ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Public Health Assessment for

EVALUATION OF CURRENT (1990 TO 2003) AND FUTURE CHEMICAL EXPOSURES IN THE VICINITY OF THE OAK RIDGE RESERVATION (USDOE)
OAK RIDGE, ANDERSON COUNTY, TENNESSEE
EPA FACILITY ID: TN1890090003
SEPTEMBER 12, 2005

For Public Comment

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

Comment Period Ends:

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PUBLIC HEALTH ASSESSMENT

EVALUATION OF CURRENT (1990 TO 2003) AND FUTURE CHEMICAL EXPOSURES IN THE VICINITY OF THE OAK RIDGE RESERVATION

U. S. Department of Energy Oak Ridge Reservation
Oak Ridge, Anderson County, Tennessee
EPA FACILITY ID: TN1890090003

Prepared by:

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Foreword

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the Superfund law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency, EPA, and the individual states regulate the investigation and cleanup of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by scientists from ATSDR and from states with which ATSDR has cooperative agreements. The public health assessment program allows flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document or it could be a compilation of several health consultations—the structure may vary from site to site. Whatever the form of the public health assessment, the process is not considered complete until public health issues at the site are addressed.

Exposure

As the first step in the evaluation, ATSDR scientists review environmental data to see what chemicals are present, where the chemicals were found, and how people might come into contact with the chemicals. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When environmental data does not allow ATSDR to fully evaluate exposure, the report will indicate what further sampling data is needed.

Health Effects

If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these exposures may result in harmful effects. ATSDR recognizes that developing fetuses, infants, and children can be more sensitive to exposures than are adults. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable than adults. Thus, the health impact to the children is considered first when evaluating exposure and the potential adverse effects to a community. The health impacts to other groups within the community (such as the elderly, chronically ill, and people engaging in high-exposure practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic, and epidemiologic studies and the data collected in disease registries, to determine the likelihood of health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. In this case, this report suggests what further public health actions are needed.

Conclusions

This report presents conclusions about the public health threat, if any, posed by a site. Any health threats that have been determined for high-risk groups (such as children, the elderly, chronically ill people, and people engaging in high-risk practices) are summarized in the Conclusions section of the report. Ways to stop or reduce exposure are recommended in the Public Health Action Plan section.

ATSDR is primarily an advisory agency, so its reports usually identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies or research on specific hazardous substances.

Community

ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the comments received from the public are responded to in the final version of the report.

Comments

If, after reading this report, you have questions or comments, we encourage you to send them to us. Letters should be addressed as follows:

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Acronyms

ATSDR	Agency for Toxic Substances and Disease Registry
CDC	Centers for Disease Control and Prevention
CDD	chlorinated dibenzo-p-dioxin
CEL	cancer effect level
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CREG	cancer risk evaluation guide (ATSDR)
CSF	cancer slope factor
DOE	U.S. Department of Energy
EFPC	East Fork Poplar Creek
EMEG	environmental media evaluation guide (ATSDR)
EPA	U.S. Environmental Protection Agency
FAMU	Florida Agriculture and Mechanical University
FDA	U.S. Food and Drug Administration
HCDD	hexachlorodibenzo-p-dioxin
HCH	hexachlorocyclohexane
LOAEL	lowest-observed-adverse-effect level
MCPA	2-methyl-4-chlorophenoxyacetic acid
MCPP	2-(2-methyl-4-chlorophenoxy) propionic acid
MRL	minimal risk level (ATSDR)
mg/kg/day	milligrams per kilogram per day
NAS	National Academy of Sciences
NPL	National Priorities List
NOAEL	no-observed-adverse-effect level
OREIS	Oak Ridge Environmental Information System
ORR	Oak Ridge Reservation
ORRHES	Oak Ridge Reservation Health Effects Subcommittee
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
ppb	parts per billion
ppm	parts per million
RBC	risk-based concentration (EPA)
RCRA	Resource Conservation and Recovery Act
RDA	Recommended Dietary Allowance
RfD	reference dose (EPA)
RMEG	reference dose media evaluation guide (ATSDR)
TCDD	tetrachlorodibenzo-p-dioxin
TDEC	Tennessee Department of Environment and Conservation
TDOH	Tennessee Department of Health
TEF	toxic equivalency factor
TEQ	toxic equivalent
TSCA	Toxic Substances Control Act
µg/day	micrograms per day
µg/dL	micrograms per deciliter
$\mu g/m^3$	micrograms per cubic meter
WBR	Watts Bar Reservoir
WHO	World Health Organization

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I. Summary

In 1942, the federal government established the Oak Ridge Reservation (ORR) in Anderson and Roane Counties in Tennessee as part of the Manhattan Project to research, develop, and produce special nuclear materials for nuclear weapons. In 1989, ORR was added to the U.S. Environmental Protection Agency's (EPA's) National Priorities List, because over the years, ORR operations have generated a variety of radioactive and nonradioactive wastes that are present in old waste sites or that have been released to the environment. The U.S. Department of Energy (DOE) is cleaning up ORR under a Federal Facility Agreement with EPA and the Tennessee Department of Environment and Conservation (TDEC). DOE, EPA, and TDEC are working together to investigate and remediate site-related chemical releases or waste sites from past and present activities at the site.

Since 1992, the Agency for Toxic Substances and Disease Registry (ATSDR) has responded to requests and addressed health concerns of community members, civic organizations, and other government agencies by working extensively to determine whether levels of environmental contamination at and near ORR present a public health hazard to communities surrounding ORR. During that time, ATSDR has identified and evaluated several public health issues and has worked closely with many parties. ATSDR is the principal federal public health agency charged with evaluating human health effects of exposure to hazardous substances in the environment. Whereas the Tennessee Department of Health (TDOH) conducted the Oak Ridge Health Studies to evaluate whether off-site populations have been exposed in the past, ATSDR's activities have focused on current public health issues related to Superfund cleanup activities at the site.

To expand on the efforts of TDOH, ATSDR scientists conducted a review and a screening analysis of TDOH's Phase I and Phase II screening-level evaluation of past exposure (1944 to 1990) to identify contaminants of concern for further evaluation. Based on this review, ATSDR scientists are conducting public health assessments (PHAs) on the release of iodine 131, mercury releases from the Y-12 plant, PCBs, radionuclides from White Oak Creek, uranium releases from the Y-12 plant, uranium and fluoride releases from the K-25 complex, and other topics such as the Toxic Substances Control Act (TSCA) incinerator and off-site groundwater. In conducting these PHAs, ATSDR scientists are evaluating and analyzing the information and findings from previous studies and investigations to assess the public health implications of past and current exposure. This PHA documents ATSDR's screening of recent (1990 to 2003)[1] environmental data, addresses whether additional chemicals require further evaluation, and discusses the public health implications related to estimated exposures. Polychlorinated biphenyls (PCBs), mercury, and the groundwater pathway are not addressed in this PHA; those chemicals will be evaluated in separately released PHAs.

According to the information reviewed for this PHA, ATSDR concludes that current and future exposures to ORR site-related chemicals (individually or in combination) in soil, sediment, surface water, biota (other than fish), and air do not pose a public health hazard. Very limited "dioxin" data exist for fish; therefore, exposure to dioxins in fish poses an indeterminate public health hazard. The available data on dioxins in fish are on fish of an unidentified species from a

[1] Data prior to 1990 was evaluated during TDOH's past screening evaluation. ATSDR initiated the current screening evaluation in 2003 and used that as the cut-off year for new data.

pond near K-25. In the absence of additional data on dioxins in fish near ORR, ATSDR recommends following the current fish advisories. Following current fish advisories will reduce exposure to contaminants in fish. For cadmium, less than 50 percent of the vegetables sampled did not have detectable levels of cadmium and exposure is not expected to result in adverse health effects for the general population. However, if an individual were to eat vegetables from a garden at the reported cadmium levels (based on the data for beets, kale, and tomatoes) on a continuous basis (yearly garden with freezing/canning of excess harvest for later consumption) then health effects (e.g., proteinuria) could occur in those individuals.

II. Background

II.A. Site Description

In 1942, the federal government established the Oak Ridge Reservation (ORR), located in Anderson and Roane Counties in Tennessee, as part of the Manhattan Project to research, develop, and produce special nuclear materials for nuclear weapons (ChemRisk 1993a; TDOH 2000). Four facilities were built. The Y-12 plant, the K-25 complex, and the S-50 site were created to enrich uranium, and the X-10 site was created to demonstrate processes for producing and separating plutonium (TDOH 2000). The Clinch River forms the southern and western boundaries of the reservation, and most of the property is within the Oak Ridge city limits (EUWG 1998). (See Figure 1 for the location of ORR.)

When the federal government acquired ORR in 1942, the reservation consisted of 58,575 acres (91.5 square miles). Since that time, the federal government has transferred 24,340 acres (38.0 square miles) to other parties, such as the city of Oak Ridge and the Tennessee Valley Authority. The U.S. Department of Energy (DOE) continues to control the remaining 34,235 acres (53.5 square miles) (ORNL 2002). See Figure 2 for the original and current ORR boundaries. Most of the contamination is located at the three main facilities. These areas are heavily guarded and fenced and access to these areas requires a clearance badge.

II.B. Operational History

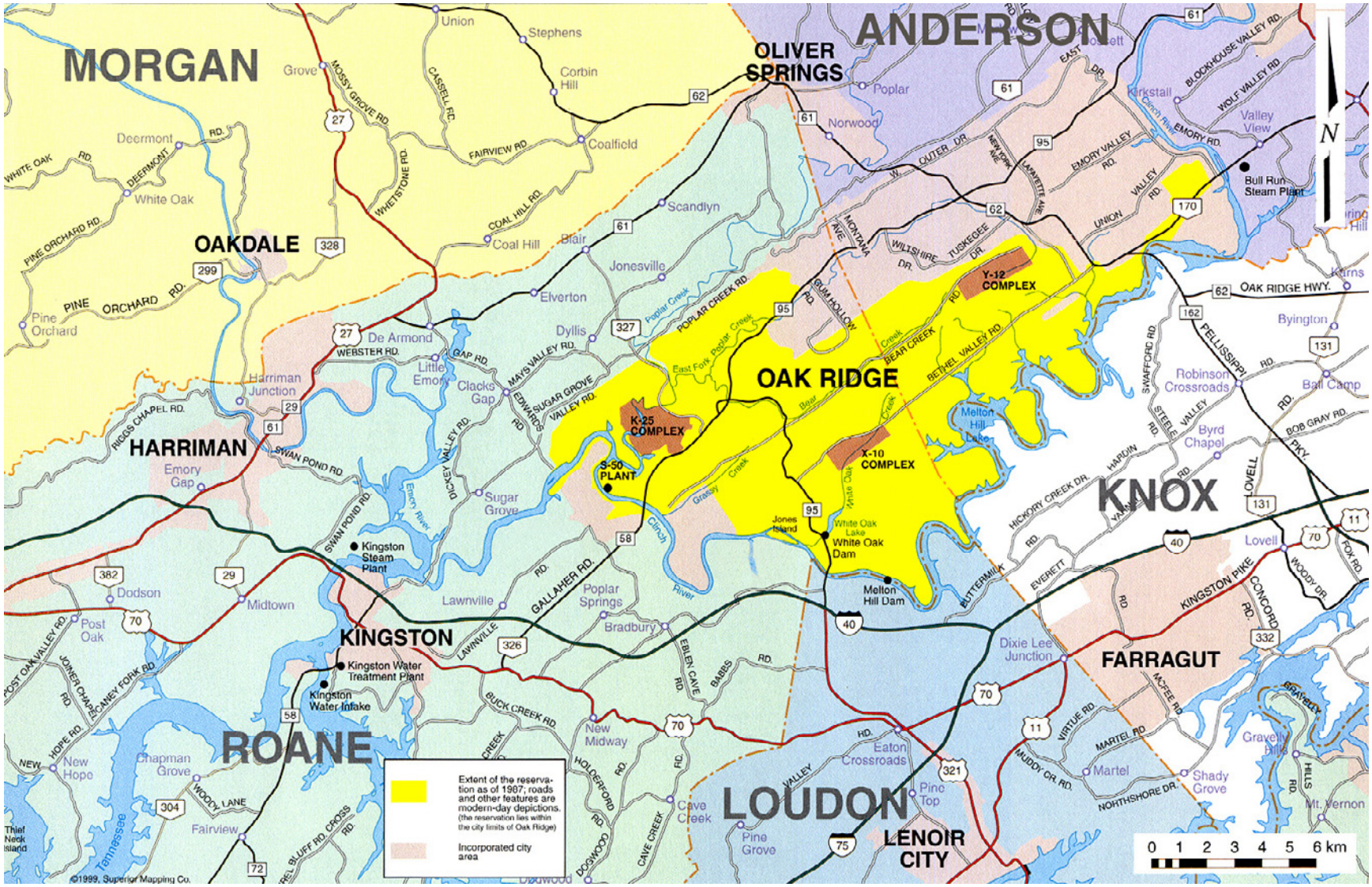
Y-12 Plant

The Y-12 plant was built in 1943, to house equipment used to electromagnetically enrich uranium. The atomic bomb that was dropped in Hiroshima, Japan, contained uranium produced at the Y-12 plant (TDOH 2000). In 1952, the facilities were converted to fabricate nuclear weapon components (ChemRisk 1999). During the Cold War, a column-exchange process (Colex) that used large quantities of mercury as an extraction solvent to enrich lithium in lithium 6 was built and operated (TDOH 2000). At the end of the Cold War, the Y-12 missions were curtailed. In 1992, the major focus of the Y-12 plant was the remanufacture of nuclear weapon components and the dismantlement and storage of strategic nuclear materials from retired nuclear weapons systems. The Y-12 plant is now known as the Y-12 National Security Complex and is primarily used to disassemble nuclear weapons and to store highly enriched uranium (TDOH 2000).

X-10 Site

The X-10 site (formerly known as the Clinton Laboratories and is now part of what is referred to as the Oak Ridge National Laboratory) was built in 1943, as a pilot plant to produce and separate plutonium. The government had intended to operate the facility for only one year; however, operations were continued and expanded (ChemRisk 1993a; TDOH 2000). Over time, operations at X-10 grew to include non-weapons related activities, such as nuclear fission product separation, nuclear reactor safety and development, and radionuclide production for worldwide use in the medical, industrial, and research fields. Today, the Oak Ridge National Laboratory receives worldwide recognition as a facility for research and development in several areas of science and technology (ChemRisk 1993a). In addition, the Oak Ridge National Laboratory produces numerous radioactive isotopes that have significant uses in medicine and research (TDEC 2002).

Figure 1. Location of Oak Ridge Reservation



Source: ChemRisk 1999

Figure 2. Original and Current ORR Boundaries

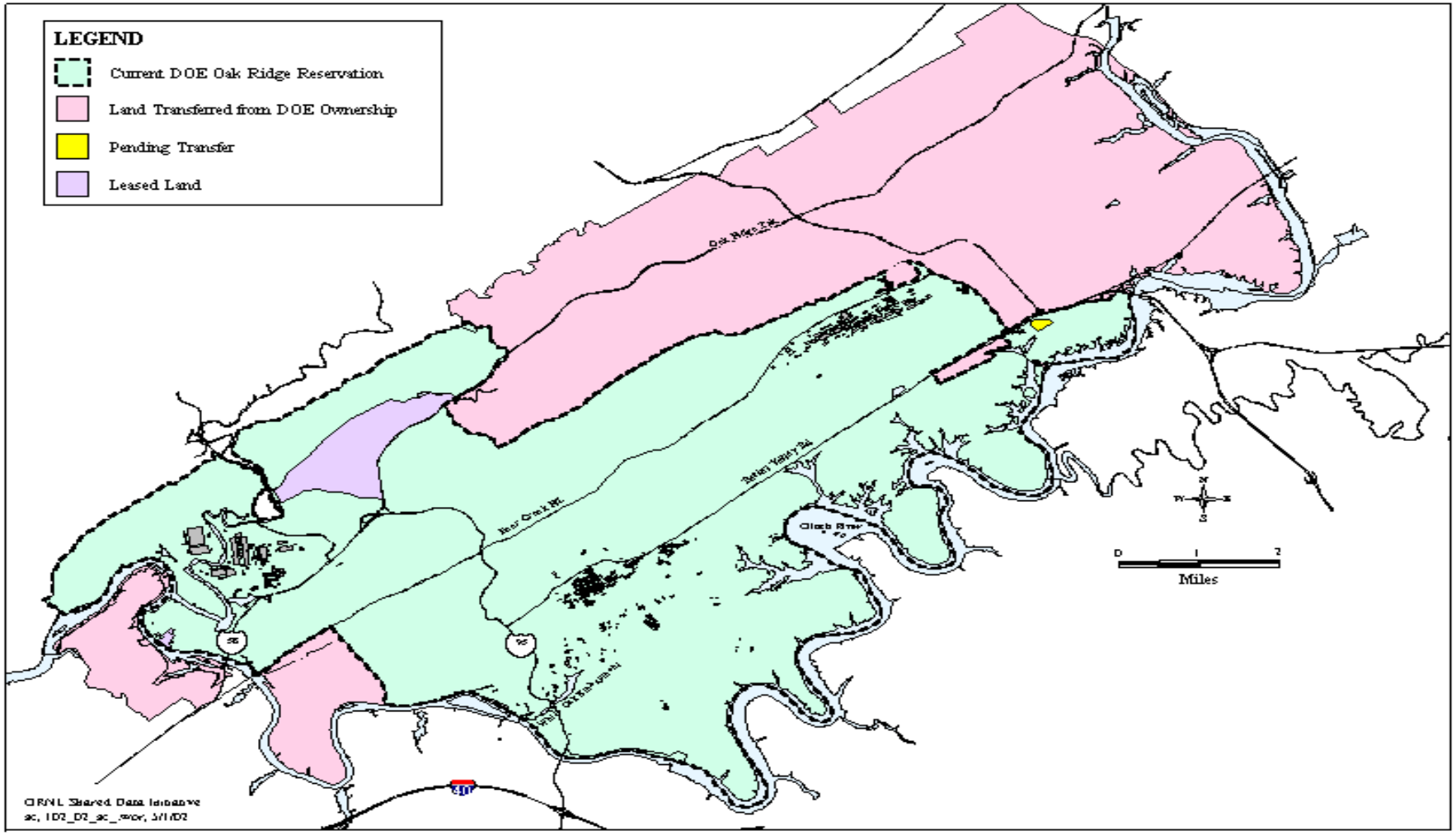


Fig. 1.2. Original DOE land purchase and current reservation boundaries.

Source: ORNL 2002

K-25 Complex

The main objective of the K-25 complex (also known as the Oak Ridge Gaseous Diffusion Plant) from 1945 to 1964, was to use gaseous diffusion to enrich weapons-grade uranium (ChemRisk 1999; EPA 2002a). From 1965 to 1985, the site used uranium hexafluoride in the gaseous diffusion process to manufacture commercial-grade uranium (EUWG 1998). All gaseous diffusion operations ceased at the site in 1985 (ChemRisk 1993a; ORHASP 1999). Since the K-25 complex was officially closed in 1987, many activities have been conducted to clean up wastes and to restore the environment around the site. Since 1996, reindustrialization has been the focus of the K-25 complex, which was consequently renamed the East Tennessee Technology Park (ORHASP 1999; TDOH 2000). The site also maintains the Toxic Substances and Control Act (TSCA) incinerator, which is the only facility in the country authorized to incinerate wastes with radioactive and hazardous contaminants that contain polychlorinated biphenyls (PCBs) (TDEC 2002).

S-50 Site

Construction of the former S-50 liquid thermal diffusion plant began on June 6, 1944, and operations were underway by October 1944. The purpose of the plant was to assess the financial and scientific feasibility of separating uranium 235 from uranium 238 through liquid thermal diffusion. Because of several equipment malfunctions and releases to the Clinch River and to the air, the plant operated for less than a year and was closed in September 1945 (ChemRisk 1999). Because all of the facility's buildings were destroyed and buried in 1946, there are no physical remains of the S-50 site (ChemRisk 1999; TDEC 2002).

II.C. Remedial and Regulatory History

Because ORR operations have generated a variety of radioactive and chemical wastes, ORR was added to the National Priorities List (NPL) in 1989 (EPA 2002b). DOE is conducting cleanup activities at ORR under a Federal Facility Agreement, which is an interagency agreement with the U.S. Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC). This agreement allows for input from the public. These parties are working together to investigate and take remedial action on hazardous waste from past and present activities at the site. DOE is integrating required measures from the Resource Conservation and Recovery Act (RCRA) with response actions under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

> The Federal Facility Agreement, which was implemented on January 1, 1992, is a legally binding agreement to establish timetables, procedures, and documentation for remediation actions at ORR. The Federal Facility Agreement is available online at http://www.bechteljacobs.com/ettp_ffa.shtml.

Contaminants such as uranium and mercury are present in old waste sites, which occupy 5 to 10 percent of ORR. The abundant rainfall (an annual average of 55 inches) and high water tables (for example, 0 to 20 feet below ground surface) on the reservation contribute to leaching of these contaminants, resulting in contaminated soil, surface water, sediments, and groundwater (EUWG 1998).

Since 1986 (when initial cleanup activities commenced), DOE has initiated approximately 50 response actions under the Federal Facility Agreement that address contamination and disposal issues on the reservation. To consolidate investigation and remediation of environmental contamination, the contaminated areas were divided into five large tracts of land, generally associated with the major hydrologic watersheds (EUWG 1998). The annual *Remediation Effectiveness Reports for the U.S. Department of Energy Oak Ridge Reservation* documents the progress of ongoing remedial actions and future planned actions at the site (e.g., SAIC 2004).

II.D. Land Use and Natural Resources

ORR currently has a little over 34,000 acres. The three major DOE installations—the East Tennessee Technology Park (formerly the K-25 complex and the Oak Ridge Gaseous Diffusion Plant), Oak Ridge National Laboratory (formerly the X-10 site), and the Y-12 National Security Complex (formerly the Y-12 plant)—occupy about 30 percent of that acreage. The remaining 70 percent was established as a National Environmental Research Park in 1980, to provide protected land for environmental science research and education and to demonstrate that energy technology development can coexist with a quality environment. Large portions of the reservation, much of which had formerly been cleared for farmland, have grown into full forests over the past several decades. Some of this land includes areas known as “deep forest” that contain ecologically significant flora and fauna; portions of ORR are considered to be biologically rich (SAIC 2002).

ORR also included an area set aside for residential, commercial, and support services. The city of Oak Ridge was created in 1942, to provide housing to the employees of ORR and was originally controlled by the military (Friday and Turner 2001). The self-governing portion of the city of Oak Ridge comprises about 14,000 acres and contains housing, schools, parks, shops, offices, and industrial areas. The urban population of Oak Ridge continued to grow over several decades, and some residential properties are next to the ORR boundary line. Outside the urban areas, much of the region (about 40 percent) is still a pattern of farms and small communities, as it was historically (ChemRisk 1993b).

A number of maps of this area indicate a wide range of land types, including urban or built-up land, agricultural land, rangeland, forestland, water, and wetlands, as well as land uses, including residential, commercial, public and semi-public, industrial, transportation, communication, utility, and extractive (e.g., mining) (ChemRisk 1993b).

Agriculture (beef and dairy cattle) and forestry had been the two predominant land uses in the area around ORR; however, both of these uses are currently declining. For many years, milk was produced, bottled, and distributed locally. Corn, tobacco, wheat, and soybeans were the major crops grown in the area. Small game and waterfowl are hunted in the area (both on and off ORR), and deer are hunted during certain periods (ChemRisk 1993b). Radiological monitoring is performed during the annual deer hunts to “provide assurance that harvested animals do not contain levels of radionuclides which would result in significant internal exposure to humans consuming meat from the animals” (Teasley 1995). Fishing is not permitted on site, however, fish can move into public ally accessed areas. Most of the contamination is located at the three main facilities. These areas are heavily guarded and fenced and access to these areas requires a clearance badge.

