal absorption of uranium does not appear to vary substantially by age. Recent information suggests that children 5 years old and older absorb uranium from the gastrointestinal tract at the same rate as adults (ICRP 1995a; ATSDR 1999b). Gastrointestinal absorption rates are not known for children under 5. Because there is no indication that absorption rates in small children (younger than 5) are higher than in adults, ATSDR scientists assumed that the absorption rate for a child is equal to the *maximum* absorption rate for an adult (or 5%).

ATSDR scientists also made assumptions about how much of the uranium absorbed into the blood is distributed to the kidney. Biokinetic models of uranium distribution in adults indicate that a maximum of 12% of the absorbed dose of soluble uranium is distributed to the kidneys (ICRP 1979, 1995a; Zhao and Zhao 1990). Therefore, ATSDR scientists assumed that 12% of the estimated body dose was distributed to the kidney. This may overestimate the fraction of uranium distributed to the kidneys of children, because the distribution in children is lower (approximately 9.5% for a child under 10) than in adults due to elevated uptake by bone (ATSDR 1999b; ICRP 1995a). Measurements of uranium in bones of persons exposed to uranium in the environment indicate that the concentration in children is higher than adults, because children have immature skeletons (ICRP 1995a).

We compared our estimated exposure doses for chemical uranium to health-based guidelines for ingested uranium to determine whether further evaluation of public health hazard was warranted. Additional information about the health-based guidelines for uranium is provided in the "Public Health Implications" section of this report.

Radiation

For radiation effects, the whole body and bone surface are the major target organs for ingested uranium and other radionuclides in biota. We calculated committed effective doses (whole body) and equivalent doses (bone surface) for both hypothetical exposure scenarios for biota pathways.

Past Exposure

Because routine sampling was not conducted for all types of biota near the Fernald site during its period of operation, ATSDR scientists used CDC=s *estimated* concentrations in biota (vegetables, meat, milk, eggs, and fish) near the site to predict levels of *past* human exposure that may have resulted from consumption of these foods (Killough et al. 1998b). The CDC=s estimated past uranium concentrations in biota near the Fernald site are presented in Table 19 (above). We used these estimated values to calculate *past chemical* exposure doses for biota pathways. Our estimated doses for the two hypothetical exposure scenarios are presented in Table 22 (below).

Health-Based Guidelines for Chemical Uranium

There are two types of health guidelines for ingestion of chemical uranium: (1) a *body dose* which is presented as milligrams of uranium per kilogram body weight per day (or mg/kg/day), and (2) a *dose to the kidney* which is presented as micrograms of uranium per gram kidney (or µg/g).

Table 22. Estimated maximum past uranium (chemical) exposure doses for hypothetical exposure scenarios for biota pathways

Scenario	Estimated Exposure Doses* (in mg/kg/day)					
	Vegetables	**Meat**	**Milk**	**Eggs**	**Fish**	Total Biota
Scenario #1: child	0.001	0	0.001	0	0	0.002
Scenario #2: adult	0.0003	0	0	0	0	0.0007
Estimated Kidney Doses* (in µg/g)						
Scenario #1: child	0.0005	0	0	0	0	0.001
Scenario #2: adult	0.0002	0	0	0	0	0.0004

Key

mg/kg/day = milligrams of uranium per kilogram of body weight per day μg/g = micrograms of uranium per gram of kidney

* Equations used to estimate doses for this pathway are described in Appendix BCExposure Doses and Health-Based Guidelines.

Our estimated exposure doses (*body doses*) under past conditions at the site do not exceed the health-based guidelines for ingested chemical uranium. Likewise, our estimated kidney doses are considerably lower than the proposed lower limit threshold for kidney toxicity (Morris and Meinhold 1995).

Although our estimated doses do not exceed health-based guidelines for ingested uranium, ATSDR scientists evaluated the public health hazard for this pathway together with other exposure pathways (i.e., groundwater, soil, air, and surface water) that contribute to total uranium exposure to Fernald residents. This evaluation is presented in the "Public Health Implications" section of this report.

Past exposures to radioactive contaminants in biota were addressed in the Fernald Dosimetry Reconstruction Project and Fernald Risk Assessment Projects (Voilleque et al. 1995; Shleien et al. 1995; Killough et al. 1998a, 1998b; CDC 1998, 1999). A description of these projects, conducted by and for CDC, is provided in Appendix D of this report.

Current Exposure

ATSDR scientists used maximum current uranium concentrations in biota sampled near the Fernald facility to estimate *current* chemical exposure doses. These uranium concentrations are presented in Table 19 (above). ATSDR=s estimated chemical exposure doses for exposure to uranium in biota pathways are presented in Table 23 (below).