II.E. Demographics

Demographic data provide information on the size and characteristics of a given population. ATSDR examined demographic data to determine the number of people living in the vicinity of ORR and to determine the presence of sensitive populations, such as children (age 6 years and younger), women of childbearing age (age 15 to 44 years), and the elderly (age 65 years and older). According to the 2000 U.S. Census, 153 children, 403 women of childbearing age, and 423 elderly persons live within a quarter mile from ORR; and 778 children, 1,935 women of childbearing age, and 1,681 elderly persons live within a mile of ORR (see Figure 3).

Demographics also provide details on population mobility and residential history in a particular area. This information helps ATSDR evaluate how long residents might have been exposed to environmental contaminants. The numbers of people living in the counties surrounding ORR from 1940 to 2000 are listed in Table 1. The numbers of people living in the main cities within these counties from 1940 to 2000 are listed in Table 2.

Table 1. Population of Surrounding Counties from 1940 to 2000

County	*1940*	*1950*	*1960*	*1970*	*1980*	*1990*	*2000*
Anderson County	26,504	59,407	60,032	60,300	67,346	68,250	71,330
Blount County	41,116	54,691	57,525	63,744	77,770	85,969	105,823
Knox County	178,468	223,007	250,523	276,293	319,694	335,749	382,032
Loudon County	19,838	23,182	23,757	24,266	28,553	31,255	39,086
Meigs County	6,393	6,080	5,160	5,219	7,431	8,033	11,086
Morgan County	15,242	15,727	14,304	13,619	16,604	17,300	19,757
Rhea County	16,353	16,041	15,863	17,202	24,235	24,344	28,400
Roane County	27,795	31,665	39,133	38,881	48,425	47,227	51,910

Sources: U.S. Bureau of the Census 1900–1990, 2000

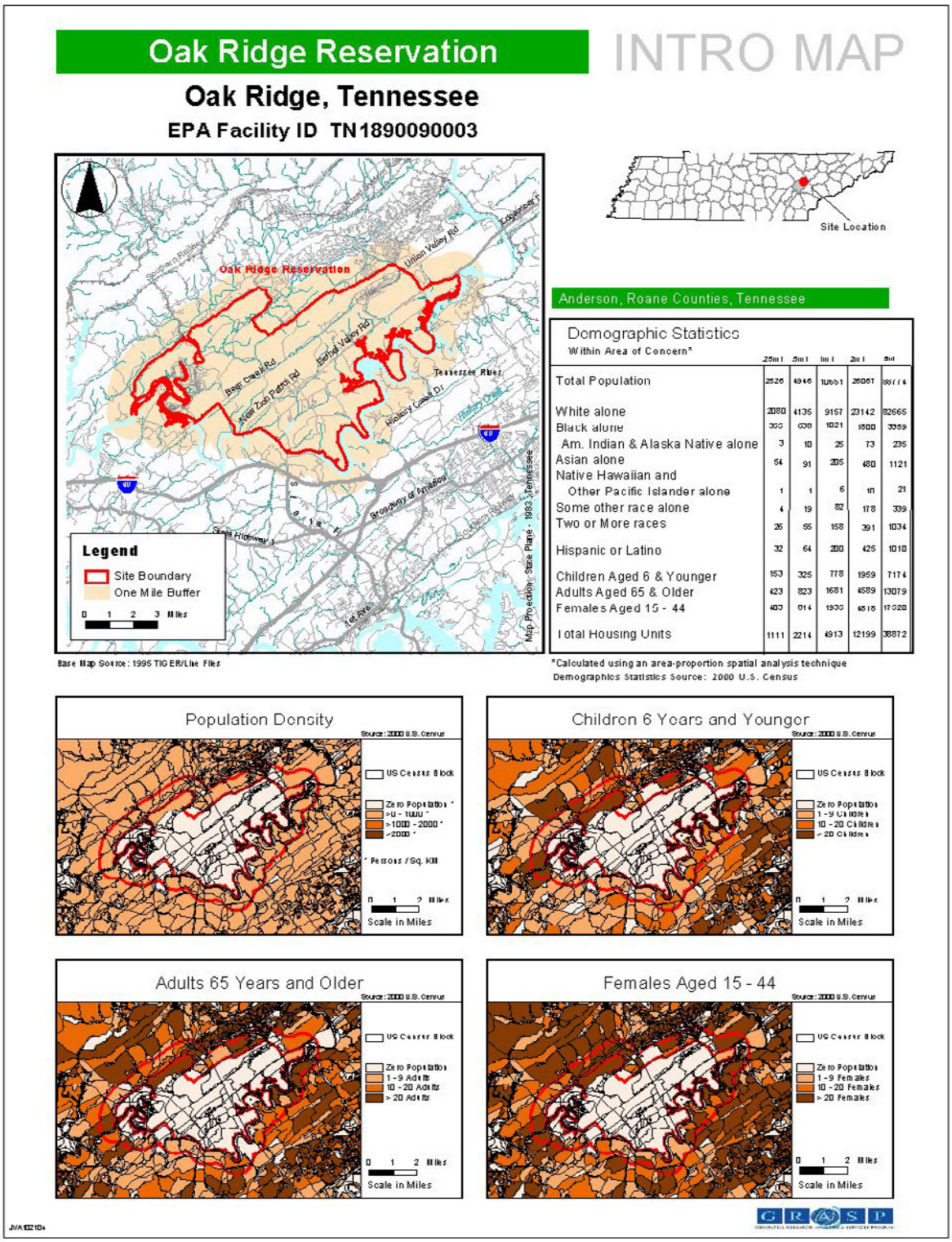
Table 2. Population of Surrounding Cities from 1940 to 2000

	1940	*1950*	*1960*	*1970*	*1980*	*1990*	*2000*
Clinton	2,761	3,712	4,943	4,794	7,790	8,972	9,409
Harriman	5,620	6,389	5,931	8,734	8,303	7,119	6,744
Kingston	880	1,627	2,010	4,142	4,561	4,552	5,264
Knoxville	111,580	124,769	111,827	174,587	175,045	165,121	173,890
Lenoir City	4,373	5,159	4,979	5,324	5,505	6,147	6,819
Loudon	3,017	3,567	3,812	3,728	4,199	4,026	4,476
Maryville	5,609	7,742	10,348	13,808	17,480	19,208	23,120
Oak Ridge	3,000*	30,229	27,169	28,319	27,662	27,310	27,387
Oliver Springs	--	189	1,163	3,405	3,659	3,433	3,303
Rockwood	3,981	4,272	5,345	5,259	5,695	5,348	5,774
Spring City	1,569	1,725	1,800	1,756	1,951	2,199	2,025

Sources: ChemRisk 1993b; City of Oak Ridge 1989; Convention and Visitors Bureau 2003; U.S. Census Bureau 1940, 1950, 1960, 1970, 1980, 1990, 2000

* Combined population on land that was established as Oak Ridge in 1942, with 13,000 initial residents.

Figure 3. Demographics Within a 5-mile Radius of ORR



Oak Ridge, Tennessee was established in Anderson County in 1942, for the 13,000 people expected to work at ORR (Friday and Turner 2001). In order to present decade-by-decade size comparison for the available census intervals, Table 2 understates the city's dramatic population growth and its contrast with the growth of its neighbors. By July 1944, the population of Oak Ridge had increased to 50,000. The population peaked at 75,000 in 1945, and decreased to 30,229 by 1950, and to 27,169 by 1960, but was relatively stable thereafter (see Table 2) (City of Oak Ridge 1989). In 1959, about 14,000 acres within the city of Oak Ridge became self-governing (ChemRisk 1993b). Almost since its establishment, the city of Oak Ridge has been the largest population center in eastern Tennessee (ChemRisk 1993b).

II.F. Public Health Activities

Since 1992, ATSDR has addressed the health concerns of community members, civic organizations, and other government agencies by working extensively to determine whether levels of environmental contamination at and near ORR present a public health hazard. During this time, ATSDR has identified and evaluated several public health issues and has worked closely with many parties, including community members, civic organizations, physicians, and several federal, state, and local environmental and health agencies. Since the Tennessee Department of Health (TDOH) conducted the Oak Ridge Health Studies to evaluate whether off-site populations have experienced exposures in the *past*, ATSDR's activities have focused on *current* and *future* public health issues with Superfund cleanup activities at the East Fork Poplar Creek and the Watts Bar Reservoir. The ATSDR ORR Web site (http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html) highlights the major public health activities conducted by ATSDR at ORR.

Oak Ridge Reservation Health Effects Subcommittee. The ORRHES was established in 1999, by ATSDR and the Centers for Disease Control and Prevention (CDC) under the authority of the Federal Advisory Committee Act, and as a subcommittee of the U.S. Department of Health and Human Services' Citizens Advisory Committee on Public Health Service Activities and Research at DOE sites. The subcommittee consists of people who represent diverse interests, expertise, backgrounds, and communities, as well as liaison members from federal and state agencies. It was created to provide a forum for communication and collaboration between the citizens and the agencies that are evaluating public health issues and conducting public health activities at ORR. To help ensure citizen participation, the meetings of the subcommittee's work groups are open to the public and everyone can attend and present their ideas and opinions. The subcommittee performs the following functions:

- Serves as a citizen advisory group to CDC and to ATSDR and makes recommendations on matters related to public health activities and research at ORR.
- Gives citizens an opportunity to collaborate with agency staff members and to learn more about the public health assessment process and other public health activities.
- Helps to prioritize the public health issues and community concerns to be evaluated by ATSDR.

The ORRHES created various work groups to conduct in-depth exploration of specific issues and present findings to the subcommittee for deliberation. Work group meetings are open to all who wish to attend and participate.

ATSDR Field Office. In 2001, ATSDR opened a field office in the city of Oak Ridge. The office was opened to promote collaboration between ATSDR and the communities surrounding ORR by providing community members with opportunities to become involved in ATSDR's public health activities at ORR. The ATSDR field office is located at 1975 Tulane Avenue, Oak Ridge, Tennessee. ATSDR's field office staff can be contacted by calling 865-220-0295.

Other Public Health Activities. ATSDR, CDC's National Center for Environmental Health and National Institute for Occupational Safety and Health, TDOH, TDEC, and DOE have responded over the years to workers and communities concerned about potential exposures and reported unexplained illnesses afflicting workers and residents. The *Compendium of Public Health Activities* outlines the past and present strategies used to address and evaluate public health issues related to chemical and radioactive substances released from ORR. The compendium can be found on the ATSDR ORR Web site at http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html.

Where can one obtain more information on ATSDR's activities at Oak Ridge?

ATSDR has conducted several analyses that are not documented here, as have other agencies that have been involved with this site. Community members can find more information on ATSDR's past activities by the following three ways:

1. *Visit one of the records repositories*. Copies of ATSDR's publications on ORR, along with publications from other agencies, can be viewed in records repositories at the ATSDR Field Office in Oak Ridge, DOE Information Center, Harriman Public Library, Kingston City Library, Oak Ridge Public Library, Roane State Community College, and the Rockwood Public Library. For directions to these repositories, please contact the ATSDR Oak Ridge field office at (865) 220-0295.

2. *Visit the ATSDR or ORRHES Web sites*. These Web sites include our past publications, schedules of future events, and other materials. ATSDR's Web site is at http://www.atsdr.cdc.gov/and the ORRHES site is at http://www.atsdr.cdc.gov/HAC/oakridge. The most comprehensive summary of past activities can be found at http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html.

3. *Contact ATSDR directly*. Residents can contact representatives from ATSDR directly by dialing the agency's toll-free number, 1-888-42ATSDR (1-888-422-8737).

II.G. Past Screening Evaluation

In 2001, ATSDR scientists conducted a review and analysis of TDOH's Oak Ridge Health Studies to identify contaminants that require further public health evaluation. During the Phase I and Phase II screening evaluations, the TDOH conducted extensive reviews of available information and conducted qualitative and quantitative analyses of past (1944 to 1990) releases and off-site exposures to hazardous substances from the entire ORR (see Figure 4).

- *Phase I* of the Oak Ridge Health Study is a Dose Reconstruction Feasibility Study. This feasibility study evaluated all past releases of hazardous substances and operations at ORR. The objective of the study was to determine the quantity, quality, and potential usefulness of the available information on the past releases and subsequent exposure pathways. Phase I of the health studies began in May 1992, and was completed in September 1993. A brief summarizing the Phase I Feasibility Study is provided in Appendix C.

- *Phase II (also referred to as the Oak Ridge Dose Reconstruction)* of the Oak Ridge Health Study began in mid-1994, and was completed in early 1999. Phase II primarily consisted of a dose reconstruction study focusing on past releases of radioactive iodine, radionuclides from White Oak Creek, mercury, and PCBs. In addition to the full dose reconstruction analyses, the Phase II effort also included additional detailed screening analyses for releases of uranium and several other toxic substances that had not been fully characterized in Phase I (a brief in Appendix C summarizes the Screening-Level Evaluation of Additional Potential Materials of Concern, Task 7).

On the basis of ATSDR's review and analysis of TDOH's Phase I and Phase II screening evaluations, ATSDR scientists are conducting public health assessments on Y-12 uranium releases; K-25 uranium and fluoride releases; releases of radionuclides from White Oak Creek; Y-12 mercury releases; X-10 iodine 131 releases; PCBs released from X-10, Y-12, and K-25; and other issues of community concern, such as the Toxic Substances Control Act (TSCA) incinerator and off-site groundwater. The public health assessment is the primary public health process ATSDR is using to further evaluate these contaminants.

This public health assessment documents ATSDR's screening of recent (1990 to 2003)[2] environmental data to address whether additional chemicals require further evaluation and discusses the public health implications related to estimated exposure doses.

[2] Data prior to 1990 was evaluated during TDOH's past screening evaluation. ATSDR initiated the current screening evaluation in 2003.

Figure 4. State of Tennessee Screening Process For Past Exposure

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Oak Ridge Health Study Phase I Report - Dose Reconstruction Feasability Study

Task 1 and Task 2

Process: Are there sufficient quantities of contaminants associated with significant off-site releases?

NO →

Results — Not a Contaminant of Concern

Americium 241*	Selenium 75	Acetic acid	Nitric acid
Californium 252	Uranium 233	Ammonium hydroxide	Phosgene
Carbon 14*	Berkelium	Chlorofluorocarbons (Freons)	Potassium hydroxide
Cobalt 57	Estinsteinium	Chlorine trifluoride	Sulfuric acid
Cesium 134	Fermium	Fluorine and various fluoride compounds	Sodium hydroxide
Curium 242, 243, 244	Lithium	Hydrochloric acid	Polyaromatic hydrocarbons
Europium 152, 154*, 155	Benzene	Hydrogen peroxide	Asbestos
Phosphorus 32*	Chloroform	Hydrofluoric acid	Pesticides

Type of Screening/Rational — Qualitative Evaluation
- Used in small quantities.
- Not believed to be associated with significant off-site releases.

YES ↓

Task 3 and Task 4

Process: Is the contaminant a high priority for further study based on the relative magnitude of potential hazard?

NO →

Results

Carbon tetrachloride	Iodine 129
Methylene chloride	Krypton 85
Tetrachloroethylene	Ruthenium 103
1,1,1-Trichloroethane	Thorium 232
Trichloroethylene	Protactinium 233
Argon 41	Plutonium 238, 239*, 240*
	Xenon 133

* Screened again in Task 4

Type of Screening/Rational — Relative Hazard Ranking Evaluation
- The relative potential hazard is less than 1% of the screening hazard calculated for the contaminant that poses the greatest potential to impact off-site populations.
- All but two contaminants had a relative potential hazard of less than 0.03%.

YES ↓

Dose Reconstruction

Tasks 1-5

Process: Highest priority contaminants for further study

Results — Highest Priority Contaminants

Iodine 131 - X-10 radioactive lanthanum process
Radionuclide releases from White Oak Creek - X-10 chemical separation processes
Mercury - Y-12 lithium separation and enrichment operations
PCBs - K-25/Y-12 transformers/machining
Uranium - K-25/Y-12 gaseous diffusion operations/production operations

Type of Screening/Rational — Dose Reconstruction
- Described and quantify past releases.
- Characterized environmental concentrations.
- Defined potential human exposure pathways.
- Described potentially exposed populations.
- Estimated historical human exposures and doses.
- Estimated human health hazards.

Oak Ridge Dose Reconstruction-Task 7 Report- Screening-level Evaluation of Additional Potential Materials

Qualitative Screening

Process: Are quantities and forms used likely to pose an off-site health hazard?

NO →

Results — Not a Contaminant of Concern

Boron carbide	Tellurium
Boron nitride	Triplex coating
Yttrium boride	Carbon fibers
Titanium boride	Glass fibers
Rubidium bromide	Four-ring polyphenyl ether
Rubidium nitrate	Zirconium

Type of Screening/Rational — Qualitative Evaluation
- Evaluated for quantities used, forms used, and manners of use.
- Unlikely that off-site releases of materials could have been sufficient to pose an off-site health hazard.

YES ↓

Threshold Quantity Approach

Process: Are on-site inventories sufficient to pose an off-site health hazard?

NO →

Results

Niobium
TMAB
Zirconium

Type of Screening/Rational — Threshold Quantity Approach
- Estimated inventories of materials were determined to be below a conservatively calculated health-based threshold quantity.
- On-site quantities have little likelihood of being released off-site in quantities that could pose a health hazard.

YES ↓

Quantitative Screening

Process: Does the conservatively estimated dose exceed the EPA Reference Dose? Does the conservatively estimated cancer risk exceed the lifetime cancer risk of 1 in 10,000?

NO →

Results

Tritium* (cancer)
Neptunium 237 (cancer)
Beryllium (noncancer)

* Screened again in Task 4

Type of Screening/Rational — Quantitative Two-Level Evaluation
- Estimated doses or cancer risks for a maximally exposed reference individual were compared to the EPA Reference Dose or the lifetime cancer risk of 1 in 10,000.
- Identified materials for which doses or risks are clearly below a minimum level of health concern.

YES ↓

Candidates for Further Study

Process: Potential and high priority candidates for further study

YES →

Results — Potential Candidates

Beryllium (cancer)	Lithium (noncancer)
Chromium (cancer, noncancer)	Nickel (cancer, noncancer)
Copper (noncancer)	Technetium 99 (cancer)

High Priority Candidates

Arsenic (cancer, noncancer)
Lead (noncancer)

Type of Screening/Rational — Quantitative Two-Level Evaluation
- Estimated doses or cancer risks for a typically exposed reference individual were compared to the EPA Reference Dose or the lifetime cancer risk of 1 in 10,000.
- Identified materials for which doses or risks are above a minimum level of health concern.
- Potential and high priority candidates will be evaluated using ATSDR's screening processs

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III. Evaluation of Environmental Contamination and Potential Exposure Pathways

III.A. Introduction

What Does Exposure Mean?

ATSDR's public health assessments are driven by exposure, or contact. Chemicals released into the environment have the potential to cause harmful health effects, but a release does not always result in exposure. People can only be exposed to a chemical if they come in contact with that contaminant. For exposure to occur, a completed exposure pathway must exist. If no one comes in contact, then exposure does not occur, and thus adverse health effects would not result. Often the general public does not have access to the source area of contamination or areas where contaminants are moving through the environment. Understanding how people have access to these areas becomes important in determining whether people could come in contact with the contaminants.

> A completed exposure pathway has five elements: (1) a source of contamination, (2) an environmental media (such as, soil, water, or air) through which a chemical is transported, (3) a point of exposure, (4) a route of exposure, and (5) an exposed population (receptor population). The source is the place where the chemical was released. The environmental media transport the chemicals. The point of exposure is the place where persons come in contact with the media. The route of exposure (for example, ingestion, inhalation, or dermal contact) is the way the contaminant enters the body. The people exposed are called the receptor population. A potential exposure pathway exists when one or more of the elements is missing, but available information suggests that exposure is possible.

The route a chemical takes from its source (where it began) to its exposure point (where it ends), and how people can contact it (how people get exposed) is called the exposure pathway. ATSDR identifies and evaluates exposure pathways by considering how people might come into contact with a chemical. An exposure pathway could involve air, surface water, groundwater, soil, sediment, or even plants and animals. Exposure can occur by breathing, eating, drinking, or by skin contact with a substance containing the chemical contaminant.

How Does ATSDR Determine Which Exposure Situations to Evaluate?

ATSDR scientists evaluate site-specific conditions to determine whether people are being exposed to site-related chemicals. When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (soil, water, air, or biota) is occurring through ingestion, dermal (skin) contact, or inhalation.

If exposure is possible, ATSDR scientists then consider whether environmental contamination is present at levels that might affect public health. ATSDR evaluates environmental contamination using available environmental sampling data and, in some cases, modeling studies.

More information about the ATSDR evaluation process can be found in ATSDR's *Public Health Assessment Guidance Manual* at http://www.atsdr.cdc.gov/HAC/HAGM/ or by contacting ATSDR at 1-888-42-ATSDR. An interactive program that provides an overview of the public health assessment process ATSDR uses to evaluate whether people will be harmed by hazardous

materials is available at http://www.atsdr.cdc.gov/training/public-health-assessment-overview/html/index.html.

If Someone is Exposed, Will They Get Sick?

Chemical exposure does not always result in harmful health effects. The type and degree of health effects that occur in an individual as the result of contact with a chemical depend on the exposure concentration (how much), the frequency of exposure (how often), duration of exposure (how long), the route or pathway of exposure (breathing, eating, drinking, or skin contact), and potentially the combination of chemicals. Once exposure occurs, factors such as age, sex, genetics, lifestyle, nutritional status, and health status of the exposed individual influence how that individual absorbs, distributes, metabolizes, and excretes the contaminant. Taken together, these factors and characteristics determine the health effects that can occur as a result of exposure to a chemical.

III.B. Methodology

ATSDR screened all available current chemical data to determine whether concentrations were above ATSDR's comparison values (see description below). Figure 5 illustrates ATSDR's chemical screening process. ATSDR also reviewed relevant toxicologic and epidemiologic data to obtain information about the toxicity of the chemicals to more completely understand the public health implications of exposure.

Comparing Environmental Concentrations to Comparison Values

A comparison value is used by ATSDR to screen chemicals that require additional evaluation.

ATSDR uses the term "conservative" to refer to values that are protective of public health in essentially all situations.

ATSDR selects chemicals for further evaluation by comparing the maximum environmental concentrations against media-specific health-based comparison values. The maximum concentrations are used at this step of the screening process as a conservative measure even though we know that people are exposed to a range of concentrations and not just the maximum reported levels. Comparison values are developed by ATSDR from available scientific literature concerning exposure and health effects. Comparison values are derived for each of the media and reflect a concentration that is not expected to cause harmful health effects for a given contaminant, assuming a standard daily contact rate (for example, the amount of water or soil consumed or the amount of air breathed) and representative body weight (child or adult). Because they reflect concentrations that are much lower than those that have been observed to cause adverse health effects, comparison values are protective of public health in essentially all exposure situations. As a result, **exposure to chemical concentrations detected at or below ATSDR's comparison values are not expected to cause health effects in people. Therefore, levels below media-specific comparison values do not pose a public health hazard and are not evaluated further for a given media.**

Figure 5. ATSDR Chemical Screening Process

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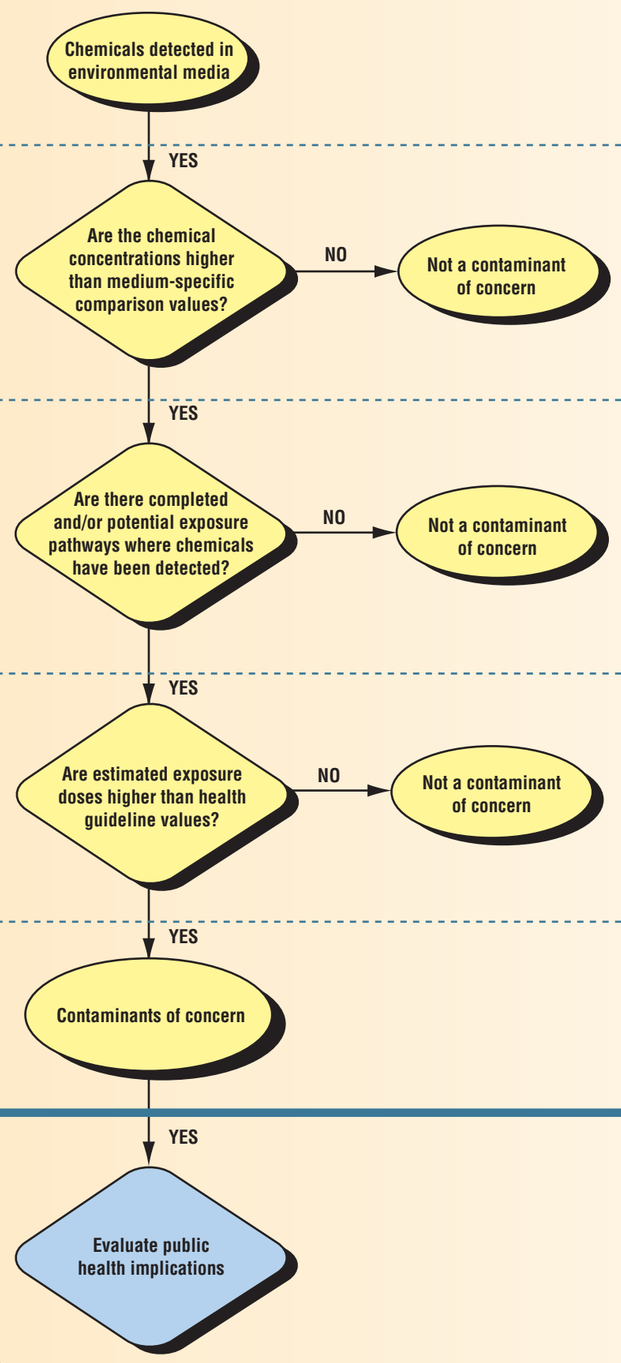
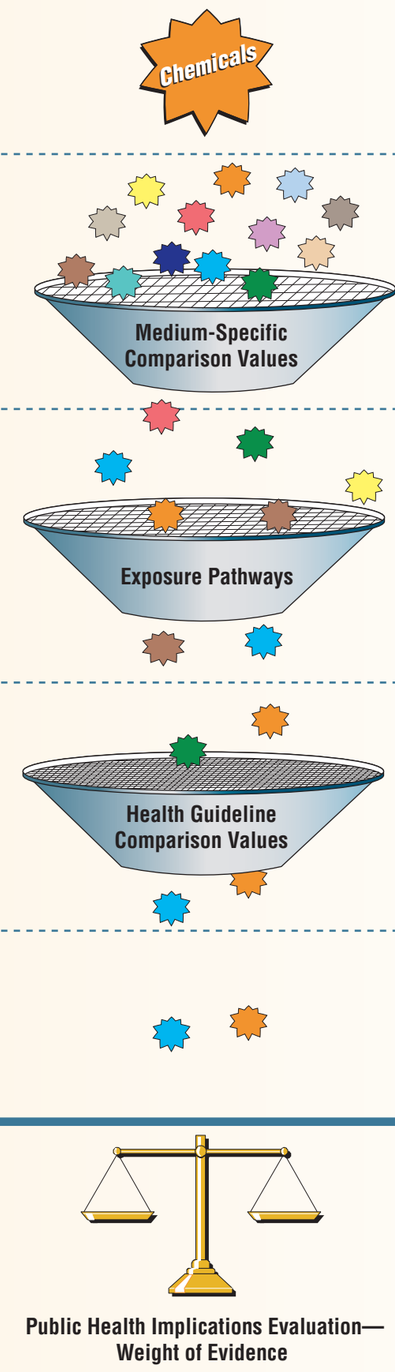
Decision Diagram



Illustration



Criteria

Preliminary Screening

- Based on the results of environmental investigations
- Based on maximum exposure conditions
  - maximum concentration detected
  - maximum exposure duration
  - maximum exposure frequency
  - maximum exposure bioavailability

Pathway Evaluation

- Can or are exposures occurring
- Identify potential or completed exposure pathways

Exposure Dose Comparison

- Estimate doses based on site-specific exposure conditions
- Use more realistic exposure assumptions
  - realistic concentrations
  - realistic exposure duration
  - realistic exposure frequency
  - realistic exposure bioavailability
  - site-specific receptor population

Contaminants of Concern

- Evaluate the public health implications of contaminants of concern in greater detail

Public Health Implications

- Review toxicologic, medical, epidemiologic, and other scientific data on the contaminants of concern
- Evaluate whether contaminants of concern can affect public health in the vicinity of the site

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ATSDR's cancer risk evaluation guides (CREGs), environmental media evaluation guides (EMEGs), and reference dose media evaluation guides (RMEGs) are conservative, health-based comparison values developed for screening environmental concentrations for further evaluation. EPA's risk-based concentration (RBC) is a health-based comparison value developed to screen sites not yet on the NPL, respond rapidly to citizens' inquiries, and spot-check formal baseline risk assessments.

While concentrations at or below the respective comparison value can be considered safe, it does not automatically follow that any environmental concentration exceeding a comparison value would be expected to produce adverse health effects. Comparison values are not health effect thresholds. ATSDR comparison values represent concentrations that are many times lower than levels at which no effects were observed in studies on experimental animals or in human epidemiologic studies. The likelihood that adverse health outcomes will actually occur depends on site-specific conditions, individual differences, and factors that affect the route, magnitude, and duration of actual exposure. **If contaminant concentrations are above comparison values, ATSDR further analyzes exposure variables (such as site-specific exposure duration and frequency) for health effects, including the toxicity of the chemical, epidemiology studies, and the weight of evidence.**

Weight-of-evidence: The extent to which the available scientific information support the hypothesis that a substance causes an adverse effect in humans. For example, factors which determine the weight-of-evidence that a chemical poses a hazard to humans include the number of tissue sites affected by the agent; the number of animal species, strains, sexes, and number of experiments and doses showing a response; the dose-response relationship, statistical significance in the occurrence of the adverse effect in treated subjects compared with untreated controls; and the timing of the occurrence of the adverse effect.

Essential nutrients (e.g., calcium, magnesium, phosphorus, potassium, and sodium) are minerals that maintain basic life functions; therefore, certain doses are recommended on a daily basis. Because these chemicals are necessary for life, screening guidelines do not exist for them. They are found in many foods, such as milk, bananas, and table salt. For example, the Food and Nutrition Board of the Institute of Medicine of the National Academy of Sciences has recommended the following adequate intakes (AI) and Recommended Dietary Allowance (RDA) for phosphorus: for infants 0 to 6 months and 7 to 12 months, the AI is 100 and 275 milligrams per day (mg/day), respectively. For children 1 to 3 years and 4 to 8 years, the RDA is 460 and 500, respectively. For children 9 to 18 years, the RDA is 1,250 mg/day. Adults 19 years and older have an RDA of 700 mg/day. A no-observed-adverse-effect level (NOAEL) for phosphorus for adults is 10.2 grams/day—or more than 10,000 mg/day. Therefore, calcium, magnesium, phosphorus, potassium, and sodium were not considered for further evaluation.

A **NOAEL** is the highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals in a study.

Comparing Estimated Exposure Doses to Screening Guideline Values

If chemical concentrations are above comparison values, ATSDR further evaluates the chemical and potential exposure. ATSDR does this by calculating exposure doses and comparing the doses to protective screening guideline values, including ATSDR's minimal risk levels (MRLs) and

EPA's reference doses (RfDs). **Estimated exposure doses that are less than screening guideline values are not a public health hazard and are not evaluated further.**

> An exposure dose, expressed in milligrams per kilogram per day (mg/kg/day), is the estimated amount of chemical a person is exposed to over time.

When estimating hypothetical exposure doses, health assessors evaluate chemical concentrations to which people could have been exposed, together with the length of time and the frequency of exposure. Collectively, these factors influence an individual's physiological response to chemical exposure and potential outcomes. Where possible, ATSDR used site-specific information regarding the frequency and duration of exposures. When site-specific information was not available, ATSDR employed several protective assumptions to estimate exposures.

The following general equation was used to calculate exposure doses:

$$\text{Estimated exposure dose} = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

where:

C = Concentration of chemical
IR = Intake Rate
EF = Exposure Frequency, or number of exposure events per year of exposure
ED = Exposure Duration, or the duration over which exposure occurs
BW = Body Weight
AT = Averaging Time, or the period over which cumulative exposures are averaged

Environmental concentrations of most soil and sediment contaminants are log-normally distributed; meaning that a few samples have high concentrations while most of the samples have much lower concentrations (Shacklette and Boergen 1984). EPA soil screening guidance (EPA 1996a, 2002c) recommends use of a spatially averaged concentration (i.e., the 50th percentile concentration over the exposure area). However, ATSDR chose to use a more conservative second-tier screening concentration[3] (defined as one standard deviation above the average concentration) to estimate exposure doses during this phase of the screening process (i.e., to identify chemicals for further evaluation) to account for the variability of the samples. Use of the second-tier screening concentration is a health protective estimate of the concentration, and results in a more conservative (protective) screening process since the exposure doses are calculated using a concentration that is higher than the average concentration.

Using the general equation given above, the exposure parameters listed in Table 3, and the second-tier screening concentration, ATSDR derived hypothetical exposure doses for residents living near the site. ATSDR compared these estimated site-specific exposure doses against noncancer and cancer screening guideline values. ATSDR's MRLs and EPA's RfDs are estimated doses of daily human exposure to substances that are likely to be without appreciable risk of adverse *noncancer* health effects over a specified duration of exposure. MRLs and RfDs

[3] For chemicals detected in at least 10 percent of the samples, the second-tier screening concentrations were calculated using detected concentrations only and do not take into account nondetected values. For chemicals detected in less than 10 percent of the samples, ATSDR calculated second-tier screening concentrations using 1/2 the detection limit for nondetected samples.

are derived for chemicals using the NOAEL/lowest-observed-adverse-effect level (LOAEL)/uncertainty factor approach. They are derived when reliable and sufficient human or animal data exist to identify the most sensitive health effect for a given route of exposure. MRLs and RfDs are generally based on the most sensitive end point considered to be of relevance to humans. Because of the lack of precise toxicologic information on people who might be most sensitive (for example, infants, the elderly, or persons who are nutritionally or immunologically compromised) to the effects of hazardous substances, MRLs and RfDs have built-in safety factors, making these values considerably lower than doses at which health effects have been observed. Therefore, these screening guideline values are below doses that cause adverse health effects in people most sensitive to such effects. Consistent with the public health principle of prevention, ATSDR uses this conservative (protective) approach to maximize human health protection and to address this uncertainty in toxicologic information.

These chemical-specific guideline values, which serve as screening levels, are used to identify chemicals for further consideration. It is important to note that MRLs and RfDs are not thresholds for health effects and are not intended to define cleanup or action levels. They are intended only to serve as a screening tool to help public health professionals decide what chemicals and pathways to look at more closely. While estimated exposure doses that are less than MRLs or RfDs are not considered to be a public health hazard, exposure to doses above these screening values does not automatically imply that adverse health effects will occur. Rather, it is an indication that ATSDR should further examine the health effect levels reported in the scientific literature and more fully review exposure potential.

In addition, to screen for cancer effects, estimated chronic-exposure doses (30-year exposure averaged over 70 years) were multiplied by EPA's cancer slope factors (CSFs), which estimate the relative potency of carcinogens. This calculation estimated a theoretical excess cancer risk expressed as the proportion of a population that might be affected by a carcinogen during a lifetime of exposure. For example, an estimated cancer risk of 1×10^{-6} predicts the probability of one additional cancer over background in a population of 1 million. Because conservative models are used to derive CSFs, the doses associated with these hypothetical risks are typically orders of magnitude lower than doses reported in the toxicologic literature to cause carcinogenic effects. As such, a low cancer risk estimate indicates that the toxicology literature would support a finding that no excess cancer risk is likely. A higher cancer risk estimate, however, indicates that ATSDR should carefully review the scientific literature before making conclusions about potential cancer risks.

Table 3. Parameters Used in the Exposure Dose Calculations for ORR

	Soil	*Sediment*	*Surface Water*	*Biota*			
				Fish		*Game*	*Vegetation*
Ingestion Rate				*Subsistence*	*Recreational*		
▪ Adult	0.00005 kg/day	0.0001 kg/day	0.5 liter/day*	0.065 kg/day	0.008 kg/day	0.002 kg/day	0.0016 kg/kg/day§
▪ Child	0.0002 kg/day	0.0001 kg/day	0.5 liter/day*	0.02 kg/day	0.003 kg/day	0.001 kg/day	0.0016 kg/kg/day§
▪ Pica child	0.005 kg/day	N/A	N/A	N/A	N/A	N/A	N/A
Exposure Frequency							
▪ Adult	291.2 days/yr	12 days/yr		365 days/yr			
▪ Child	291.2 days/yr	12 days/yr		365 days/yr			
▪ Pica child	52 days/yr	N/A		N/A			
Exposure Duration							
▪ Adult	30 yrs						
▪ Child	6 yrs						
▪ Pica child	3 yrs						
Body Weight							
▪ Adult	70 kg						
▪ Child	13 kg						
▪ Pica child	10 kg						
Averaging Time	Noncancer			Cancer/Lifetime			
▪ Adult	365 days/yr*30 yrs			365 days/yr*70 yrs			
▪ Child	365 days/yr*6 yrs			N/A			
▪ Pica child	365 days/yr*3 yrs			N/A			

*The surface water ingestion rate was changed to 0.15 liter/day for the public health evaluation (see Section IV.C) to represent a three-hour swimming event (EPA 1999).

§The body weight parameter is built into the ingestion rate for the vegetation dose equation.

Exposure doses are not calculated for the air pathway. Screening guidelines are reported in concentrations.

Cancer doses assume a 30-year exposure averaged over a 70-year lifetime.

kg = kilogram

N/A = not applicable

yr = year

Comparing Estimated Exposure Doses to Health Effects Levels

If the MRLs or RfDs are exceeded, ATSDR determines the public health implications of estimated exposures by examining the effect levels discussed in the scientific literature and more fully reviews exposure potential. ATSDR reviews available human studies as well as experimental animal studies. This information is used to understand the disease-causing potential of a chemical and to compare site-specific exposure dose estimates with doses reported to result in illness. This process enables ATSDR to weigh the available evidence in light of uncertainties and offer perspective on the plausibility of harmful health outcomes under site-specific conditions.

Sources for Health-based Guidelines

By Congressional mandate, ATSDR prepares toxicological profiles for hazardous substances found at contaminated sites. Toxicological profiles were used to evaluate potential health effects at ORR. ATSDR's toxicological profiles are available on the Internet at http://www.atsdr.cdc.gov/toxpro2.html or by contacting the National Technical Information Service (NTIS) at 1-800-553-6847. EPA also develops health effects guidelines, and in some cases, ATSDR relied on EPA's guidelines to evaluate potential health effects. These guidelines are found in EPA's Integrated Risk Information System (IRIS)—a database of human health effects that could result from exposure to various substances found in the environment. IRIS is available on the Internet at http://www.epa.gov/iris. For more information about IRIS, call EPA's IRIS hotline at (301) 345-2870 or send an e-mail to Hotline.IRIS@epamail.epa.gov.

III.C. Environmental Data

As discussed earlier, ATSDR's public health assessments are driven by exposure. If no one comes in contact with a contaminant, then no exposure occurs, and thus no health effects could occur. Therefore, this screening of current and future chemical exposures focuses primarily on contaminants detected in off-site locations, where exposures are more likely to occur (as opposed to on-site locations, where access is restricted[4]). However, because there are limited off-site air samples, and people have access to on-site fish and game, on-site exposures to these media are also included. ATSDR is evaluating exposures to chemicals detected in off-site groundwater in a separate, pathway-specific public health assessment.

For this document, ATSDR's evaluation used environmental sampling data within the ORRHES Area of Interest (see Figure 6) from 1990 to 2003. The Oak Ridge Environmental Information System (OREIS)—a centralized, standardized, quality-assured, and configuration-controlled environmental data management system—supplied the data. Because an abundance of environmental data exist for ORR, DOE created an electronic data management system (OREIS) to integrate all of the data into a single database. This database was developed to facilitate public and government access to environmental data related to ORR operations, while also maintaining data quality. DOE's objective was to ensure that the database had long-term retention of the environmental data and useful methods to access the information. OREIS contains data related to

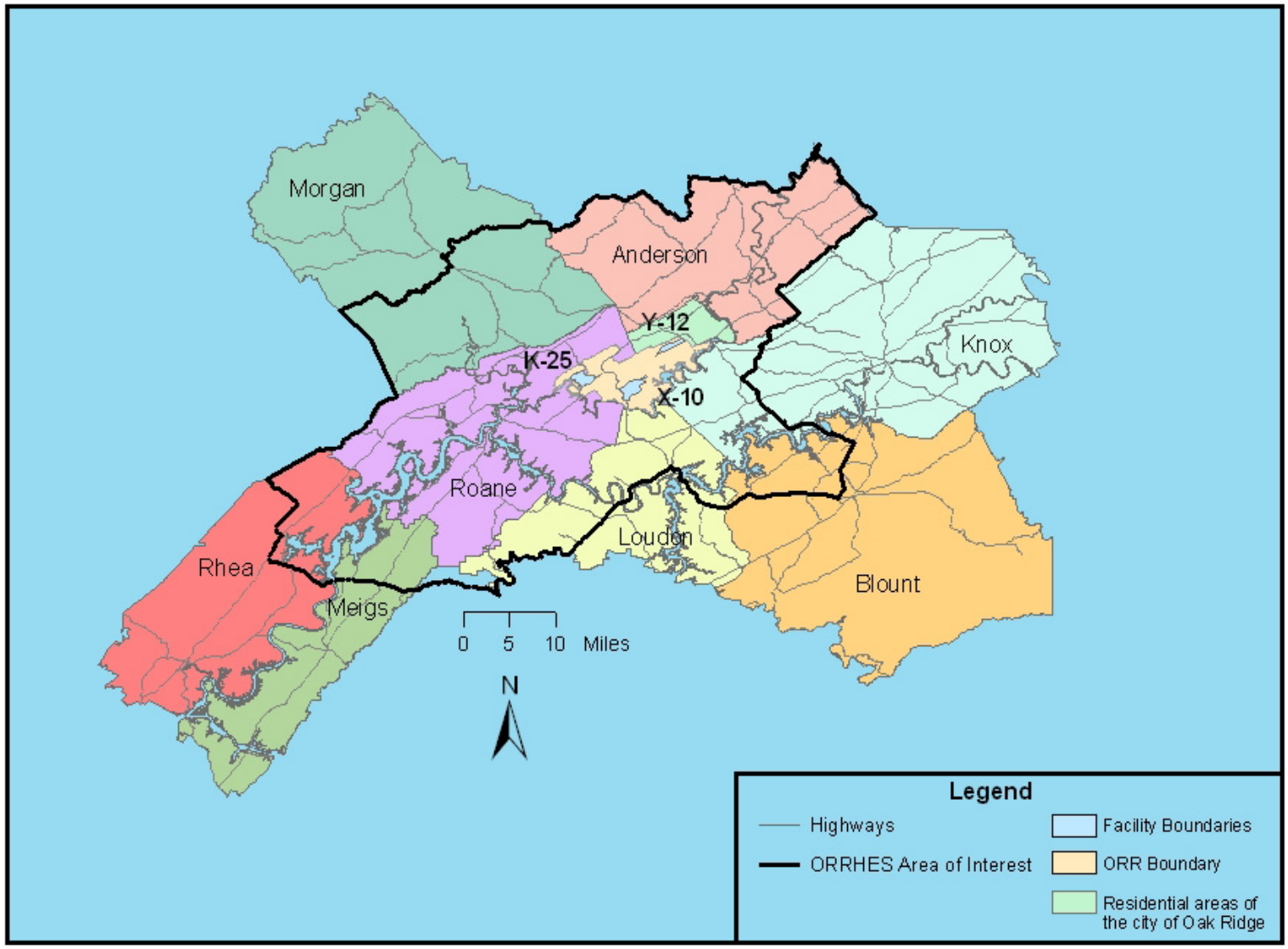
[4] Most of the contamination is located at the three main facilities. These areas are heavily guarded and fenced and access to these areas requires a clearance badge.

compliance, environmental restoration, and surveillance activities. Information from all key surveillance activities and environmental monitoring efforts are entered into OREIS. The environmental data are entered as studies are completed.

The public can access the database at the Information Resource Center (located at 475 Oak Ridge Turnpike, Oak Ridge, TN), which has a computer linked to OREIS. In addition, all of the OREIS files are stored onto CD-ROM, which were then used to make all of the data accessible to the public via the Internet at http://www-oreis.bechteljacobs.org/oreis/help/oreishome.html (ATSDR et al. 2000).

Past, current, and future exposure scenarios to PCBs and mercury will be addressed in chemical-specific public health assessments. Two health assessments are being written to address exposure to uranium from ORR. The Y-12 Uranium Releases Public Health Assessment has already been released. Copies of the document can be obtained from the Oak Ridge Field Office and ATSDR's Web site (www.atsdr.cdc.gov). A second public health assessment is being prepared to address past and current exposure to uranium and fluoride releases from the K-25 complex. ATSDR scientists are also conducting public health assessments on the release of iodine 131, radionuclides from White Oak Creek, and the TSCA incinerator.

Figure 6. ORRHES Area of Interest



III.D. Screening Results

Off-site Soil

The OREIS Environmental Database contains almost 10,000 records[5] of chemicals sampled in off-site soil from November 5, 1990, to September 1, 2001. These samples were analyzed for a total of 286 chemicals[5].

ATSDR compared the maximum chemical concentration for each chemical detected off site to its conservative health-based comparison value. The maximum concentrations for 22 chemicals were detected above comparison values. ATSDR calculated exposure doses for these 22 chemicals, using the equation described in Section III.B Methodology and the exposure parameters listed in Table 3. ATSDR then compared these exposure doses to the acute and chronic noncancer and cancer screening guidelines (see Table 4, Table 15, and Table 16). Four chemicals exceeded noncancer and/or cancer screening guidelines, and are further evaluated in the Public Health Implications section (see Section IV). Chemicals without screening guidelines are discussed in Appendix B. Pica child exposures are evaluated in the Children's Health Considerations section (see Section IV.B).

Chemicals Detected Above Comparison Values in Off-site Soil (22 chemicals)

Inorganics

- Arsenic
- Cadmium
- Chromium
- Iron
- Lead

Organics

- Benzidine
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- bis(2-Chloroethyl) ether
- Chrysene
- trans-Chlordane
- Dibenzo(a,h)anthracene

Organics (continued)

- 3,3'-Dichlorobenzidine
- Heptachlor epoxide
- Hexachlorobenzene
- Hexachlorodibenzo-p-dioxin (HCDD)
- Indeno(1,2,3-cd)pyrene
- n-Nitroso-di-n-butylamine
- n-Nitrosodi-n-propylamine
- 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)

Chemicals With Exposure Doses Above Cancer/Noncancer Screening Guidelines in Off-site Soil (4 chemicals)

Inorganics

- Arsenic
- Iron
- Lead

Organics

- Benzidine

[5] Records for mercury, uranium, and PCBs are not included in the total since they are being evaluated separately in chemical-specific health assessments.