Table 23. Estimated maximum current uranium (chemical) exposure doses for hypothetical exposure scenarios for biota pathways

Scenario	**Estimated Exposure Doses* (in mg/kg/day)**					
	Vegetables	**Meat**	**Milk**	**Eggs**	**Fish**	**Total Biota Dose**
Scenario #1: child child	0.008	NA	0	NA	0	0.009
Scenario #2: adult	0.002	NA	0	NA	0	0.002
	Estimated Dose to the Kidney* (μg/g)					
Scenario #1: child	0.003	NA	0	NA	0	0.003
Scenario #2: adult	0.001	NA	0	NA	0	0.001

Key
mg/kg/day = milligrams of uranium per kilogram of body weight per day
μg/g = micrograms of uranium per gram of kidney
NA = not analyzed

* Equations used to estimate doses are discussed in Appendix BCExposure Doses and Health-Based Guidelines.

Our estimated chemical exposure doses for scenario #1, ingestion of biota by a child, slightly exceeds the health-based guideline for ingested chemical uranium. Our estimated kidney doses for both scenarios are many times lower than the proposed lower-bound threshold for kidney toxicity (Morris and Meinhold 1995). ATSDR scientists evaluated the public health hazard for this pathway together with other exposure pathways (i.e., groundwater, soil, air, and surface water) that contribute to total uranium exposure to Fernald residents. This evaluation is presented in the "Public Health Implications" section of this report.

ATSDR scientists= estimated committed effective doses (whole body) and equivalent doses (bone surface) for radioactive contaminants in biota pathways for the site are presented in Table 24 (below). The elevated bone surface dose for a child from milk is attributed mainly from concentrations of radium 228. Further evaluation of human exposure to radioactive contaminants in biota, including a determination of whether these estimated doses present an increased likelihood of developing fatal cancers and bone cancer, is discussed in the "Public Health Implications" section of the report.

Table 24. Estimated maximum *current* exposure doses from radioactive contaminants for hypothetical exposure scenarios for biota pathways

Scenario	Biota Type	**Estimated Committed Effective Dose (whole body) for Intake in Year With Maximum Concentrations**	**Estimated Committed Equivalent Dose (Bone Surface) for Intake in Year With Maximum Concentrations**
Scenario #1: child	Vegetables	8.2 ± 1.4 mrem (0.082 ± 0.014 mSv)	117 ± 19 mrem (1,17 ± 0.19 mSv)
	Meat	< 1.3 mrem (< 0.013 mSv)	< 47 mrem (< 0.47 mSv)
	Milk	19.3 ± 14.3 mrem (0.193 ± 0.143 mSv)	587 ± 439 mrem (5.87 ± 4.39 mSv)
	Fish	< 0.1 mrem (< 0.001 mSv)	< 1 mrem (< 0.01 mSv)
	Total	**28.8 ± 15.7 mrem** **(0.288 ± 0.157 mSv)**	**752 ± 458 mrem** **(7.52 ± 4.58 mSv)**
Scenario #2: adult	Vegetables	6.9 ± 1.1 mrem (0.069 ± 0.011 mSv)	108 ± 18 mrem (1.08 ± 0.18 mSv)
	Meat	< 2 mrem (< 0.02 mSv)	< 75 mrem (< 0.75 mSv)
	Milk	3.1 ± 2.1 mrem (0.031 ± 0.021 mSv)	93 ± 63 mrem (0.93 ± 0.63 mSv)
	Fish	< 0.1 mrem (< 0.001 mSv)	< 1 mrem (< 0.01 mSv)
	Total	**12.1 ± 3.2 mrem** **(0.121 ± 0.032 mSv)**	**277 ± 81 mrem** **(2.77 ± 0.81 mSv)**

Key
mrem = millirems
mSv = millisieverts (1 mSv = 100 mrem)

Potential Future Exposure

Remediation activities at the Fernald site are expected to continue for several years. During that time, former production buildings will be destroyed and contaminated soils around and under these buildings will be removed from the area and transported to an off-site disposal area. This should minimize releases to air, soil, and surface water. In turn, this should limit the uptake and accumulation of contaminants in plants, animals, and animal products and the potential for human exposure to chemicals and radioactive contaminants in biota off site of the Fernald facility.

According to available sampling, there is no indication that future activities will result in human exposure to contaminated biota off site of the Fernald facility. However, if additional information becomes available indicating that contaminants have been released or migrated to biota off site, biota pathways should be re-evaluated.

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Agency for Toxic Substances and Disease Registry, 1825 Century Blvd, Atlanta, GA 30345
Contact CDC: 800-232-4636 / TTY: 888-232-6348