Off-site Sediment

The OREIS Environmental Database contains about 56,000 records[6] of chemicals sampled in off-site sediment from January 15, 1990, to September 1, 2001. These samples were analyzed for a total of 319 chemicals[6].

ATSDR compared the maximum chemical concentration for each chemical detected off-site to its conservative health-based comparison value. The maximum concentrations for 33 chemicals were detected above comparison values. ATSDR calculated exposure doses for these 33 chemicals, using the equation described in Section III.B Methodology and the exposure parameters listed in Table 3. ATSDR then compared these exposure doses to the noncancer and cancer screening guidelines (see Table 17 and Table 18). None of the chemicals detected in off-site sediment exceeded noncancer or cancer screening guidelines. Therefore, exposure to off-site sediment is not a health concern. Chemicals without screening guidelines are discussed in Appendix B.

Chemicals Detected Above Comparison Values in Off-site Sediment (33 chemicals)

Inorganics	*Organics*	*Organics (continued)*
▪ Arsenic	▪ Aldrin	▪ Dieldrin
▪ Cadmium	▪ Benzo(a)anthracene	▪ Heptachlor
▪ Copper	▪ Benzo(a)pyrene	▪ Heptachlor epoxide
▪ Iron	▪ Benzo(b)fluoranthene	▪ Hexachlorobenzene
▪ Lead	▪ Benzo(k)fluoranthene	▪ Hexachlorocyclohexane (HCH), alpha-
▪ Manganese	▪ bis(2-Chloroethyl) ether	▪ HCH, beta-
	▪ cis-Chlordane	▪ HCH, delta-
	▪ trans-Chlordane	▪ HCH, gamma-
	▪ DDD, p,p'-	▪ HCDD
	▪ DDE, p,p'-	▪ Indeno(1,2,3-cd)pyrene
	▪ DDT, p,p'-	▪ n-Nitrosodi-n-propylamine
	▪ di(2-Ethylhexyl)phthalate	▪ Pentachlorophenol
	▪ Dibenzo(a,h)anthracene	▪ Toxaphene
	▪ 3,3'-Dichlorobenzidine	

Off-site Surface Water

The OREIS Environmental Database contains more than 93,000 records[6] of chemicals sampled in off-site surface water from January 8, 1990, to September 10, 2002. These samples were analyzed for a total of 310 chemicals[6].

ATSDR compared the maximum chemical concentration for each chemical detected off site to its conservative health-based comparison value. The maximum concentrations for 75 chemicals were detected above comparison values. ATSDR calculated exposure doses for these 75 chemicals, using the equation described in Section III.B Methodology and the exposure

[6] Records for mercury, uranium, and PCBs are not included since they are being evaluated separately in chemical-specific health assessments.

parameters listed in Table 3. ATSDR then compared these exposure doses to the noncancer and cancer screening guidelines (see Table 19 and Table 20). None of the chemicals detected in off-site surface water exceeded noncancer or cancer screening guidelines. Therefore, exposure to off-site surface water is not a health concern. Chemicals without screening guidelines are discussed in Appendix B.

Chemicals Detected Above Comparison Values in Off-site Surface Water (75 chemicals)

Inorganics

- Aluminum
- Ammonia
- Antimony
- Arsenic
- Barium
- Beryllium
- Boron
- Cadmium
- Chlorine
- Chromium
- Copper
- Iron
- Lead
- Lithium
- Manganese
- Nickel
- Nitrate
- Nitrate and Nitrite
- Selenium
- Silver
- Thallium
- Vanadium
- Zinc

Organics

- Aldrin
- Benzene
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Bis(2-chloroethyl) ether
- Bromodichloromethane
- Bromoform
- Carbazole
- Carbon tetrachloride
- cis-Chlordane
- trans-Chlordane
- Chlorodibromomethane
- Chloroethane
- Chloromethane
- Chrysene
- Dibenzo(a,h)anthracene
- 3,3'-Dichlorobenzidine
- 1,2-Dichloroethane
- 1,3-Dichloropropene, cis-
- 1,3-Dichloropropene, trans-
- Di(2-ethylhexyl)phthalate
- Dieldrin
- 2,4-Dinitrophenol
- 4,6-Dinitro-o-cresol

Organics (continued)

- HCDD
- Heptachlor
- Heptachlor epoxide
- Hexachlorobenzene
- Hexachlorobutadiene
- alpha-HCH
- beta-HCH
- delta-HCH
- Hexachloroethane
- Indeno(1,2,3-cd)pyrene
- Methoxychlor
- Methylene chloride
- 2-Nitroaniline
- 3-Nitroaniline
- 4-Nitroaniline
- Nitrobenzene
- n-Nitrosodi-n-propylamine
- n-Nitrosodiphenylamine
- Pentachlorophenol
- TCDD
- 1,1,2,2-Tetrachloroethane
- 1,1,2-Trichloroethane
- 2,4,6-Trichlorophenol
- Toxaphene
- Trichloroethylene
- Vinyl chloride

Biota

Fish

The OREIS Environmental Database contains more than 16,000 records[7] of chemicals sampled in fish (e.g., bass, catfish, and sunfish) from May 29, 1990, to August 14, 2002. A total of 147 different chemicals[7] were analyzed—43 chemicals in fish collected from East Fork Poplar Creek (EFPC), 64 chemicals in fish collected from the Clinch River, 81 chemicals in fish collected from the Watts Bar Reservoir (WBR), and 124 chemicals in fish collected from on-site locations.

Subsistence-level comparison values do not exist for chemicals detected in fish species. Therefore, as an initial screen, ATSDR calculated exposure doses for chemicals detected in fish samples using the equation described in Section III.B Methodology, the subsistence exposure parameters listed in Table 3, and the average of the maximum concentrations for each group/species[8]. ATSDR compared these exposure doses to noncancer and cancer screening guidelines. Estimated exposure doses for the following 12 chemicals exceeded the screening guidelines in at least one location.

Chemicals With Initial Screen Exposure Doses Above Screening Guidelines (12 chemicals)

Inorganics	*Organics*
▪ Arsenic	▪ Aldrin
▪ Cadmium	▪ Benzo(a)pyrene
▪ Chromium	▪ Dibenzo(a,h)anthracene
▪ Thallium	▪ Dieldrin
	▪ HCH, alpha-
	▪ Heptachlor epoxide
	▪ TCDD
	▪ Toxaphene

As a second screen, ATSDR calculated recreational and subsistence-level exposure doses using the second-tier screening concentrations for the chemicals listed above and compared these doses to noncancer and cancer screening guidelines (see Table 21 through Table 28). For this level of the evaluation, the fish were grouped by species as well as by location[9]. Chemicals that exceeded noncancer or cancer screening guidelines in at least one fish species during this second level of screening are further evaluated in the Public Health Implications section (see Section IV). Chemicals without screening guidelines are discussed in Appendix B.

[7] Records for mercury, uranium, and PCBs are not included since they are being evaluated separately in chemical-specific health assessments.

[8] The maximum concentrations for each group/species of fish were averaged since individual species data for multiple chemicals in multiple locations were available. In addition, people may only eat certain species and/or different species have different territorial and behavioral patterns (chemicals may accumulate differently in different species at different locations).

[9] As a second screen, ATSDR believes that grouping the data by species and location provides a more comprehensive representation of potential exposure patterns and estimated exposure doses in the ORR population.

Chemicals With Second Screen Exposure Doses Above Screening Guidelines in EFPC Fish (6 chemicals)

Inorganics	*Organics*
▪ Arsenic	▪ Dibenzo(a,h)anthracene
▪ Cadmium	▪ Dieldrin
▪ Chromium	▪ Heptachlor epoxide

Chemicals With Second Screen Exposure Doses Above Screening Guidelines in Clinch River Fish (6 chemicals)

Inorganics	*Organics*
▪ Arsenic	▪ Aldrin
	▪ Dieldrin
	▪ HCH, alpha-
	▪ Heptachlor epoxide
	▪ Toxaphene

Chemicals with Second Screen Exposure Doses above Screening Guidelines in WBR Fish (8 chemicals)

Inorganics	*Organics*
▪ Arsenic	▪ Aldrin
▪ Chromium	▪ Dieldrin
	▪ HCH, alpha-
	▪ Heptachlor epoxide
	▪ TCDD
	▪ Toxaphene

Chemicals with Second Screen Exposure Doses above Screening Guidelines in On-site Fish (8 chemicals)

Inorganics	*Organics*
▪ Arsenic	▪ Aldrin
▪ Cadmium	▪ Dieldrin
▪ Thallium	▪ HCH, alpha-
	▪ Heptachlor epoxide
	▪ Toxaphene

Game

The OREIS Environmental Database contains a little more than 2,200 records[10] of chemicals sampled in game species (e.g., turtle and wood duck) from March 28, 1990, to May 23, 1996. A total of 118 different chemicals were analyzed—27 chemicals[10] in game collected from off-site locations and 118 chemicals[10] in game collected from on-site locations.

Comparison values do not exist for chemicals detected in game species. Therefore, as an initial screen, ATSDR calculated exposure doses using the equation described in Section III.B Methodology, the exposure parameters listed in Table 3, and the average of the maximum concentrations. ATSDR compared these exposure doses to noncancer and cancer screening guidelines. No exposure doses for chemicals detected in game from off-site locations exceeded the screening guidelines. Calculated exposure doses exceeded the screening guidelines for the following eight chemicals detected in game from on-site locations.

Chemicals with Initial Screen Exposure Doses above Screening Guidelines in On-site Game (8 chemicals)

Inorganics	*Organics*
▪ Aluminum	▪ 4,6-Dinitro-o-cresol
▪ Antimony	▪ 2,4-Dinitrophenol
▪ Cadmium	
▪ Iron	
▪ Manganese	
▪ Thallium	

As a second screen, ATSDR calculated exposure doses using the second-tier screening concentrations for the chemicals listed above and compared these doses to noncancer screening guidelines[11] (see Table 29). For this level of the evaluation, the game samples collected on site were grouped by species. Exposure doses for seven of the eight chemicals exceeded noncancer screening guidelines during this second level of screening, and are further evaluated in the Public Health Implications section (see Section IV). Chemicals without screening guidelines are discussed in Appendix B.

Chemicals With Second Screen Exposure Doses Above Screening Guidelines in On-site Game (7 chemicals)

Inorganics	*Organics*
▪ Antimony	▪ 4,6-Dinitro-o-cresol
▪ Cadmium	▪ 2,4-Dinitrophenol
▪ Iron	
▪ Manganese	
▪ Thallium	

[10] Records for mercury and PCBs are not included since they are being evaluated separately in chemical-specific health assessments.

[11] During the second level of screening, chemicals detected in game species were evaluated for noncarcinogenic effects only—cancer screening guidelines are not available for these chemicals.

Off-site Vegetation

The OREIS Environmental Database contains 236 records[12] of chemicals sampled in vegetation (e.g., beets, kale, and tomato) from July 30, 1992, to September 8, 1992. These samples were analyzed for a total of six chemicals[12].

Comparison values do not exist for chemicals detected in vegetation. Therefore, as an initial screen, ATSDR calculated exposure doses for the six chemicals using the equation described in Section III.B Methodology, the exposure parameters listed in Table 3, and the average of the maximum concentrations. ATSDR compared these exposure doses to noncancer and cancer screening guidelines. Calculated exposure doses exceeded the screening guidelines for the following three chemicals detected in vegetation from off-site locations.

Chemicals with Initial Screen Exposure Doses above Screening Guidelines in Off-site Vegetation (3 chemicals)

Inorganics

- Arsenic
- Cadmium
- Chromium

As a second screen, ATSDR calculated exposure doses using the second-tier screening concentrations for the chemicals listed above and compared these doses to noncancer and cancer screening guidelines (see Table 30 and Table 31). For this level of the evaluation, the vegetation samples were grouped by type. All three chemicals exceeded noncancer and/or cancer screening guidelines during this second level of screening, and are further evaluated in the Public Health Implications section (see Section IV).

Chemicals with Second Screen Exposure Doses above Screening Guidelines in Off-site Vegetation (3 chemicals)

Inorganics

- Arsenic
- Cadmium
- Chromium

Air

The OREIS Environmental Database contains about 1,100 records[12] of chemicals sampled in the air from July 31, 1997, to June 30, 2002, from air monitoring stations near the East Tennessee Technology Park. Five different chemicals[12] were analyzed at these locations.

ATSDR compared the maximum chemical concentration for each chemical to its conservative health-based comparison value. Based on this initial screen (see Table 32), ATSDR further evaluated the following three chemicals in the Public Health Implications section (see Section IV). Beryllium and lead were not detected above comparison values.

[12] Records for mercury and uranium are not included since they are being evaluated separately in chemical-specific health assessments.

Chemicals Detected Above Comparison Values in Air (3 chemicals)

Inorganics

- Arsenic
- Cadmium
- Chromium

Figure 7shows the results of ATSDR's chemical screening process.

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Figure 7. Results from ATSDR's Chemical Screening Process

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Decision Diagram

Results

Criteria

Pathway Evaluation

Are there completed and/or potential exposure pathways where chemicals have been detected?

NO → **Not a contaminant of concern**

Results: Off-site Soil • Off-site Sediment • Off-site Surface Water • Off-site and On-site Fish • Off-site and On-site Game • Off-site Vegetation • Off-site and On-site Air

Criteria

- Can or are exposures occurring
- Identify potential or completed exposure pathways

YES ↓

Preliminary Screening

Are the chemical concentrations higher than medium-specific comparison values?

NO → **Not a contaminant of concern**

YES ↓

Chemicals Detected Above Comparison Values

Soil	Sediment		Surface Water			Fish*	Game*	Vegetation*	Air
22 chemicals	***33 chemicals***		***75 chemicals***			***12 chemicals***	***8 chemicals***	***3 chemicals***	***3 chemicals***
Arsenic	Aldrin	Heptachlor	Aldrin	Chlorodibromomethane	Manganese	Aldrin	Aluminum	Arsenic	Arsenic
Benzidine	Arsenic	Heptachlor epoxide	alpha-HCH	Chloroethane	Methoxychlor	Arsenic	Antimony	Cadmium	Cadmium
Benzo(a)anthracene	Benzo(a)anthracene	Hexachlorobenzene	Aluminum	Chloromethane	Methylene chloride	Benzo(a)pyrene	Cadmium	Chromium	Chromium
Benzo(a)pyrene	Benzo(a)pyrene	Indeno(1,2,3-cd)pyrene	Ammonia	Chromium	Nickel	Cadmium	4,6-Dinitro-o-cresol		
Benzo(b)fluoranthene	Benzo(b)fluoranthene	Iron	Antimony	Chrysene	Nitrate	Chromium	2,4-Dinitrophenol		
Benzo(k)fluoranthene	Benzo(k)fluoranthene	Lead	Arsenic	Copper	Nitrate and Nitrite	Dibenzo(a,h)anthracene	Iron		
Cadmium	Cadmium	Manganese	Barium	delta-HCH	2-Nitroaniline	Dieldrin	Manganese		
Chlordane, trans	Chlordane, cis	n-Nitrosodi-n-propylamine	Benzene	Di(2-ethylhexyl)phthalate	3-Nitroaniline	HCH, alpha	Thallium		
bis(2-Chloroethyl) ether	Chlordane, trans	Pentachlorophenol	Benzo(a)anthracene	Dibenzo(a,h)anthracene	4-Nitroaniline	Heptachlor epoxide			
Chromium	bis(2-Chloroethyl) ether	Toxaphene	Benzo(a)pyrene	1,2-Dichloroethane	Nitrobenzene	TCDD			
Chrysene	Copper		Benzo(b)fluoranthene	1,3-Dichloropropene, cis-	n-Nitrosodi-n-propylamine	Thallium			
Dibenzo(a,h)anthracene	DDD, p,p'-		Benzo(k)fluoranthene	1,3-Dichloropropene, trans-	n-Nitrosodiphenylamine	Toxaphene			
3,3'-Dichlorobenzidine	DDE, p,p'-		Beryllium	2,4-Dinitrophenol	Pentachlorophenol				
HCDD	DDT, p,p'-		beta-HCH	3,3'-Dichlorobenzidine	Selenium				
Heptachlor epoxide	Dibenzo(a,h)anthracene		Bis(2-chloroethyl) ether	Dieldrin	Silver				
Hexachlorobenzene	3,3'-Dichlorobenzidine		Boron	4,6-Dinitro-o-cresol	TCDD				
Indeno(1,2,3-cd)pyrene	Dieldrin		Bromodichloromethane	HCDD	1,1,2,2-Tetrachloroethane				
Iron	di(2-Ethylhexyl)phthalate		Bromoform	Heptachlor	Thallium				
Lead	HCDD		Cadmium	Heptachlor epoxide	Toxaphene				
n-Nitroso-di-n-butylamine	HCH, alpha		Carbazole	Hexachlorobenzene	1,1,2-Trichloroethane				
n-Nitrosodi-n-propylamine	HCH, beta		Carbon tetrachloride	Hexachlorobutadiene	2,4,6-Trichlorophenol				
TCDD	HCH, delta		cis-Chlordane	Hexachloroethane	Trichloroethylene				
	HCH, gamma		trans-Chlordane	Indeno(1,2,3-cd)pyrene	Vanadium				
			Chlorine	Iron	Vinyl chloride				
				Lead	Zinc				
				Lithium					

* Comparison values do not exist for chemicals detected in fish, game, and vegetation. Therefore, as an initial screen, ATSDR calculated exposure doses using the average of the maximum concentrations and compared these exposure doses to noncancer and cancer screening guidelines.

Criteria

- Based on the results of environmental investigations
- Based on maximum exposure conditions
  - maximum concentration detected
  - maximum exposure duration
  - maximum exposure frequency
  - maximum exposure bioavailability

YES ↓

Exposure Dose Comparison

Are estimated exposure doses higher than screening guidelines?

NO → **Not a contaminant of concern**

YES ↓

Chemicals With Exposure Doses Above Cancer/Noncancer Screening Guidelines

Soil	Sediment	Surface Water	Fish		Game	Vegetation	Air*
4 chemicals	***0 chemicals***	***0 chemicals***	***11 chemicals***		***7 chemicals***	***3 chemicals***	***3 chemicals***
Arsenic (pica only)			Aldrin	Heptachlor epoxide	Antimony	Arsenic	Arsenic
Benzidine			Arsenic	TCDD	Cadmium	Cadmium	Cadmium
Iron			Cadmium	Thallium	4,6-Dinitro-o-cresol	Chromium	Chromium
Lead (pica only)			Chromium	Toxaphene	2,4-Dinitrophenol		
			Dibenzo(a,h)anthracene		Iron		
			Dieldrin		Manganese		
			HCH, alpha		Thallium		

* Chemicals in air were retained for further evaluation based on the initial screen against comparison values.

Criteria

- Estimate doses based on site-specific exposure conditions
- Use more realistic exposure assumptions
  - realistic concentrations
  - realistic exposure duration
  - realistic exposure frequency
  - realistic exposure bioavailability
  - site-specific receptor population

YES ↓

Contaminants of Concern

Contaminants of concern

YES ↓

Chemicals Evaluated for Public Health Implications

Aldrin & Dieldrin • Antimony • Arsenic • Benzidine • Cadmium • Chromium • Dibenzo(a,h)anthracene • 4,6-Dinitro-o-cresol • 2,4-Dinitrophenol
Dioxin • Heptachlor epoxide • HCH, alpha • Iron • Lead • Manganese • Thallium • Toxaphene

Criteria

- Evaluate the public health implications of contaminants of concern in greater detail

Public Health Implications

Evaluate public health implications

Conclusions

ATSDR concludes that current and future exposures to site-related chemicals (individually or in combination) in soil, sediment, surface water, biota, and air do not pose a public health hazard. Because there is very limited data, exposure to dioxins in fish poses an indeterminate public health hazard. Therefore, ATSDR recommends following the current fish advisories.

Criteria

- Review toxicologic, medical, epidemiologic, and other scientific data on the contaminants of concern
- Evaluate whether contaminants of concern can affect public health in the vicinity of the site

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IV. Public Health Implications

IV.A. Introduction

A release of a chemical does not always result in human exposure, and human exposure does not always result in adverse health effects.

This section of the public health assessment evaluates public health implications of acute and chronic exposure to chemicals of concern for adults and children. In these evaluations, ATSDR considered multiple factors, including bioavailability, chemical and physical properties, and the frequency and duration of the estimated exposures. For cases in which a population is affected by more than one exposure pathway, ATSDR also considered the combinations of chemicals and exposure routes. ATSDR considered characteristics of the exposed populations—such as age, sex, genetics, lifestyle, and nutritional status, health status, which influence how a person absorbs, distributes, metabolizes, and excretes contaminants. Where appropriate, these characteristics are included in the chemical-specific discussions.

When comparing actual health effect levels in the scientific literature, ATSDR tries to estimate more realistic exposure scenarios to use for comparison. For example, 0.15 liters per day (L/day) (the amount of water ingested during a three hour swimming event; EPA 1999) was used as the surface water ingestion rate in the Public Health Implications section instead of 0.5 L/day, which was used in the screening evaluation. In this level of the evaluation, an average concentration is used to estimate a more probable exposure dose. Not all chemicals were detected in all samples. Therefore, it is more likely that people would be exposed to a range of concentrations over time.

> For chemicals detected in at least 10 percent of the samples, averages were calculated using detected concentrations only and do not take into account nondetected values. Even though this method tends to overestimate the true average values, ATSDR chose to base its health evaluations on the more conservative averages to be more protective of public health. For chemicals detected in less than 10 percent of the samples, ATSDR calculated averages using 1/2 the detection limit for nondetected samples.

In the case of pica behavior (see the Children's Health Considerations section), the estimated exposure doses were calculated using the maximum concentration and then compared to acute health effects levels (acute MRLs) since this exposure pattern can be episodic and short term.

As previously discussed, health guidelines (MRLs and RfDs) are derived for chemicals using the NOAEL/LOAEL/uncertainty factor approach. Generally, the uncertainty factor (also known as the safety factor) consists of multiples of 10, each representing a specific area of uncertainty inherent in the available animal or human study data. For example, a factor of 10 could be used to account for differences between animals and humans; a second factor of 10 could then be used to account for differences among people; while an additional factor of 10 could be used to account for the use of a LOAEL, instead of a NOAEL. An additional uncertainty factor that is greater than zero and less than or equal to 10 can also be used. The magnitude of the factor depends on the professional assessment of scientific uncertainties of the study and database (e.g., the completeness of the overall database and the number of species tested). Health guidelines are

generally based on the LOAELs reported in the literature, very often from a single study. In addition to the critical study, other studies can provide chemical-specific, dose-response data.

The following discussion focuses primarily on contaminants detected in off-site locations. Because there are limited off-site air samples, however, and people have access to on-site fish and game, on-site exposures to these media are also discussed when appropriate.

IV.B. Children's Health Considerations

Woman and children can sometimes be affected differently from the general population by chemicals in the environment. The effect of hormonal variations, pregnancy, and lactation can change the way a woman's body responds to some chemicals. Past exposures experienced by the mother, as well as exposure during pregnancy and breast-feeding, can expose a fetus or infant to chemicals through the placenta or breast milk. Depending on the stage of pregnancy, the nature of the chemical involved, and the dose of that chemical, fetal exposure can result in a variety of problems, including miscarriage, still birth, and birth defects.

ATSDR recognizes that developing fetuses, infants, and children have unique vulnerabilities. Children are not small adults; a child's exposure can differ from an adult's in many ways. A child drinks more liquid, eats more food, and breathes more air per unit of body weight than an adult, and has a larger skin surface area in proportion to body volume. A child's behavior and lifestyle also influence exposure levels. Children crawl on the floor, put things in their mouths, play closer to the ground, and spend more time outdoors. These behaviors can result in longer exposure durations and higher intake rates.

In addition, children's metabolic pathways, especially in the first few months after birth, are less developed than those of adults. In some cases, children are better able than adults to deal with chemicals, but in others, they are less able and more vulnerable. Some chemicals that are not highly toxic in adults are in infants.

Children grow and develop rapidly in the first few months and years of life. Some organ systems, especially the nervous and respiratory systems, can be permanently damaged if exposed to high levels of certain chemicals during this period. Also, young children have less ability to avoid hazards, because they lack knowledge and depend on adults for decisions.

This public health assessment evaluates hazards to children displaying pica behavior (a craving for non-nutritive substances like soil). Information on the incidence of soil pica behavior is limited. A study described in EPA's *Exposure Factors Handbook* (EPA 1999) showed that the incidence of soil pica behavior was approximately 16 percent among children from a rural black community in Mississippi. This behavior was described as a cultural practice among the community surveyed, however, so that community may not represent the general population. In five other studies, only one child, out of more than 600, ingested an amount of soil significantly greater than the range in other children. Although these studies did not include data for all populations and represented short-term ingestion only, it can be assumed that the incidence rate of child pica behavior in the general population is low.

There is little information on the amount of soil ingested (measured in mg/day) by children with pica behavior (EPA 1999). Ingestion rates between 1,000 and 10,000 mg/day have been used to

estimate exposure doses for pica children. In this health assessment, ATSDR assumed a soil ingestion rate of 5,000 mg/day for 52 days per year (once a week) to represent pica behavior in children aged 1 to 3 years old. ATSDR believes that this is a health protective assumption and likely overestimates soil consumption. In the case of pica behavior, estimated exposure doses were calculated using the maximum surface soil concentration that was located in an area of likely exposure. ATSDR then compared these doses to acute health effects levels (e.g., acute MRLs) since this exposure pattern can be episodic and short term (see Table 4). Doses that are less than the acute MRLs are not considered to be of health concern. They have built-in safety factors, making them considerably lower than levels at which health effects have been observed.

ATSDR evaluated pica exposures to the 22 chemicals detected above comparison values in off-site soil. As shown in Table 4, most of the chemicals were not detected at levels of concern for children exhibiting pica behavior. Only potential pica exposure to soil containing arsenic, iron, and lead are evaluated further.

Table 4. Estimated Pica Child Exposure Doses for Chemicals in Off-Site Soil Compared to Acute Screening Guidelines

Chemical	*Maximum Concentration (ppm)*	*Pica Child Exposure Dose (mg/kg/day)*	*Acute Screening Guideline (mg/kg/day)*	*Source*	*Does the pica dose exceed the screening guideline?*
Inorganics					
Arsenic	77.3	5.5E-03	0.005	Acute MRL	Yes
Cadmium	41.3	2.9E-03	0.02	Tox Profile*	No
Chromium	*Below comparison values*				
Iron	31,500	158 mg/day	10 mg/day	RDA	Yes
Lead	625	4.5E-02	0.02	Acute LOAEL	Yes
Organics					
Benzidine	4.13	2.9E-04	0.003	RfD	No
Benzo(a)anthracene	4.13	2.9E-04	0.003	RfD§	No
Benzo(a)pyrene	4.13	2.9E-04	0.003	RfD§	No
Benzo(b)fluoranthene	4.13	2.9E-04	0.003	RfD§	No
Benzo(k)fluoranthene	*Below comparison values*				
bis(2-Chloroethyl) ether	4.13	2.9E-04	0.0075	Tox Profile†	No
Chrysene	*Below comparison values*				
trans-Chlordane	2.8	2.0E-04	0.001	Acute MRL (chlordane)	No
Dibenzo(a,h)anthracene	4.13	2.9E-04	0.003	RfD§	No
3,3'-Dichlorobenzidine	4.13	2.9E-04	0.003	RfD (benzidine)	No
Heptachlor epoxide	0.97	6.9E-05	0.008	Tox Profile*	No
Hexachlorobenzene	4.13	2.9E-04	0.008	Acute MRL	No
HCDD	*Below comparison values*				
Indeno(1,2,3-cd)pyrene	4.13	2.9E-04	0.003	RfD§	No
n-Nitroso-di-n-butylamine	4.13	2.9E-04	0.095	Acute MRL (n-nitrosodi-n-propylamine)	No
n-Nitrosodi-n-propylamine	0.79	5.6E-05	0.095	Acute MRL	No
TCDD	*Below comparison values*				

Pica doses were calculated using the following formula:

pica dose = (maximum concentration*0.005 kg/day*52 days/year*3 years)/(10 kg*(365 days/year*3 years))

Soil samples collected from Atomic City Auto Parts were not included since this is a separate industrial site where children are unlikely to have access and the contaminated soil has been removed. These data were not removed during the screening assessment or from the summary information provided in Table 15 and Table 16.

"Below comparison values" means that when the Atomic City Auto Parts data were removed, the remaining soil concentrations were below the conservative health-based comparison values.

* The acute screening guideline was derived from limited acute toxicological data available in ATSDR's Toxicological Profile. A safety factor of 100 or 1,000 was applied to account for differences between animals and humans and to account for the use of a LOAEL, instead of a NOAEL. These acute screening guidelines should be considered unofficial and are for use in this health assessment only.

§The acute screening guideline was derived from the chronic oral RfD for anthracene. A safety factor of 100 was applied for use of a chronic guideline value. These acute screening guidelines should be considered unofficial and are for use in this health assessment only.

†The acute screening guideline was derived from an acute LD50 value available in ATSDR's Toxicological Profile. A safety factor of 10,000 was applied for use of an LD50 value. This acute screening guideline should be considered unofficial and is for use in this health assessment only.

AMRL = acute minimal risk level
mg/kg/day = milligram per kilogram per day
RfD = reference dose
LOAEL = lowest-observed-adverse-effect level
ppm = parts per million
RDA = Recommended Dietary Allowance

Arsenic

Arsenic is naturally occurring in the environment and is usually combined with other elements such as oxygen, chlorine, and sulfur. When combined with these elements arsenic is called inorganic arsenic. When combined with carbon and hydrogen, it is called organic arsenic. The organic forms of arsenic are usually less harmful than the inorganic forms (ATSDR 2000a). To be protective of public health during the screening evaluation, ATSDR assumed that all of the arsenic was in the more harmful inorganic form.

The estimated pica child exposure dose for arsenic in soil (5.5×10^{-3} mg/kg/day) is slightly above the acute MRL using the maximum detected concentration (77.3 ppm), which was collected from a residential property. The next highest residential concentration (12.7 ppm; collected on the same day from the same location as the maximum concentration) is not at a level of health concern (estimated exposure dose of 9.0×10^{-4} mg/kg/day is below the acute MRL). The acute MRL is based on a study in which health effects were observed in people exposed to 5.0×10^{-2} mg/kg/day of arsenic through ingesting poisoned soy sauce (Mizuta et al. 1956). ATSDR does not expect pica child exposures to result in adverse health effects in the ORR area; however, if pica children are exposed to the maximum concentration then adverse acute effects may occur (e.g., gastrointestinal distress, vomiting, or diarrhea).

Iron

Iron is a naturally occurring element in the environment. Iron is also an important mineral, which assists in the maintenance of basic life functions. It combines with protein and copper to make hemoglobin, which transports oxygen in the blood from the lungs to other parts of the body, including the heart. It also aids in the formation of myoglobin, which supplies oxygen to muscle tissues (ANR 2003). Without sufficient iron, the body cannot produce enough hemoglobin or myoglobin to sustain life. Iron deficiency is a condition that occurs when the body does not receive enough iron. Despite the fact that iron is the fourth most abundant metal in the earth's crust, iron deficiency is the world's most common cause of anemia. The National Academy of Sciences' (NAS) RDA for children is 10 mg/day (FDA 1997). The U.S. Food and Drug Administration's (FDA) Reference Daily Intake for iron is 18 mg/day (Kurtzweil 1993).

According to the FDA, doses greater than 200 mg per event could poison or kill a child (FDA 1997). Doses of this magnitude are generally the result of children accidentally ingesting iron pills, and not from ingesting iron in soil or water. Acute iron poisoning has been reported in children less than 6 years of age who have accidentally overdosed on iron-containing supplements for adults. Because iron is not considered to cause harmful health effects in general, toxicological and epidemiological literature is limited.

For comparison, ATSDR calculated a daily consumption from exposure to the iron in soil using a modification of the dose equation (Dose = Concentration × Intake Rate). Exposure to the maximum concentration of iron collected from a residential area (31,500 ppm) would increase a pica child's daily consumption of iron by 158 mg/day, assuming 100 percent absorption. The median daily intake of dietary iron is roughly 11 to 13 mg/day for children 1 to 8 years old and 13 to 20 mg/day for adolescents 9 to 18 years old (NAS 2001). While the estimated daily consumption of iron for a pica child exceeds the NAS and FDA recommended intake guidelines,

the daily increase in consumption is not likely to cause a pica child's daily dose to exceed levels known to induce poisoning (greater than 200 mg/event). Further, to the authors' knowledge, no case of acute iron toxicity has ever occurred as a direct result of soil consumption. The absence of such cases probably reflects the large amount of soil that would have to be ingested combined with the much lower intestinal absorption of iron from soil than from food, and the fact that humans self regulate the body's iron level. Therefore, ATSDR does not expect that children exhibiting pica behavior would experience adverse health effects from exposure to iron in soil.

Lead

Lead is a naturally occurring bluish-gray metal found in small amounts in the Earth's crust and in all media in the environment. The harmful effects from lead exposure have been known for a long time. Young children and fetuses have been the main focus of health effects research because they are the most sensitive individuals. Because of health concerns, lead from gasoline, paints and ceramic products, caulking, and pipe solder has been dramatically reduced in the past few decades.

Six surface soil lead concentrations exceeded the screening value (400 ppm). The five highest detected surface soil lead concentrations were located on the Atomic City Auto Parts industrial property where soil removal activities have been conducted (the contaminated soil has been removed). The only remaining soil sample (625 ppm) that exceeded the soil screening value is located in a residential area.

Assuming 100 percent bioavailability of the lead, the estimated exposure dose (4.5×10^{-2} mg/kg/day) for a child exhibiting pica behavior was slightly above the noncancer screening guideline (0.02 mg/kg/day; acute LOAEL in a human study). Further, ATSDR reviewed 122 studies of human and animal exposures to various doses of lead. In general, exposure doses below 0.001 mg/kg/day do not harm humans or animals. Exposure doses between 0.001 and 0.01 mg/kg/day produce minor changes in blood cells. Harmful effects are seen in animals when doses reach and exceed 0.01 mg/kg/day (ATSDR 1999b). However, studies indicate that not all of the ingested lead is absorbed via the gastrointestinal tract.

> As a prudent public health practice, ATSDR supports routine blood lead testing, especially for children. For more information about CDC's Childhood Lead Poisoning Prevention Program, visit http://www.cdc.gov/nceh/lead/lead.htm.

In humans, there is a correlation between the levels of lead in blood and the harmful effects that may result. Blood lead levels can be elevated via exposure to contaminated soil, paint, dust, air food, and/or drinking water. Neurological effects are the most important health effect. The Centers for Disease Control and Prevention (CDC) considers a child to have an elevated blood lead level if the amount of lead is 10 micrograms per deciliter (μg/dL) or higher. Epidemiologic studies have consistently found that non-pica children's blood lead levels increase by about 3.8 μg/dL for every 1,000 ppm increase in soil lead levels. The lead concentrations in soil ranged from 5.3 to 625 ppm.

Hypothetically, if children exhibiting routine pica behavior were exposed to 625 ppm of lead in soil with 100 percent absorption, their blood lead levels could exceed 10 μg/dL. While ATSDR

believes that this scenario is unlikely, the Agency supports the recommendation that all children have their blood lead levels tested—especially between the ages of 6 months and 6 years.

IV.C. Public Health Evaluation

Chronic exposure to specific chemicals of concern are discussed in this section of this report. The discussion of potential health effects for each chemical of concern is based on calculated exposure doses for current and future scenarios and documented health effects from human and animal studies. It is important to remember that an exposed person would not necessarily experience adverse health effects. It is also important to note that ATSDR is *assuming* exposure to the contaminated media. The location of each detection is not individually evaluated to determine whether anyone is actually being exposed.

ATSDR evaluated the pathway-specific exposure doses for populations that may be exposed to specific chemicals via multiple exposure pathways to reflect a total estimated dose. Of all the chemicals screened for current and future exposure scenarios (off-site soil, sediment, surface water, biota, and air; on-site fish, game, and air), none are expected to result in adverse effects when considered across pathways.

Table 5 summarizes the completed and potential exposure pathways. This table presents the exposure pathways, exposure routes, affected populations for each contaminant that exceed screening guidelines (see Table 15 through Table 32), and the public health implications for each chemical and pathway. A more detailed discussion of each chemical follows the table.

Table 5. Summary of Completed and Potential Exposure Pathways for Off-site Chemicals of Concern

Chemical	*Retained Pathway(s)*	*Exposure Route(s)*	*Potentially Affected Population(s)*	*Public Health Implication*
Aldrin / Dieldrin	Biota (fish)	Ingestion	Child & adult – subsistence	None expected
Antimony	Biota (on-site game)	Ingestion	Child	None expected
Arsenic	Biota (fish & vegs) Air	Ingestion Inhalation	Child & adult Adult	None expected None expected
Benzidine	Soil	Ingestion	Adult	None expected
Cadmium	Biota (fish & game) Biota (vegetables) Air	Ingestion Ingestion Inhalation	Child & adult Child & adult Child & adult	None expected None expected (see text) None expected
Chromium	Biota (fish & vegs) Air	Ingestion Inhalation	Child & adult Adult	None expected None expected
Dibenzo(a,h)anthracene	Biota (EFPC crayfish)	Ingestion	Adult – subsistence	None expected
2,4-Dinitrophenol	Biota (unknown game)	Ingestion	Child	None expected
4,6-Dinitro-o-cresol	Biota (unknown game)	Ingestion	Child	None expected
Dioxin	Biota (unknown fish)	Ingestion	Child & adult	Indeterminate – follow fish advisories
Heptachlor epoxide	Biota (fish)	Ingestion	Child & adult – subsist & rec	None expected
Alpha-HCH	Biota (fish)	Ingestion	Adult – subsistence	None expected
Iron	Soil Biota (unknown game)	Ingestion Ingestion	Child Child & adult	None expected None expected
Manganese	Biota (unknown game)	Ingestion	Child	None expected
Thallium	Biota (fish & game)	Ingestion	Child & adult	None expected
Toxaphene	Biota (fish)	Ingestion	Child & adult – subsistence	None expected

EFPC = East Fork Poplar Creek
rec = recreational fishing
subsist = subsistence fishing
vegs = vegetation

Aldrin/Dieldrin

Aldrin and dieldrin are the common names of two structurally similar compounds that were once used as insecticides. These chemicals are made in a laboratory and do not occur naturally in the environment. The two chemicals are discussed together because aldrin readily changes into dieldrin once it enters the environment or the body.

Aldrin and dieldrin are no longer produced or used. From the 1950s until 1970, aldrin and dieldrin were used extensively as insecticides on crops such as corn and cotton. The U.S. Department of Agriculture canceled all uses of aldrin and dieldrin in 1970. In 1972, however, EPA approved aldrin and dieldrin for killing termites. Use of aldrin and dieldrin to control termites continued until 1987. In 1987, the manufacturer voluntarily canceled the registration for use in controlling termites.

As shown in Table 21 through Table 28, the estimated exposure doses for children and adults under the subsistence fishing exposure scenario are above their respective noncancer and cancer screening guidelines for aldrin/dieldrin in fish (mainly sunfish). As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential from fish ingestion. The aldrin and dieldrin levels detected in all other media are not at levels of health concern (i.e., the estimated doses are below the noncancer and cancer screening guidelines) and will not be discussed further.

Table 6 shows estimated exposure doses for media that exceeded the noncancer or cancer screening guideline for aldrin and dieldrin, respectively. For this level of the evaluation, however, ATSDR calculated the estimated exposure doses using average concentrations to more closely reflect expected exposure patterns (people are exposed to a range of concentrations over time).

Table 6. Exposure Doses for Aldrin and Dieldrin

Media	*Average Concentration (ppm)*	*Subsistence-level Exposure Dose (mg/kg/day)*		
		Child	*Adult*	*Lifetime*
Aldrin				
Clinch River Sunfish	0.042	6.5E-05	3.9E-05	1.7E-05
WBR Sunfish	0.035	5.4E-05	3.3E-05	1.4E-05
On-site Sunfish	0.039	6.0E-05	3.6E-05	1.6E-05
Dieldrin				
EFPC Sunfish	0.040	6.2E-05	3.7E-05	1.6E-05
Clinch River Sunfish	0.045	6.9E-05	4.2E-05	1.8E-05
WBR Sunfish	0.041	6.3E-05	3.8E-05	1.6E-05
On-site Sunfish	0.060	9.2E-05	5.6E-05	2.4E-05
Clinch River Catfish	0.012	1.8E-05	1.1E-05	4.8E-06
WBR Catfish	0.009	1.4E-05	8.4E-06	3.6E-06
On-site Catfish	0.012	*Below screening guidelines*		4.8E-06
On-site Bass	0.027	4.2E-05	2.5E-05	1.1E-05

The chronic MRL for aldrin is 3.0×10^{-5} mg/kg/day.
The chronic MRL for dieldrin is 5.0×10^{-5} mg/kg/day.
"Below screening guidelines" means that the calculated doses were below screening guidelines during the second-tier screening evaluation (see Section III.D).

Based on the reported results, sunfish contained the highest levels of aldrin and dieldrin. The estimated exposure doses for consumption of catfish, crayfish, and bass are lower than estimated exposure doses for consumption of sunfish. As such, sunfish will be used as a surrogate for all species since the estimated exposure doses from eating sunfish would be the greatest.

All exposure doses for recreational fishing exposure patterns were below levels of concern for all species. Aldrin/dieldrin exposure doses from ingestion (subsistence) of sunfish are above their respective screening guidelines in multiple locations (e.g., Clinch River, East Fork Poplar Creek, Watts Bar, and on-site sampling locations). In all these locations, if "sunfish" represents 25 percent of the ingested fish over a lifetime of subsistence level exposures (using the average concentrations) then the exposure doses are below screening guidelines for both cancer and noncancer effects. This means that a person could eat about 13 pounds of aldrin/dieldrin-contaminated fish (sunfish having the highest average level) per year for 30 years and not experience adverse health effects. Therefore, adverse health effects are not expected.

Further, the noncancer screening guidelines for aldrin and dieldrin are based on studies in which adverse effects were observed at doses of 2.5×10^{-2} mg of aldrin/kg/day and no adverse effects were observed at doses of 5.0×10^{-3} mg of dieldrin/kg/day (ATSDR 2002). Cancer effects were reported at doses ranging from 0.33 to 1.5 mg/kg/day (ATSDR 2002). All of the subsistence-level exposure doses (i.e., children and adults eating 16 lbs fish/year and 52 lbs fish/year, respectively) are at least two to three orders of magnitude below these health effects levels (see Table 6).

Antimony

Antimony is a silvery white metal that is naturally found in the environment. It can enter the body when a person eats food contaminated with it. After a few hours, a small amount enters the bloodstream and mostly distributes to the liver, lungs, intestines, and spleen. Antimony then leaves the body in urine and feces over several weeks (ATSDR 1992).

As shown in Table 29, the estimated exposure dose for a child eating on-site game is above the antimony noncancer screening guideline. As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential for this pathway. The antimony levels detected in all other media are not at levels of health concern (i.e., the estimated doses are below the noncancer screening guidelines).

The estimated exposure dose for a child ingesting on-site game was above the noncancer screening guideline when assuming 100 percent absorption. Antimony is only slowly absorbed from the gastrointestinal tract, however. Based on animal data, gastrointestinal absorption of antimony was estimated to be 2 to 7 percent (ATSDR 1992). To account for this poor absorption, ATSDR assumed that 10 percent of the antimony was absorbed. The estimated exposure dose using an absorption value of 10 percent (5.0×10^{-5} mg/kg/day) is below the noncancer screening guideline (4.0×10^{-4} mg/kg/day). Remember that the screening guideline is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects. The screening guideline has built-in safety factors, making it considerably lower than levels at which health effects have been observed. Estimated doses that

are less than this value are not considered to be of health concern. As such, exposure to antimony is not expected to result in adverse health effects.

Arsenic

Arsenic is naturally occurring in the environment and is usually combined with other elements such as oxygen, chlorine, and sulfur. When combined with these elements arsenic is called inorganic arsenic. When combined with carbon and hydrogen, it is called organic arsenic. The organic forms of arsenic are usually less harmful than the inorganic forms (ATSDR 2000a). To be protective of public health during the screening evaluation, ATSDR assumed that all of the arsenic was in the more harmful inorganic form.

The estimated exposure doses for children and adults ingesting fish and vegetation (Table 21 through Table 28, Table 30, and Table 31), and for people inhaling air (Table 32) are above the arsenic noncancer and cancer screening guidelines. As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential from these pathways. The arsenic levels detected in soil, sediment, surface water, and game are not at levels of health concern (i.e., the estimated doses are below the noncancer and cancer screening guidelines) and will not be discussed further.

Table 7 shows the exposure doses for media that exceeded the arsenic noncancer or cancer screening guidelines. For this level of the evaluation, however, ATSDR recalculated the estimated exposure doses using average concentrations to represent more realistic exposure scenarios and assumed that 10 percent of the total arsenic detected in fish and crayfish was in the inorganic form.

Table 7. Estimated Exposure Doses for Arsenic

Media	*Average Concentration (ppm)*	*Exposure Dose (mg/kg/day)*		
		Child	*Adult*	*Lifetime*
EFPC Crayfish	0.38	5.8E-05	3.5E-05	1.5E-05
On-site Crayfish	0.25	3.8E-05	2.3E-05	9.9E-06
Clinch River Catfish	0.64	9.8E-05	5.9E-05	2.5E-05
WBR Catfish	0.23	3.5E-05	2.1E-05	9.2E-06
Clinch River Sunfish	0.45	6.9E-05	4.2E-05	1.8E-05
WBR Sunfish	0.12	1.8E-05	1.1E-05	4.8E-06
On-site Sunfish	0.19	2.9E-05	1.8E-05	7.6E-06
Clinch River Bass	0.28	4.3E-05	2.6E-05	1.1E-05
WBR Bass	0.18	2.8E-05	1.7E-05	7.2E-06
On-site Bass	0.22	3.4E-05	2.0E-05	8.8E-06
WBR Unknown Fish	0.17	2.6E-05	1.6E-05	6.8E-06
On-site Unknown Fish	0.31	4.8E-05	2.9E-05	1.2E-05
Off-site Kale	1.4	2.2E-03	2.2E-03	9.6E-04
Off-site Tomato	1.5	2.4E-03	2.4E-03	1.0E-03
Air	0.00056 µg/m^3	N/A		

The chronic MRL for arsenic is 3.0×10^{-4} mg/kg/day.
Exposure doses for fish represent subsistence-level fishing.
ATSDR assumed that 10 percent of the total arsenic detected in fish and crayfish was in the inorganic form.
Air CREG = 0.0002 µg/m^3
N/A = not applicable

Ingestion is the primary way arsenic enters the body. Once in the body, the liver changes some of the arsenic into a less harmful organic form. This process is effective as long as the dose of inorganic arsenic remains below 5.0×10^{-2} mg/kg/day (ATSDR 2000a). Both inorganic and organic forms of arsenic leave the body in urine. Studies have shown that 45 to 85 percent of the arsenic is eliminated within one to three days (Buchet et al. 1981a; Crecelius 1977; Mappes 1977; Tam et al. 1979b); however, some will remain for several months or longer.

The metabolism (i.e., how it is broken down in the body) of inorganic arsenic has been extensively studied in humans and animals. ATSDR's estimated doses are well below those that inhibit the body's ability to detoxify or change it to non-harmful forms (doses greater than 5.0×10^{-2} mg/kg/day inhibit detoxification). Therefore, normal metabolic processes should handle the arsenic a person would receive from the various exposure pathways.

There is some indication in the scientific literature that some dermal health effects could result from ingesting a lower dose of arsenic—hyperkeratosis and hyperpigmentation were reported in humans exposed to 1.4×10^{-2} mg/kg/day of arsenic in their drinking water for more than 45 years (Tseng et al. 1968). However, because estimates of water intake and dietary arsenic are highly uncertain in this and similar studies, some scientists argue that reported effects may actually be associated with doses higher than 1.4×10^{-2} mg/kg/day. Further, these effects have never been reported in a U.S. population.

Fish

Fish and shellfish can accumulate arsenic, but the arsenic found in fish is mostly (>80 percent) in an organic form (arsenobetaine or fish arsenic), which is not harmful (ATSDR 2000a; Francesconi and Edmonds 1997; NAS 2001; FDA 1993). The U.S. Food and Drug Administration (FDA) proposes that 10 percent of the total arsenic be estimated as inorganic arsenic (FDA 1993). When ATSDR applied this factor, the estimated subsistence-level exposure doses for arsenic in fish were below the screening guidelines. Further, all subsistence-level exposure doses are below the level at which the body can detoxify inorganic arsenic into the less harmful form (5.0×10^{-2} mg/kg/day; see Table 7). Thus, the subsistence-level exposure doses are below levels of health concern; eating fish with the detected levels of arsenic is not expected to result in adverse health effects.

Vegetation

Limited vegetable data (18 kale samples and 15 tomato samples) were used to evaluate exposure to arsenic via locally grown vegetables. Arsenic was detected in 55 to 60 percent of the kale and tomato samples analyzed. Plants vary in the amount of arsenic they absorb from the soil and where they store arsenic. Some plants move arsenic from the roots to the leaves, while others absorb and store it in the roots only.

- Fruit-type vegetables, such as tomatoes, concentrate arsenic in the roots, and less arsenic is taken up in the fruit.
- Leafy vegetables also store arsenic in their roots, but some is stored in the stems and leaves. Lettuce and some members of the *Brassica* plant family (such as collards, kale, mustard, and

turnip greens) store more arsenic in the leaves than other crops, but not at concentrations high enough to cause concern.

- Root crops such as beets, turnips, carrots, and potatoes absorb most of the arsenic in the surface skin of the vegetable. Peeling the skins of root crops, can help eliminate the portion of the plant that contains arsenic.

Arsenic was detected in 60 percent or less of the kale and tomato samples. The exposure doses are below the level at which the body can detoxify inorganic arsenic into the less harmful form (5.0×10^{-2} mg/kg/day; see Table 7). Further, people are not expected to consume their yearly diet of vegetables from local gardens and a portion of arsenic in plants is in the less toxic form (organic arsenic). Therefore, ATSDR does not expect adverse health effects to result from exposure to arsenic in locally grown produce.

Air

Limited air monitoring data collected on ORR were used to evaluate exposure to arsenic via the inhalation pathway. The average air level was 0.00056 micrograms per cubic meter ($\mu g/m^3$)—which slightly exceeds the comparison value of 0.0002 $\mu g/m^3$. Air samples were collected on ORR, thus the surrounding population would have been exposed to lower levels due to dispersion, downwash effects, and increasing distance. Therefore, ATSDR does not believe that adverse effects would result in the general population from air related arsenic exposure.

Benzidine

Benzidine is a manufactured chemical that does not occur naturally. It is a crystalline solid that may be grayish-yellow, white, or reddish-gray. In the environment, benzidine is found in either its “free” state (as an organic base), or as a salt. Benzidine was used to produce dyes for cloth, paper, and leather. It is no longer produced or used commercially in the United States.

In soil, most benzidine is likely to be strongly attached to soil particles, so it does not easily pass into underground water. Benzidine can slowly be destroyed by certain other chemicals, light, and some microorganisms (for example, bacteria). Certain fish, snails, algae, and other forms of water life may take up and store very small amounts of benzidine, but accumulation in the food chain is unlikely.

As shown in Table 16, the estimated exposure dose for adults exposed to benzidine in off-site soil is above the cancer screening guideline. As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential from exposure to benzidine in soil. The benzidine levels detected in all other media are not at levels of health concern (i.e., the estimated doses are below the noncancer and cancer screening guidelines or benzidine was not detected).

Very little information is available on the noncancer health effects that may be caused by exposure to benzidine. Benzidine contact with your skin could possibly cause a skin allergy. Benzidine can cause cancer in humans. This has been shown in studies of workers who were exposed for many years to levels much higher than the general population would experience. It is

important to note that most of the workers did not develop cancer, even after such high exposures. When cancer does occur, most often it is cancer of the urinary bladder.

Benzidine was detected in two of 26 off-site surface soil samples. The two surface soil samples were from two separate residential properties, located approximately 0.5 mile apart. The reported concentrations were above ATSDR's cancer screening value for soil. The estimated exposure dose for a person exposed for 125 days per year for 30 years is below the cancer screening value. Based on the conservative exposure assumptions, the tightly bound nature of benzidine to soil and organic material, and the unlikelihood that the general population or people living near the two locations would come into routine contact with benzidine-impacted surface soil (detected in less than 8 percent of the samples), ATSDR does not expect adverse health effects from exposure to benzidine in surface soil.

Cadmium

Cadmium is an element that occurs naturally in the Earth's crust. All soils and rocks, including coal and mineral fertilizers, contain some cadmium. Pure cadmium is a soft, silver-white metal. It is often found as part of small particles in air. It does not have a distinctive flavor or smell; therefore, indistinguishable in water, food, or air. Food and cigarette smoke are the largest potential sources of cadmium exposure for the general population. Average cadmium levels in U.S. foods range from 2 to 40 parts of cadmium per billion parts of food (ppb). Average cadmium levels in cigarettes range from 1,000 to 3,000 ppb. The current U.S. average dietary intake of cadmium in adults is about 4.0×10^{-4} mg/kg/day; smokers receive an additional amount—about 4.0×10^{-4} mg/kg/day—from cigarettes (ATSDR 1999a). Most ingested cadmium passes through the gastrointestinal tract without being absorbed (Kjellstrom et al. 1978 ATSDR 1999a).

The estimated exposure doses for children and adults eating EFPC fish (Table 21), on-site fish (Table 27), on-site game (Table 29), and vegetables (Table 30); and people inhaling the air (Table 32) are above the ATSDR cadmium screening guidelines. As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential from these pathways. The cadmium levels detected in soil, sediment, and surface water are not at levels of health concern (i.e., the estimated doses are below the noncancer screening guidelines) and will not be discussed further.

Table 8 shows the exposure doses for media that exceeded the cadmium screening guidelines using the second-tier screening concentrations. ATSDR does not have a specific screening value for cadmium in biota (crayfish, fish, game, or vegetables) but has derived an MRL of 0.0002 mg/kg/day for chronic oral exposure to cadmium. The chronic oral MRL is based on a lifetime accumulated threshold of 2,000 mg of cadmium from dietary sources. The threshold is associated with kidney effects (e.g., proteinuria, or protein in the urine) seen in residents of cadmium-polluted areas of Japan. The average cadmium concentration in locally grown rice was used as the measure of cadmium intake and proteinuria was used as the index of renal damage. A relevant consideration is whether the proteinuria caused by cadmium exposure should be considered an adverse effect. The increased excretion of low-molecular-weight proteins *per se* probably has no adverse effect on health. Although, several studies have indicated that increased calcium excretion also occurs at about the same level as proteinuria, and this is an adverse effect

if it leads to increased calcium wasting and osteoporosis, particularly in post-menopausal women.

EPA has calculated oral chronic RfDs for cadmium of 0.001 and 0.0005 mg/kg/day for ingestion of food and water, respectively. The critical effect is significant proteinuria in humans chronically exposed to cadmium, using a NOAEL of 200 mg of cadmium per gram wet weight in the renal cortex and a kinetic model assuming 2.5 or 5 percent cadmium absorption from food or water, respectively and 0.01 percent cadmium excretion per day (EPA 2004b). ATSDR's chronic oral MRL (0.0002 mg/kg/day) is comparable to the EPA RfD for water (0.0005 mg/kg/day). This is probably due to the fact that the moisture content of cooked rice is about 75 percent, roughly a 3:1 ratio of water-to-rice. As such, when evaluating exposures via the consumption of rehydrated foods (such as rice, pasta, and beans), ATSDR uses the MRL/RfD for water, but when considering exposures from hydrated foods (such as fish, game, and vegetables) then ATSDR uses the RfD for food since it more closely matches the expected media being evaluated.

Table 8. Exposure Doses for Cadmium

Media		***Average Concentration (ppm)***	***Exposure Dose (mg/kg/day)***	
			Child	***Adult***
EFPC Crayfish	Subsistence	3	4.6E-03	2.8E-03
	Recreational		6.9E-04	3.4E-04
On-site Crayfish	Subsistence	2.1	3.2E-03	2.0E-03
	Recreational		4.8E-04	2.4E-04
EFPC Sunfish	Subsistence	1.2	1.8E-03	1.1E-03
	Recreational		2.8E-04	1.4E-04
On-site Sunfish	Subsistence	0.83	1.3E-03	7.7E-04
	Recreational		1.9E-04	9.5E-05
On-site Creek Chub	Subsistence	0.86	1.3E-03	8.0E-04
	Recreational		2.0E-04	9.8E-05
On-site Bass	Subsistence	0.24	3.7E-04	2.2E-04
	Recreational		*Below screening guidelines*	
On-site Unidentified Fish	Subsistence	0.8	1.2E-03	7.4E-04
	Recreational		1.8E-04	9.1E-05
On-site unknown aquatic bird		4.3	3.3E-04	1.2E-04
On-site unknown terrestrial animal		4.5	3.5E-04	1.3E-04
Off-site Beets		0.69	1.1E-03	1.1E-03
Off-site Kale		0.6	9.6E-04	9.6E-04
Off-site Tomato (edible portion only)		0.17	2.7E-04	2.7E-04
Air		0.00065 µg/m³	N/A	

The chronic MRL for cadmium is 2.0×10^{-4} mg/kg/day.
Air CREG = 0.0006 µg/m^3
The EPA oral RfDs for cadmium are 1.0×10^{-3} mg/kg/day and 5.0×10^{-4} mg/kg/day from ingestion of food and water, respectively.
The tomato data were screened (see Section III.D) using both fruit and root samples. However, for the public health implications section we focused on the edible portion of the tomato plant (i.e., the fruit).
"Below screening guidelines" means that the calculated doses were below screening guidelines during the second-tier screening evaluation (see Section III.D).
N/A = not applicable

Fish

As noted above, most ingested cadmium passes through the gastrointestinal tract without being absorbed (Kjellstrom et al. 1978). EPA has derived an oral RfD for food that reflect differences in absorption between cadmium in food and water. The estimated exposure doses for children and adults under the recreational exposure scenario (see Table 8) are below the screening guideline for food (1.0×10^{-3} mg/kg/day) and below the NOAEL for humans (2.1×10^{-3} mg/kg/day; ATSDR 1999a).

The estimated exposure doses for subsistence behavior were above the screening guideline for sunfish, creek chub, crayfish, and an unidentified fish species for children and sunfish and crayfish for adults. The estimated exposure doses for crayfish (subsistence adults and children) were also above the human NOAEL under the default assumptions of eating approximately 16 lbs/year and 52 lbs/year for children and adults, respectively. This consumption rate for locally harvested crayfish is more than a pound/month for children and a pound/week for adults—which at that consumption level could result in health effects (e.g., proteinuria). However, we believe that the recreational consumption rates (2.4 lbs/year and 6.4 lbs/year for children and adults, respectively) are more realistic regarding locally harvested crayfish. As previously mentioned, the exposure doses for adults and children via recreational activities are below levels of concern.

The respective estimated exposure doses for subsistence behaviors regarding sunfish, creek chub, and an unidentified fish species were slightly above the EPA RfD for children—and only in EFPC sunfish for adults—but below the human NOAEL under the default assumptions of eating approximately 16 lbs/year and 52 lbs/year for children and adults, respectively. As presented in Table 7, the estimated exposure doses were calculated using limited species/area specific fish data. For onsite fish there were a total of 69 fish samples (38/69 had cadmium) and for EFPC fish there were 7 samples (7/7 sunfish had cadmium). Of the 122 fish samples for the Clinch River none of them had detectable levels of cadmium and only 2 of 88 fish samples from WBR had cadmium. Given that subsistence fishing behavior would likely occur at multiple locations (e.g. Clinch River, EFPC, and WBR) in order to provide roughly 16 lbs of fish/year and 52 lbs of fish/year for children and adults, respectively and that cadmium was infrequently detected (less than 8 percent of the fish samples), then exposure to cadmium in fish is not expected to result in adverse health effects.

Game

Adult and child exposure doses for an on-site bird and animal exceeded the ATSDR screening guideline for cadmium but were below the EPA RfD for cadmium in food (see Table 7). All other game (Canada goose and wood duck) were below the ATSDR screening guideline for cadmium. Thus, exposure to cadmium via ingestion of game is not expected to result in adverse health effects.

Vegetables

The exposure doses from eating kale and tomatoes are below EPA's RfD for ingestion of food (1.0×10^{-3} mg/kg/day). With an exposure dose of 1.1×10^{-3} mg/kg/day, eating beets only slightly exceeds the RfD, but is below the human NOAEL assuming a consumption rate of 1.3 lbs of

vegetables/year. It is conceivable that a person could grow and eat more than 1.3 lbs/year of beets and/or other vegetables—and consequently have higher exposure doses. The vegetable data is somewhat limited (40 individual samples) with about 40 percent of the beet, kale, and tomato samples having detectable levels of cadmium. Thus, if we assume that about ≥50 percent of the vegetables consumed do not have detectable levels of cadmium then exposure is not expected to result in adverse health effects for the general population. However, if an individual is eating beets, kale, tomatoes, and/or other vegetables at the reported cadmium levels on a continuous basis (yearly garden with freezing/canning of excess harvest for later consumption) then health effects (e.g., proteinuria) could occur in those individuals. To reduce cadmium exposure from routine consumption of homegrown vegetables consider building a raised-bed garden and filling it with topsoil and compost from outside sources or areas of your yard that do not have elevated levels of cadmium; or increase the organic matter in your soil by adding compost or manure from outside sources such as commercial garden centers.

Air

Limited air monitoring data collected on ORR were used to evaluate exposure to cadmium via the inhalation pathway. Air samples were collected on ORR, and the average air level was 0.00065 $\mu g/m^3$—which slightly exceeds the screening guideline of 0.0006 $\mu g/m^3$. The surrounding population would have been exposed to lower levels due to dispersion, downwash effects, and increasing distance—as such, the ambient levels would have been below the screening level. Therefore, ATSDR does not believe that adverse effects would result in the general population from air-related cadmium exposure.

Chromium

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and volcanic gases. Chromium occurs in the environment in several chemical forms depending on the valance state of the chromium metal (e.g., trivalent (III) chromium or hexavalent (VI) chromium). Trivalent chromium—an essential nutrient—is more likely to be found in the environment and the body than hexavalent chromium. Trivalent chromium helps regulate how the body uses insulin. Hexavalent chromium is considerably more toxic to humans than trivalent chromium. The absorption of orally ingested chromium is relatively poor, with less than 10 percent absorption for the trivalent and hexavalent forms (ATSDR 2000b).

The estimated exposure doses for children and adults eating EFPC crayfish (Table 21), WBR fish (Table 25), and vegetables (Table 30); and people inhaling the air (Table 32) are above the hexavalent chromium screening guidelines. As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential from these pathways. The chromium levels detected in soil, surface water, sediment, and game are not at levels of health concern (i.e., the estimated doses are below the noncancer screening guideline) and will not be discussed further.

Table 9 shows the exposure doses for media that exceeded the hexavalent chromium screening guidelines. For this level of the evaluation, however, ATSDR recalculated the estimated exposure doses using average concentrations to represent more realistic exposure scenarios. Further, because the environmental data are not specific as to valence, ATSDR estimated

exposure doses assuming that 50 percent of the measured concentrations are present as the more toxic hexavalent form. To account for chromium's poor absorption, ATSDR assumed that 10 percent of the chromium was absorbed.

Table 9. Exposure Doses for Chromium

Media	Average Concentration (ppm)	Exposure Dose (mg/kg/day)	
		Child	Adult
EFPC Crayfish	1.5	1.2E-04	*Below*
WBR Unknown Fish	5.6	4.3E-04	2.6E-04
Off-site Kale	7.6	6.1E-04	6.1E-04
Off-site Tomato	9.9	7.9E-04	7.9E-04
Air	0.0013 μg/m^3	N/A	

The chronic RfD for hexavalent chromium is 3.0×10^{-3} mg/kg/day.
Air CREG = 0.00008 μg/m^3
Exposure doses for fish represent subsistence-level fishing.
ATSDR assumed 50 percent of the chromium detected was in the more harmful hexavalent form. Therefore, doses are calculated using one half the average concentration.
To account for the poor absorption of chromium, ATSDR assumed that 10 percent of the chromium was absorbed.
"Below" means that the calculated doses were below screening guidelines during the second-tier screening evaluation (see Section III.D).
N/A = not applicable

ATSDR has not established a screening guideline for ingestion of chromium because the available data are insufficient or too contradictory to establish minimum effect levels. Because chromium is an essential nutrient, the National Research Council has established a range of "estimated safe and adequate daily dietary intakes" for chromium. The range is 50 to 200 micrograms per day (μg/day) (NAS 1989, 1994). The value at the upper end of this range, 200 μg/day, has been adopted by ATSDR as an interim guideline for oral exposure to hexavalent and trivalent chromium compounds (ATSDR 2000b). This interim guideline is equivalent to an exposure dose of 3.0×10^{-3} mg/kg/day for a 70-kilogram adult, and 2.0×10^{-2} mg/kg/day for a 13-kilogram child. It is similar to the screening guideline established by EPA for chronic ingestion of chromium VI. EPA's RfD for chronic oral exposure, based on animal studies, is 3.0×10^{-3} mg/kg/day (EPA 2004c).

Biota

The estimated exposure doses related to chromium in biota were above screening guidelines for EFPC crayfish, WBR unknown species of fish, and off-site vegetation when assuming 100 percent absorption. When considering the poor absorption of chromium from the gastrointestinal tract (less than 10 percent), however, the resulting exposure doses were below the screening guideline (see Table 9). Estimated doses that are less than the screening guideline are not considered to be of health concern. Therefore, ATSDR does not expect adverse health effects to result from exposure to chromium in biota.

Air

Limited air monitoring data collected on ORR were used to evaluate exposure to chromium via the inhalation pathway. The average concentration of chromium in measured air was

0.0013 μg/m^3, which exceeds the ATSDR cancer comparison value but is within the acceptable cancer risk level of one in 10,000. Furthermore, the average air level does not exceed EPA's established noncancer inhalation guideline value of 0.008 μg/m^3 for hexavalent chromium. Therefore, ATSDR does not expect adverse effects to result from chromium exposure in air.

Dibenzo(a,h)anthracene

Dibenzo(a,h)anthracene is one of more than 100 different polycyclic aromatic hydrocarbons (PAHs). PAHs are formed during incomplete burning and generally occur as complex mixtures, rather than single compounds. All other PAHs were below screening values individually and/or in combination for all pathways considered. Since screening values do not exist for all PAHs, ATSDR used the "toxicity equivalency factors" (TEFs) available in the scientific literature. The TEF approach can be applied to individual congeners to generate a single concentration for the compound class. The highest reported concentrations of PAHs in surface soil were located on an industrial property (i.e., Atomic City Auto Parts) where soil removal activities have been conducted (the contaminated soil has been removed). Therefore, since exposure to impacted soil on the industrial property has been eliminated via removal activities these soil concentrations were deleted from consideration for current and future soil exposure. As such, ATSDR does not expect adverse effects to result from exposure to PAHs in surface soil.

As shown in Table 22, the estimated exposure dose for adults eating EFPC crayfish at a subsistence level is above the dibenzo(a,h)anthracene cancer screening guideline. As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential from eating EFPC crayfish. The dibenzo(a,h)anthracene levels detected in all other media are not at levels of health concern (i.e., the estimated doses are below the noncancer and cancer screening guidelines or dibenzo(a,h)anthracene was not detected).

When the lifetime exposure dose is recalculated using the average concentration (0.15 parts per million, or ppm), the resulting dose (6.0×10^{-6} mg/kg/day) is below levels of concern (i.e., below the screening guideline, which utilizes safety factors making it considerably lower than levels at which health effects have been observed). Additionally, it is unlikely that people would be able to maintain a subsistence diet on crayfish alone. As such, ATSDR does not expect adverse health effects to result from exposure to dibenzo(a,h)anthracene in crayfish.

2,4-Dinitrophenol

Dinitrophenols are a class of manufactured chemicals that do not occur naturally in the environment. There are six different dinitrophenols. The most commercially important dinitrophenol, 2,4-dinitrophenol, is a yellow, odorless solid. It is used in making dyes, wood preservatives, explosives, and insect control substances, and as a photographic developer.

As shown in Table 29, the estimated exposure doses for children and adults eating on-site game are above the 2,4-dinitrophenol noncancer screening guideline. As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential from eating on-site game. The 2,4-dinitrophenol levels detected in soil, sediment,

surface water, and on-site fish are not at levels of health concern (i.e., the estimated doses are below the noncancer screening guideline or 2,4-dinitrophenol was not detected)[13].

To further evaluate exposure through eating game, ATSDR recalculated the exposure doses using the average concentration (55 ppm) to represent more a realistic exposure scenario. The estimated exposure doses for children and adults eating on-site game (unknown terrestrial animals) are 4.2×10^{-3} mg/kg/day and 1.6×10^{-3} mg/kg/day, respectively. Only the child dose slightly exceeds EPA's chronic RfD for 2,4-dinitrophenol (2.0×10^{-3} mg/kg/day). Six samples were used to estimate the exposure doses. The LOAEL (2.0 mg/kg/day) used to derive the chronic RfD is from a human study and incorporates an uncertainty factor of 1,000. The highest estimated exposure dose was about 475 times less than the LOAEL. Based on the low number of samples, the margin of safety relative to the LOAEL, and the conservative assumptions used for the estimation of exposure doses, adverse effects are not expected from eating on-site game.

4,6-Dinitro-o-cresol

Dinitrocresols are a class of manufactured chemicals that do not occur naturally in the environment. There are 18 different dinitrocresols. The most commercially important dinitrocresol, 4,6-dinitro-o-cresol, is a yellow, odorless solid. It is used primarily for insect control and crop protection.

As shown in Table 29, the estimated exposure doses for children eating game caught on site are above the 4,6-dinitro-o-cresol noncancer screening guideline. As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential from eating on-site game. The 2,4-dinitrophenol levels detected in soil, sediment, surface water, and on-site fish are not at levels of health concern (i.e., the estimated doses are below the noncancer screening guideline or 4,6-dinitro-o-cresol was not detected)[14].

The frequency of detection was low for the data set (17 percent or one in six samples). Therefore, only this one detected sample (3.5 ppm) was used to estimate the exposure dose. The estimated exposure dose for children eating on-site game (unknown terrestrial animals) is 2.7×10^{-4} mg/kg/day. This dose only slightly exceeds EPA's provisional RfD for 4,6-dinitro-o-cresol (1.0×10^{-4} mg/kg/day). Based on the low frequency of detection and conservative assumptions used for the estimation of exposure doses, adverse effects are not expected.

Dioxin (chlorinated dibenzo-p-dioxins)

Chlorinated dibenzo-p-dioxins (CDDs) are a family of 75 chemically related compounds commonly known as chlorinated dioxins. One of these compounds is called 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). It is one of the most toxic of the CDDs and is the most studied.

In their pure forms, CDDs are crystals or colorless solids. CDDs enter the environment as mixtures containing a number of individual components. CDDs are not intentionally manufactured by industry except for research purposes. They (mainly 2,3,7,8-TCDD) may be

[13] 2,4-Dinitrophenol was not sampled in off-site fish, off-site game, or vegetation.
[14] 2,4-Dinitrophenol was not sampled in off-site fish, off-site game, or vegetation.

formed during the chlorine bleaching process at pulp and paper mills. CDDs are also formed during chlorination by waste and drinking water treatment plants. They can occur as contaminants in the manufacture of certain organic chemicals. CDDs are released into the air as emissions from municipal solid waste and industrial incinerators as well.

The estimated exposure doses for people eating unknown species of fish from WBR (Table 25 and Table 26) were above the dioxin noncancer and cancer screening guidelines. Therefore, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential from fish ingestion. The dioxin levels detected in soil, sediment, and surface water are not at levels of health concern (i.e., the estimated doses are below the noncancer and cancer screening guidelines)[15].

Table 10. Exposure Doses for Dioxin

Media		*Average Total Relative Concentration (ppm)*	*Exposure Dose (mg/kg/day)*		
			Child	*Adult*	*Lifetime*
Unknown Fish	Subsistence	0.000028	4.3E-08	2.6E-08	1.1E-08
	Recreational		6.5E-09	3.2E-09	1.4E-09

The chronic MRL for TCDD is 1.0×10^{-9} mg/kg/day.
Total relative concentrations were calculated using the toxic equivalency factor (TEF) approach for dioxins. This approach to evaluating health hazards has been developed and used to some extent to guide public health decisions (see EPA 1996b and ATSDR 2000c for more details). In short, the TEF approach compares the relative potency of individual congeners with that of TCDD, the best-studied member of this chemical class. The concentration or dose of each dioxin-like congener is multiplied by its TEF to arrive at a toxic equivalent (TEQ), and the TEQs are added to give the total toxic equivalency. The total toxic equivalency is then compared to reference exposure levels for TCDD expected to be without significant risk for producing health hazards.

The estimated exposure doses for children and adults eating fish (unknown species) from WBR are above the screening guidelines (see Table 10). The data set used to estimate the exposure dose consisted of three fish samples collected from a pond near the K-25 complex. Due to the lack of "dioxin" fish data, ATSDR classifies the potential for public health effects to result from exposure to dioxin in fish as an indeterminate public health hazard. There is very limited dioxin data for fish—as such exposure to dioxins in fish poses an indeterminate public health hazard. The available fish data is from a pond near the K-25 complex from an unknown/unidentified fish species. In the absence of additional data, ATSDR recommends following the current fish advisories. If community members are concerned and wish to reduce their exposure, they can follow the cleaning and cooking methods presented in *A Guide to Healthy Eating of the Fish You Catch*, provided in Appendix C.

[15] Dioxins and furans were not sampled in EFPC fish, Clinch River fish, on-site fish, off-site game, or vegetation.

Fish Advisories for Waterways Near ORR

Tennessee River
Catfish, striped bass, hybrid striped bass, and white bass should not be eaten. Children, pregnant women, and nursing mothers should not consume sauger, carp, smallmouth, buffalo, and largemouth bass, but other people can consume one meal per month.

Clinch River
Striped bass should not be eaten. Children, pregnant women, and nursing mothers should not consume catfish and sauger, but other people can consume one meal per month.

East Fork Poplar Creek
No fish should be eaten.

For the advisory, go to http://www.state.tn.us/environment/wpc/publications/advisories.pdf.

Heptachlor epoxide

Heptachlor epoxide is a breakdown product of heptachlor, a synthetic chemical used prior to 1988, for killing insects in homes, in buildings, and on food crops. Heptachlor epoxide was not manufactured—bacteria in the environment form heptachlor epoxide from heptachlor. Ingestion of soil containing heptachlor epoxide is one way the chemical can enter the body. The toxicokinetics (i.e., absorption, distribution, metabolism, and excretion) of heptachlor epoxide is not well studied in humans, however. Animal studies suggest that heptachlor epoxide is primarily stored in adipose tissue (i.e., fat). One animal study reported that the levels of heptachlor epoxide decreased to below detection limits 6 to 8 weeks after exposure (ATSDR 1993a).

As shown in Table 15, and Table 21 through Table 28, the estimated exposure doses for children and adults under the subsistence fishing exposure scenarios are above the chronic oral screening guidelines for heptachlor epoxide. The only recreational exposure scenario above the heptachlor epoxide noncancer screening guideline is for a child eating sunfish from EFPC. As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential from fish ingestion. The heptachlor epoxide levels detected in soil, sediment, surface water, and game are not at levels of health concern (i.e., the estimated doses are below the noncancer and cancer screening guidelines) and will not be discussed further[16].

Table 11 shows the exposure doses for media that exceeded the heptachlor epoxide noncancer and cancer screening guidelines. For this level of the evaluation, however, ATSDR recalculated the estimated exposure doses using average concentrations to represent more realistic exposure scenarios.

[16] Heptachlor epoxide was not sampled in off-site game and vegetation.

Table 11. Exposure Doses for Heptachlor Epoxide

Media		*Average Concentration (ppm)*	*Exposure Dose (mg/kg/day)*		
			Child	*Adult*	*Lifetime*
EFPC Sunfish	Subsistence	0.038	5.8E-05	3.5E-05	1.5E-05
	Recreational		8.8E-06	*Below screening guidelines*	
Clinch River Sunfish	Subsistence	0.04	6.2E-05	3.7E-05	1.6E-05
	Recreational		*Below screening guidelines*		
WBR Sunfish	Subsistence	0.031	4.8E-05	2.9E-05	1.2E-05
	Recreational		*Below screening guidelines*		
On-site Sunfish	Subsistence	0.031	4.8E-05	2.9E-05	1.2E-05
	Recreational		*Below screening guidelines*		
Clinch River Catfish	Subsistence	0.005	7.7E-06	4.6E-06	2.0E-06
	Recreational		*Below screening guidelines*		
WBR Catfish	Subsistence	0.005	7.7E-06	4.6E-06	2.0E-06
	Recreational		*Below screening guidelines*		
On-site Catfish	Subsistence	0.009	1.4E-05	8.4E-06	3.6E-06
	Recreational		*Below screening guidelines*		

The chronic RfD for heptachlor epoxide is 1.3×10^{-5} mg/kg/day.
"Below screening guidelines" means that the calculated doses were below screening guidelines during the second-tier screening evaluation (see Section III.D).

The estimated exposure doses for adults and children eating fish are above their respective guidelines for noncancer and cancer effects (see Table 21 through Table 28). The highest exposure doses were for subsistence children and adults eating sunfish from the Clinch River. The Clinch River data set used to estimate exposure doses had 13 percent detects (13/100 sunfish samples). It appears that as the number of fish samples increases the percent detected decreases (EFPC 6/7, on-site 15/36, Watts Bar 8/50, and Clinch River 13/100). The oral screening guideline for heptachlor epoxide is based on a study in which liver-to-body weight ratios were significantly increased in dogs fed heptachlor epoxide at doses of 1.25×10^{-2} mg/kg/day for 60 weeks (Dow Chemical Company 1958). Supporting animal studies report no adverse health effects for doses ranging from 2.5×10^{-2} to 2.5×10^{-1} mg/kg/day (EPA 2004a). The estimated exposure doses are at least 400 times below these health effects levels. As such, adverse effects are not expected.

EPA classifies heptachlor epoxide as a probable human carcinogen based on rodent studies in which liver carcinomas were induced in two strains of mice and female rats (EPA 2004a). There are three epidemiologic studies of workers exposed to chlordane and/or heptachlor. One retrospective cohort study of pesticide applicators was considered inadequate in sample size and duration follow up. This study showed marginal statistically significant increased mortality from bladder cancer. Two other retrospective cohort studies were of pesticide manufacturing workers. Neither of them showed any statistically significant increased cancer mortality. Both of these populations also had confounding exposures to other chemicals (EPA 2004a).

The exposure doses for cancer effects are slightly above the cancer screening guidelines. Based on the low probability that a person would be exposed to significant levels over 30 years, the conservative exposure assumptions, and the lack of statistically significant cancer mortality in three human studies, ATSDR does not expect cancer effects from exposure to heptachlor epoxide in fish.

alpha-Hexachlorocyclohexane (alpha-HCH)

Hexachlorocyclohexanes are synthetic chemicals that were once used as insecticides. They exist in eight chemical forms called isomers. The different isomers are named according to the position of the hydrogen atoms (ATDR 2003).

The estimated exposure dose for subsistence behavior for sunfish was slightly above the cancer screening guideline in people ingesting sunfish from the Clinch River (see Table 24). The alpha-HCH levels detected in all other media are not at levels of health concern (i.e., the estimated doses are below the noncancer and cancer screening guidelines).

Sunfish were used to estimate exposure because that species had the highest reported average concentration, which calculates to the highest exposure doses. The estimated lifetime exposure is 1.7×10^{-5} mg/kg/day, which is well below the cancer effect levels reported in the literature (cancer effect levels, or CELs, range from 2 to 90 mg/kg/day; ATSDR 2003). Further, if the exposure dose is estimated using 28 years of daily exposure instead of 30 years, it is below the cancer screening value. Based on the conservative assumptions used to estimate exposure and the unlikelihood that subsistence behavior would occur with only sunfish, ATSDR does not expect adverse health effects from exposure to alpha-HCH in fish.

Iron

Iron is a naturally occurring element in the environment. In fact, it is the fourth most abundant element in the Earth's crust by weight (LANL 2001). The most common iron ore is hematite, which frequently can be seen as black sand along beaches and stream banks. It is hard and brittle, and is usually combined with other metals to form alloys, including steel.

Iron is also an important mineral, which assists in the maintenance of basic life functions. It combines with protein and copper to make hemoglobin, which transports oxygen in the blood from the lungs to other parts of the body, including the heart. It also aids in the formation of myoglobin, which supplies oxygen to muscle tissues (ANR 2003). Without sufficient iron, the body cannot produce enough hemoglobin or myoglobin to sustain life. Iron deficiency (anemia) is a condition that occurs when the body does not receive enough iron. The NAS RDA for children is 10 mg/day (FDA 1997). The FDA Reference Daily Intake for iron is 18 mg/day (Kurtzweil 1993).

The estimated exposure doses for children ingesting soil (Table 15) and people eating on-site game (Table 29) are above the iron noncancer screening guideline. As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential from these pathways. The iron levels detected in sediment, surface water, and fish are not at levels of health concern (i.e., the estimated doses are below the noncancer screening guideline) and will not be discussed further[17].

Table 12 shows the exposure doses for media that exceeded the iron noncancer screening guideline. For this level of the evaluation, however, ATSDR recalculated the estimated exposure

[17] Iron was not sampled in off-site vegetation.

doses using average concentrations to represent more realistic exposure scenarios. ATSDR also calculated daily intake rates.

Table 12. Exposure Doses and Daily Intake Rates for Iron

Media	*Average Concentration (ppm)*	*Exposure Dose (mg/kg/day)*		*Daily Intake Rates (mg/day)*	
		Child	*Adult*	*Child*	*Adult*
Off-site Soil	23,000	2.8E-01	*Below*	5	*Below*
On-site unknown terrestrial animal	7,600	5.8E-01	2.2E-01	8	15

The chronic RfD for iron is 3.0×10^{-1} mg/kg/day.
"Below" means that the calculated doses were below screening guidelines during the second-tier screening evaluation (see Section III.D).

According to the FDA, doses greater than 200 mg per event could poison or kill a child (FDA 1997). Doses of this magnitude are generally the result of children accidentally ingesting iron pills, and not from ingesting iron in soil or water. Acute iron poisoning has been reported in children less than 6 years of age who have accidentally overdosed on iron-containing supplements for adults. Because iron is not considered to cause harmful health effects in general, toxicological and epidemiological literature is limited.

Soil

Despite the fact that iron is the second most abundant metal in the earth's crust, iron deficiency is the world's most common cause of anemia. The average adult stores about 1 to 3 grams of iron in his or her body. An exquisite balance between dietary uptake and loss maintains this balance. About 1 mg of iron is lost each day through sloughing of cells from skin and mucosal surfaces, including the lining of the gastrointestinal tract. No physiologic mechanism of iron excretion exists. Consequently, absorption alone regulates body iron stores. Iron is not completely absorbed from food and the iron found in meat is absorbed to a greater degree than that in other foods. The absorption of iron from breast milk has been estimated to be about 80 percent.

Based on the child soil ingestion rate, the soil iron concentration at which the RDA of 10 mg/day would be reached was calculated to be 50,000 ppm (assuming 200 mg soil/day for 365 days/year at 100 percent absorption). Concentrations of iron in soil ranged from 5,790 to 61,600 ppm, with an average concentration of about 23,000 ppm. Further, the body normally reduces absorption of iron from the gastrointestinal tract in response to higher concentrations. As a result, the levels of iron found in the soil are not likely to pose a health hazard to children.

For comparison, ATSDR calculated a daily consumption from exposure to the iron in soil using a modification of the dose equation (Dose = Concentration × Intake Rate). Exposure to the average level of iron in the soil would increase a non-pica child's daily consumption of iron by 5 mg/day, assuming 100 percent absorption. The median daily intake of dietary iron is roughly 11 to 13 mg/day for children 1 to 8 years old and 13 to 20 mg/day for adolescents 9 to 18 years old (NAS 2001). The daily consumption of iron for a child does not exceed the NAS and FDA recommended intake guidelines, and the daily increase in consumption is not likely to cause a child's daily dose to exceed levels known to induce poisoning (greater than 200 mg/event).

Therefore, ATSDR does not expect that non-pica children would experience adverse health effects from exposure to iron in soil.

Game

Acute iron poisoning has been reported in children under 6 years of age who have accidentally overdosed on iron-containing supplements for adults. According to the FDA, doses greater than 200 mg per event could poison or kill a child (FDA 1997). Doses of this magnitude are generally the result of children ingesting iron pills however. For comparison, ATSDR calculated a daily consumption from exposure to the average concentration of game (unknown terrestrial animal) by multiplying the concentration of iron (7,600 ppm or mg/kg) by the daily ingestion rate (0.002 kg of game/day for an adult and 0.001 kg/day for a child). Based on this estimate, eating game could have increased an adult's daily consumption of iron by 15 mg/day and child's daily consumption of iron by 8 mg/day. Therefore, the daily increases in game consumption are not expected to cause a person's daily dose to exceed levels known to induce poisoning (e.g., greater than 200 mg/event). Further, the body uses a homeostatic mechanism to keep iron burdens at a constant level despite variations in the diet (Eisenstein and Blemings 1998). Therefore, ingesting game containing this level of iron is not expected to result in adverse noncancer health effects.

Manganese

Manganese is naturally found in many types of rocks and comprises about 0.1 percent of the Earth's crust (ATSDR 2000d). It is an essential trace element and is required by the body to break down amino acids and produce energy. Eating game containing manganese can result in manganese entering the body. Most manganese, however, is excreted in feces. Only 3 to 5 percent of manganese is absorbed by the body when ingested (Davidsson et al. 1988, 1989; Mena et al. 1969). Typically, people have small amounts of manganese in their bodies. Under normal circumstances, the amount is regulated so the body has neither too much nor too little (EPA 1984a). For example, if large amounts of manganese are consumed, large amounts will be excreted.

As shown in Table 29, the estimated exposure dose for a child eating on-site game is above the manganese noncancer screening guideline. As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential for this pathway. The manganese levels detected in all other media are not at levels of health concern (i.e., the estimated doses are below the noncancer screening guideline).

The Food and Nutrition Board of the National Research Council determined that 2 to 5 mg of manganese/day is an "estimated safe and adequate daily dietary intake" (NRC 1989). The World Health Organization (WHO) concluded that 2 to 3 mg/day is "adequate" and 8 to 9 mg/day is "perfectly safe" (WHO 1973). Based on these studies, EPA has determined that an appropriate reference dose for manganese in food is 10 mg/day, which EPA calculated to a NOAEL of 0.14 mg/kg/day. The estimated exposure dose for a child ingesting on-site game (9.8×10^{-2} mg/kg/day) is below this NOAEL. Further, only a small amount of manganese is absorbed, and a homeostatic mechanism regulates the amount in the body. Therefore, ATSDR does not expect adverse health effects from exposure to manganese in game.

Thallium

Pure thallium is a bluish-white metal that is found in trace amounts in the Earth's crust. In the past, thallium was obtained as a byproduct from smelting other metals; however, it has not been produced in the United States since 1984. In its pure form, thallium is odorless and tasteless. It can also be found combined with other substances such as bromine, chlorine, fluorine, and iodine to form a colorless-to-white or yellow substance. Thallium is used mostly in manufacturing electronic devices, switches, and closures, primarily for the semiconductor industry. It also has limited use in the manufacture of special glass, and for certain medical procedures.

As shown in Table 27 and Table 29, the estimated exposure doses for children and adults eating on-site fish (specifically, bass and sunfish) and game (unknown terrestrial animal) are above the thallium noncancer screening guideline. As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential from eating fish and game. The thallium levels detected in soil, sediment, surface water, and off-site fish are not at levels of health concern (i.e., the estimated doses are below the noncancer screening guideline) and will not be discussed further[18].

Table 13 shows the exposure doses for media that exceeded the thallium noncancer screening guideline. For this level of the evaluation, however, ATSDR recalculated the estimated exposure doses using average concentrations to represent more realistic exposure scenarios.

Table 13. Exposure Doses for Thallium

Media		*Average Concentration (ppm)*	*Exposure Dose (mg/kg/day)*	
			Child	*Adult*
On-site Bass	Subsistence	0.027	4.2E-05	*Below*
	Recreational		*Below screening guidelines*	
On-site Sunfish	Subsistence	1.0	1.5E-03	9.3E-04
	Recreational		2.3E-04	1.1E-04
On-site unknown terrestrial animal		1.8	1.4E-04	5.1E-05

The chronic RfD for thallium is 7.0×10^{-5} mg/kg/day.
"Below screening guidelines" means that the calculated doses were below screening guidelines during the second-tier screening evaluation (see Section III.D).

EPA has RfDs for several thallium compounds. Each RfD covers a particular compound and is based on animal studies for that compound. For example, the RfD for thallium sulfate is based on a failure to observe harmful effects in rats that were administered as much as 0.23 mg/kg/day or thallium by gavage (stomach tube). EPA divided this dose by an uncertainty factor of 3,000 to account for humans being more sensitive than rats to thallium, for some humans being more sensitive than others, and for a lack of reproductive and chronic toxicity data to derive the RfD (EPA 2004a).

On average, a person takes in about 2 micrograms of thallium per gram of food daily. The thallium dose that did not cause toxic effects in rats (2.3×10^{-1} mg/kg/day) was about 150 times higher than the estimated exposure dose for a child and 250 times higher than an adult with

[18] Thallium was not sampled in off-site vegetation.

subsistence exposure patterns for on-site fish. The exposure doses for the recreational fishing scenario and eating on-site game are thousands of times lower than the level at which no health effects were seen in rats. Based on this margin of safety, adverse effects are not expected.

Toxaphene

Toxaphene is an insecticide containing more than 670 chemicals. It is usually found as a solid or gas, and in its original form it is a yellow to amber waxy solid that smells like turpentine. It does not burn and evaporates when in solid form or when mixed with liquids. Toxaphene is also known as camphechlor, chlorocamphene, polychlorocamphene, and chlorinated camphene. Toxaphene was one of the most heavily used insecticides in the United States until 1982, when it was canceled for most uses. All uses were banned in 1990. It was used primarily in the southern United States to control insects on cotton and other crops. It was also used to control insects on livestock and to kill unwanted fish in lakes.

As shown in Table 21 through Table 28, the estimated exposure doses for children and adults ingesting fish are above the toxaphene noncancer and cancer screening guidelines. As such, ATSDR further examined the effect levels reported in the scientific literature and more fully reviewed exposure potential from fish ingestion. The toxaphene levels detected in all other media are not at levels of health concern (i.e., the estimated doses are below the noncancer and cancer screening guidelines) and will not be discussed further[19].

Table 14 shows the exposure doses for media that exceeded the toxaphene noncancer or cancer screening guidelines. For this level of the evaluation, however, ATSDR recalculated the estimated exposure doses using average concentrations to represent more realistic exposure scenarios.

[19] Toxaphene was not sampled in vegetation.

Table 14. Exposure Doses for Toxaphene

Media		*Average Concentration (ppm)*	*Subsistence-level Exposure Dose (mg/kg/day)*		
			Child	*Adult*	*Lifetime*
Clinch River Sunfish	Subsistence	0.84	1.3E-03	7.8E-04	3.3E-04
	Recreational		*Below screening guidelines*		
WBR Sunfish	Subsistence	0.7	1.1E-03	6.5E-04	2.8E-04
	Recreational		*Below screening guidelines*		
On-site Sunfish	Subsistence	0.78	1.2E-03	7.2E-04	3.1E-04
	Recreational		*Below screening guidelines*		
WBR Bass	Subsistence	0.24	3.7E-04	2.2E-04	9.6E-05
	Recreational		*Below screening guidelines*		
On-site Bass	Subsistence	1.9	2.9E-03	1.8E-03	7.6E-04
	Recreational		*Below screening guidelines*		9.3E-05
WBR Catfish	Subsistence	0.2	3.1E-04	1.9E-04	8.0E-05
	Recreational		*Below screening guidelines*		

The intermediate MRL for toxaphene is 1.0×10^{-3} mg/kg/day.
"Below screening guidelines" mean that the calculated doses were below screening guidelines during the second-tier screening evaluation (see Section III.D).

The frequency of detection was low for all data sets (ranging from 2 to 17 percent). The NOAEL (0.35 mg/kg/day) used to derive the intermediate-duration MRL is from an animal study and incorporates an uncertainty factor of 300. The highest estimated exposure dose was about 120 times less than the NOAEL. The estimated exposure doses for subsistence behavior are also well below (almost 17,000 times less than) the cancer effects levels reported in the scientific literature (CELs range from 12.9 to 55.6 mg/kg/day). Based on the low frequency of detection and conservative assumptions used for the estimation of exposure doses, adverse effects are not expected.

Multiple Chemical Exposures

ATSDR reviewed the scientific literature surrounding chemical interactions and noted that if the estimated exposure doses for individual contaminants are well below doses shown to cause adverse effects, then ATSDR considers that the combined effect of multiple chemicals is not expected to result in adverse health effects. Therefore, ATSDR does not expect interactive health effects of multiple chemicals because for each chemical evaluated the conservatively estimated exposure doses are below health effect levels reported in the scientific literature.

> ATSDR does not expect interactive health effects of multiple chemicals because for each chemical evaluated the conservatively estimated exposure doses are below health effect levels reported in the scientific literature.

Several animal and human studies (Berman et al. 1992; Caprino et al. 1983; Drott et al. 1993; Harris et al. 1984) have reported thresholds for interactions. Studies have shown that exposure to a mixture of chemicals is unlikely to produce adverse health effects as long as components of that mixture are detected at levels below the NOAEL for individual compounds (Seed et al. 1995; Feron et al. 1995). Additionally, Jonker et al. (1990) and Groten et al. (1991) demonstrated the absence of interactions at doses 10-fold or more below effect thresholds. Specifically, in two separate subacute toxicity studies in rats (Groten et al. 1997; Jonker et al. 1993), adverse effects disappeared altogether as the dose was decreased to below

the threshold level. Other studies have provided evidence that exposure to chemical mixtures, in which the chemicals were administered at doses that were near their individual thresholds, can produce additive toxic effects. For example, rats exposed to a mixture of sub-threshold doses of 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene experienced signs of liver toxicity (Stacey 1989). The dose given to the rats in this study was greater than 2000 mg/kg, while the estimated exposure doses in the U.S. and Canada are below 0.003 mg/kg/day (ATSDR 2004a).

The interactions of carcinogens are more difficult to quantify at environmental doses because a large study group (humans or animals) is needed for statistical significance at the lower doses observed from environmental exposure. In the mid-1970s, under contract to the National Cancer Institute, 12 chemicals were tested in 918 pair-wise tests in over 14,500 rats (Gough 2002). Dose levels were expected to produce tumors in 20 to 80 percent of the exposed animals. The results of that study produced no convincing evidence for synergistic carcinogen interactions while 20 possible cases of antagonism were observed (Gough 2002). In an animal study, Takayama et al. (1989) reported that 40 substances tested in combination at 1/50 of their CEL resulted in an increase in cancer. However, Hasegawa et al. (1994) reported no increase in cancer when dosing animals at 1/100 of the CEL for 10 compounds. It should be noted that typical environmental exposures to chemicals (noncarcinogens and carcinogens) are greater than 1,000 times below laboratory-induced health effect thresholds.

V. Health Outcome Data Evaluation

National, state, and local health agencies often collect and maintain statistical data on diseases or illnesses (i.e., health outcomes) or on the health status of a defined group of people. For instance, records about births and deaths are usually found at local or state agencies. Many states maintain data on birth defects and cancer. Disease and health status information are also compiled by national health agencies, such as the CDC. Private health care organizations and professional institutions and associations may also compile health outcome data.

ATSDR health assessors use health outcome data to evaluate the occurrence of illnesses or diseases in a population. A health outcome data evaluation involves gathering data from existing sources such as databases or records and analyzing the data. Common sources of health outcome data are cancer registries, birth defects registries, and death certificates that provide a count of the number of cases of disease or the number of deaths over a period of time within a specified geographic area. The analysis is conducted to see if any unusual pattern of a disease is occurring in the community being investigated as compared to another population with similar characteristics (the comparison population). The health assessor can use the results of the analysis to help identify any specific health condition that may occur more frequently in people in the community than in people in the comparison population.

Why Look at Health Outcome Data?

Health outcome data can:

- Provide a general idea of health conditions for a specific population.
- Provide an indication of whether more cases of a particular disease have occurred in a study population compared with a comparison population.
- Provide evidence of unusual patterns or distributions of disease or illness in a geographic area.
- Identify the potential need for follow-up health actions such as exposure investigations, analytic epidemiologic studies or health surveillance.
- Assist in addressing the concerns of community members about the occurrence of disease or illnesses in potentially exposed individuals.

It is important to note that health outcome data evaluations are descriptive in nature and are ***not*** analytical epidemiologic studies. Health outcome data evaluations are an important initial step in the process of identifying the nature and extent of disease in the community around a contaminated site. The primary purpose is to provide additional perspective and information for health assessors and community members about unusual rates and patterns of disease occurrence. Health outcome data evaluations can also help identify the need for public health intervention activities such as community health education. Health outcome data evaluations cannot—and are not intended to—establish cause and effect associations between environmental exposures to hazardous chemicals and adverse health effects in a community.

ATSDR scientists generally consider conducting a health outcome data evaluation to evaluate the possible health effects in a population that has been exposed to sufficiently high levels of environmental contamination to experience health effects. In this public health assessment, ATSDR screened current (1990 to 2003) environmental data and determined whether additional chemicals require further evaluation.

V.A. When Is a Health Outcome Data Evaluation Conducted?

To determine when and how to use or analyze health outcome data in the public health assessment process, ATSDR scientists receive input from epidemiologists, toxicologists, environmental scientists, and community involvement specialists. In general, health outcome data evaluations occur

1. When people are known to be contacting a chemical or chemicals in a way that could harm them,
2. When a specific health outcome has been associated with exposure to the chemical of concern,

and

3. When health outcome data are available for the community and the specific health outcome.

V.B. Should a Health Outcome Data Evaluation Be Conducted?

Based on the findings of the screening evaluation in this public health assessment, ATSDR identified completed exposure pathways for many of the chemicals that were evaluated.

Using health-protective assumptions, however, the estimated exposures of residents to the site-related contaminants are not sufficient to expect adverse health effects. Since none of the estimated chemical-specific doses are expected to cause health effects, no further analysis of health outcome data is appropriate. As noted previously, analysis of site-related health outcome data is not scientifically justified unless the level of estimated exposure is likely to result in health effects.

Although none of the estimated exposure doses for the chemicals screened in this public health assessment were found to be at levels known to cause health effects in the scientific literature, ATSDR is conducting separate public health evaluations for additional chemical and radiological substances, including iodine 131, mercury releases from the Y-12 plant, PCBs, radionuclides from White Oak Creek, uranium from the Y-12 plant, uranium and fluoride releases from the K-25 complex, and two media-specific health assessments concerning off-site groundwater and the Toxic Substances Control Act (TSCA) incinerator. ATSDR believes that these additional health evaluations are warranted due to the known releases into nearby communities and because of acknowledged uncertainty with respect to past exposures. These separate evaluations could include health outcome data evaluations, if they find that site-related exposures might have contributed to illnesses or adverse health effects.

Residents living in the communities near ORR have also expressed concerns about a perceived increase in cancer in their communities. To address these concerns, ORRHES recommended that ATSDR conduct an assessment of cancer incidence health outcome data in the eight counties surrounding ORR. ATSDR is currently conducting a cancer incidence review using cancer incidence data collected by the Tennessee Cancer Registry. This cancer incidence review is a descriptive analysis that will provide a general picture of the occurrence of different types of cancer in these counties. The purpose of conducting this evaluation is to provide residents living in ORR area with information regarding cancer rates in their area compared to the state of

Tennessee. This evaluation will only examine cancer incidence rates at the population level, not at the individual level. It is not designed to evaluate specific associations between adverse health outcomes and documented human exposures, and cannot be used to establish cause and effect associations.

VI. Community Health Concerns

Responding to community health concerns is an essential part of ATSDR's overall mission and commitment to public health. ATSDR actively gathers comments and other information from the people who live and work near ORR. ATSDR is particularly interested in hearing from residents of the area, civic leaders, health professionals, and community groups. ATSDR will be addressing these community health concerns in the ORR public health assessments that are related to those concerns.

To improve the documentation and organization of community health concerns at ORR, ATSDR developed a **Community Health Concerns Database** specifically designed to compile and track community health concerns related to the site. The database allows ATSDR to record, track, and respond appropriately to all community concerns and to document ATSDR's responses to these concerns.

Since 2001, ATSDR has compiled more than 2,500 community health concerns obtained from the ATSDR/ORRHES community health concerns comment sheets, written correspondence, phone calls, newspapers, comments made at public meetings (ORRHES and workgroup meetings), and surveys conducted by other agencies and organizations. These concerns were organized in a consistent and uniform format and imported into the database.

The community health concerns addressed in this section of the public health assessment include those in the ATSDR Community Health Concerns Database that are related to current and future chemical releases (1990–2003) from ORR. These concerns and ATSDR's responses are sorted and organized by category (chemical mixtures, future land use, general concerns, odor/stench/public nuisance, ongoing activities of health concern, screening issues, soil and sediment, and Scarboro concerns). Many of the concerns have been covered in the Community Health Concerns section of the Y-12 Uranium Releases PHA. For reference, the Y-12 Uranium Releases PHA concerns and responses are provided in Appendix E of this document. Additional community concerns will be addressed in the appropriate public health assessments.

VI.A. Chemical Mixtures

There were seventeen individual comments specifically related to chemical mixtures and potential interactive effects in the Community Health Concerns Database. In this public health assessment on screening off-site current and future chemical exposure, ATSDR considered interactive effects (cumulative, additive, synergistic, and antagonistic) of chemicals following exposure to multiple chemicals to the extent of the scientific knowledge in this area (please see the "Multiple Chemical Exposure" section on page 61). With regards to the current and future chemical exposures evaluated in this public health assessment, ATSDR does not expect interactive health effects of multiple chemicals because for each chemical evaluated the conservatively estimated exposure doses are below health effect levels reported in the scientific literature. The scientific literature surrounding chemical interactions indicates that if the estimated exposure doses for individual contaminants are below doses shown to cause adverse effects, then combined effect of multiple chemicals is not expected to result in adverse health effects. At the completion of the other chemical-specific and pathway-specific public health

assessments ATSDR will address the potential interactive effects from exposure to chemical mixtures.

VI.B. Future Land Use

There was one concern that exposure to environmental contamination is causing adverse health effects, which will negatively impact future land use issues. ATSDR has concluded that current (1990 to 2003) and future exposures to site-related chemicals in soil, sediment, surface water, biota, and air pose no apparent public health hazard. “No apparent public health hazard” means that people may be exposed to contaminated media, but that exposure to contamination is not expected to result in adverse health effects. Dioxins pose an indeterminate public health hazard in an unknown fish species, but ATSDR does not expect adverse health effects (see page 50). Exposure to mercury, PCBs, uranium, fluoride, iodine 131, off-site groundwater, and radiological releases from the White Oak Creek will be evaluated in other public health assessments.

VI.C. General Concerns

One comment was related to the issue of people who don’t generally fish from one location and whether it would be difficult to account for this type of activity. ATSDR accounted for this by using a conservative (protective) approach when calculating exposure doses—including using the species with the highest average concentration, using the sampling location with highest average concentration, and assuming adequate fish species population for recreational or subsistence behavior.

One comment was related to exposure routes, including animal migration and deer hunting. ATSDR considered multiple exposure routes (current and future exposures to site-related chemicals in soil, sediment, surface water, groundwater, biota (game, fish, and vegetables), and air) based on environmental data from 1990–2003. In 1993, ATSDR released a health consultation that evaluated whether it was safe to eat fish from EFPC. ATSDR concluded that there was not an acute health hazard for people eating fish, however, if people frequently ingested fish from EFPC at the levels reported in the health consultation over many years there was a hypothetical increased risk of adverse effects. However, ATSDR currently believes this exposure scenario is unlikely because EFPC is not a productive fishing location. Copies of this health consultation, entitled *Y-12 Weapons Plant Chemical Releases into East Fork Poplar Creek*, are available at the ATSDR Oak Ridge field office at 1975 Tulane Avenue, Oak Ridge, Tennessee (865-220-0295) or by calling ATSDR’s toll-free number (1-888-42-ATSDR).

VI.D. Odor/Stench/Public Nuisance

One commenter indicated that drinking water changes color and is sometimes cloudy. Oak Ridge receives and distributes public water from a treatment plant that collects surface water from Melton Hill Lake. The public water intake is approximately one mile upstream of ORR. Under the Safe Drinking Water Act, EPA sets standards for many substances in public drinking water and specifies treatments for providing safe drinking water. For specific questions related to your public drinking water, please call Mr. Bruce Giles (Water and Wastewater Manager) at 865-425-1875 or EPA’s Safe Drinking Water Hotline at 800-426-4791.

VI.E. On-going Activities of Health Concern

Five comments asked whether ATSDR would be screening chemicals from other currently operating plants/facilities and/or continuing releases from ORR. During the public health assessment process, ATSDR evaluates environmental data (i.e., levels of chemicals in specific media), regardless of source. As such, any contributions to soil, sediment, surface water, groundwater, biota, and air will be evaluated with respect to public health.

VI.F. Screening Issues

One commenter asked about thorium levels detected at or near the site. ATSDR reviewed available environmental data and determined that thorium levels were below screening values and thus, not a public health hazard for current and/or future exposures.

One comment stated that "the screening is done only for a finite period of time." In this public health assessment, the chemical screening process evaluated environmental data from 1990 to 2003, to assess current and future exposures.

Several comments expressed concerns about a perceived increase in cancer in the surrounding communities. To address these concerns, ORRHES requested that ATSDR conduct an assessment of cancer incidence health outcome data in the eight counties surrounding ORR. ATSDR is currently conducting a cancer incidence review using data collected by the Tennessee Cancer Registry. This cancer incidence review is a descriptive analysis that will provide a general picture of the occurrence of different types of cancer in the communities. The purpose of conducting this evaluation is to provide residents living in the ORR area with information regarding cancer rates in their area compared to the state of Tennessee. This evaluation will only examine cancer incidence rates at the population level, not at the individual level. It is not designed to evaluate specific associations between adverse health outcomes and documented human exposures, and it will not establish cause and effect associations.

Several comments were related to availability/existence of biological testing for specific chemicals. Testing methods are available for certain compounds. The most common is for blood lead levels. Mercury can also be tested in the blood and urine. A 24-hour urine collection is used for chronic exposures typically seen with environmental scenarios. Blood testing for mercury is used to assess more acute exposures associated with industrial uses and poisoning. For additional information regarding biological testing, please contact your local physician or poison control center.

VI.G. Soil, Sediment, and Surface Water Concerns

Several comments expressed concern over the "background soil sample" locations, with respect to which Counties were included. Background soil samples were collected from Morgan, Loudon, and Knox Counties, but not from Roane, Anderson, and Blount Counties. ATSDR believes that the background soil samples are representative of the area and are appropriate to use in this public health assessment.

Several concerns were expressed regarding the robustness of the soil, sediment, and surface water data used to assess exposures. ATSDR believes the data set is adequate to evaluate current

and future exposures to soil, sediment, and surface water. Appendix D contains maps that depict the number of samples and the number of chemicals collected from each location in each media.

- The OREIS Environmental Database contains almost 10,000 records of chemicals sampled in off-site soil from January 11, 1990, to September 18, 2001. A total of 286 different chemicals were analyzed.

- The OREIS Environmental Database contains about 56,000 records of chemicals sampled in off-site sediment from January 15, 1990, to September 1, 2001. A total of 319 different chemicals were analyzed.

- The OREIS Environmental Database contains more than 93,000 records of chemicals sampled in the off-site surface water from January 8, 1990, to October 8, 2002. A total of 310 different chemicals were analyzed.

VI.H. Scarboro Concerns

Scarboro residents have expressed concern that their community might be contaminated with chemicals currently being released from ORR. To address this concern, ATSDR screened and evaluated the environmental data collected by the Florida Agriculture and Mechanical University (FAMU) and EPA. ATSDR's Scarboro-specific public health evaluation follows[20].

Scarboro Environmental Sampling

In 1998, FAMU sampled soil, sediment, and surface water in the Scarboro community to address community concerns about environmental monitoring in the neighborhood. All samples were analyzed for mercury, gross alpha/beta content, uranium, and gamma emitting radionuclides. About 10 percent of the samples were also analyzed for target compound list organics, target analyte list inorganics, strontium 90, uranium, thorium, and plutonium (FAMU 1998).

In 2001, EPA collected soil, sediment, and surface water samples from the Scarboro community to respond to community concerns, to identify data gaps, and to validate the sampling performed by FAMU in 1998. All samples were subjected to a full analytical scan, including inorganic metals, volatile organic compounds, semi-volatile organic compounds, radiochemicals, organochlorine pesticides, and PCBs (EPA 2003).

Methodology

The same methodology that was used to screen and evaluate current (1990 to 2003) environmental data was applied to the Scarboro-specific health evaluation. ATSDR selected contaminants for further evaluation by comparing the maximum detected concentrations in Scarboro against health-based comparison values. Comparison values are derived using conservative exposure assumptions and reflect concentrations much lower than those that have been observed to cause adverse health effects. Thus, comparison values are protective of public health in essentially all exposure situations. As a result, concentrations detected at or below ATSDR's comparison values are not a public health hazard and are not evaluated further.

[20] Radionuclides are evaluated separately.

ATSDR derived exposure doses for those contaminants that were detected above ATSDR's comparison values. When estimating exposure doses, health assessors evaluate chemical concentrations to which people could be exposed, together with the length of time and the frequency of exposure. ATSDR applied several protective exposure assumptions to estimate exposures to Scarboro residents. ATSDR then compared the exposure doses to protective screening guideline values, including ATSDR's MRLs and EPA's RfDs. Estimated exposure doses that are less than screening guideline values are not a public health hazard and are not evaluated further.

Scarboro Results

<u>Soil</u>

- 207 chemicals were analyzed.
- 40 chemicals were detected.
- 4 chemicals were detected above comparison values (see Table 33).
- 2 chemicals were detected above noncancer screening guidelines (see Table 36).
- 0 chemicals were detected above cancer screening guidelines (see Table 37).

<u>Sediment</u>

- 206 chemicals were analyzed.
- 32 chemicals were detected.
- 2 chemicals were detected above comparison values (see Table 34).
- 0 chemicals were detected above noncancer and cancer screening guidelines (see Table 36 and Table 37).

<u>Surface Water</u>

- 201 chemicals were analyzed.
- 23 chemicals were detected.
- 2 chemicals were detected above comparison values (see Table 35).
- 0 chemicals were detected above noncancer and cancer screening guidelines (see Table 36 and Table 37).

Figure 8 shows ATSDR's chemical screening process for the Scarboro public health evaluation.

Figure 8. ATSDR Chemical Screening Process for Scarboro

ATSDR
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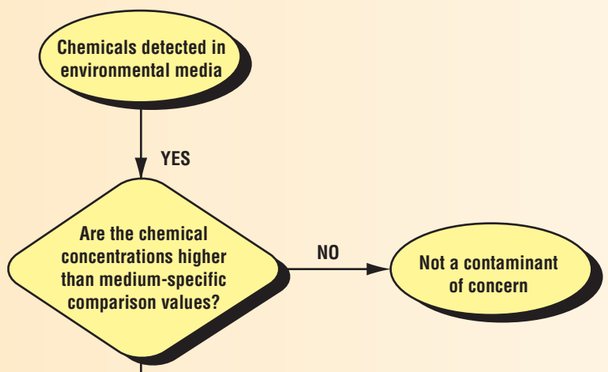
Decision Diagram

Results

Criteria

Preliminary Screening

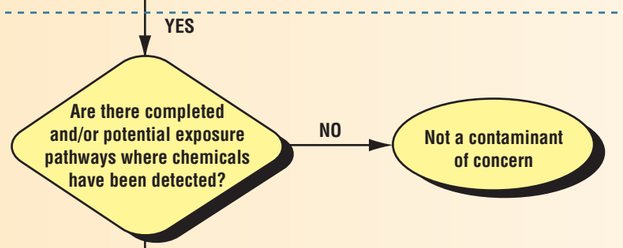


Chemicals Detected in Soil, Sediment, and/or Surface Water

Acetic acid	cis-Chlordane	Manganese
Acetone	Cobalt	Mercury
alpha-Pinene	Copper	Nickel
Aluminum	Cyclotetrasiloxane	Potassium
Antimony	DDE p,p'-	Pyrene
Arsenic	DDT p,p'-	Selenium
Barium	Di-n-butyl phthalate	Silver
Benzene ethanamine	Dodacane	Sodium
Benzoic acid	Fluoranthene	Thallium
Beryllium	gamma-Chlordane	Toluene
Bromoform	Heptachlor	Uranium-235
Butyl benzyl phthalate	Heptachlor epoxide	Uranium-238
Cadmium	Iron	Vanadium
Calcium	Lead	Zinc
Chromium	Magnesium	

- Based on the results of environmental investigations
- Based on maximum exposure conditions
  - maximum concentration detected
  - maximum exposure duration
  - maximum exposure frequency
  - maximum exposure bioavailability

Pathway Evaluation

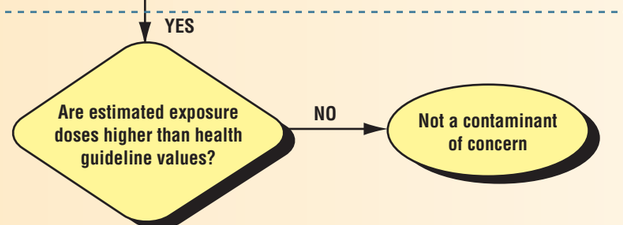


Chemicals Higher Than Comparison Values

Soil	Sediment	Surface Water
Arsenic	Arsenic	Arsenic
gamma-Chlordane	Iron	Lead
Heptachlor epoxide		
Iron		

- Can or are exposures occurring
- Identify potential or completed exposure pathways

Exposure Dose Comparison

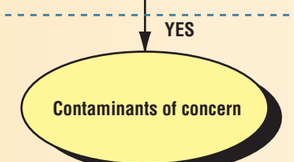


Chemicals With Completed and/or Potential Exposure Pathways

Soil	Sediment	Surface Water
Arsenic	Arsenic	Arsenic
gamma-Chlordane	Iron	Lead
Heptachlor epoxide		
Iron		

- Estimate doses based on site-specific exposure conditions
- Use more realistic exposure assumptions
  - realistic concentrations
  - realistic exposure duration
  - realistic exposure frequency
  - realistic exposure bioavailability
  - site-specific receptor population

Contaminants of Concern

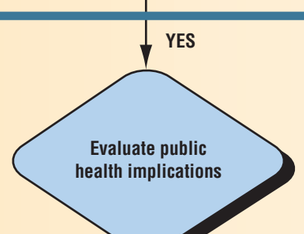


Chemicals Higher Than Health Guidelines

Soil	Sediment	Surface Water
Heptachlor epoxide		
Iron		

- Evaluate the public health implications of contaminants of concern in greater detail

Public Health Implications



Public Health Implications Evaluation—Weight of Evidence

- Review toxicologic, medical, epidemiologic, and other scientific data on the contaminants of concern
- Evaluate whether contaminants of concern can affect public health in the vicinity of the site

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Public Health Implications - Scarboro

A release of a chemical does not always result in human exposure, and human exposure does not always result in adverse health effects. Because screening guideline values were exceeded for two chemicals detected in the soil (heptachlor epoxide and iron), ATSDR examined the health effects levels discussed in the scientific literature and more fully reviewed exposure potential for these chemicals. This information is used to describe the disease-causing potential of a particular chemical and to compare site-specific dose estimates with doses shown in applicable studies to result in illness. This process enables ATSDR to weigh the available evidence in light of uncertainties and offer perspective on the plausibility of harmful health outcomes under site-specific conditions.

Heptachlor epoxide

The calculated dose for adults is below the noncancer and cancer screening guidelines for heptachlor epoxide; therefore, adults are not being exposed to heptachlor epoxide at levels of health concern. The calculated dose for pica children is below the acute screening guideline; therefore, pica children are not being exposed to heptachlor epoxide at levels of health concern. The calculated doses for a non-pica child is above the noncancer screening guideline; therefore, ATSDR further examined the harmful effect levels reported in the scientific literature and more fully reviewed exposure potential for non-pica children.

Heptachlor epoxide is a breakdown product of heptachlor, a synthetic chemical used prior to 1988, for killing insects in homes, buildings, and on food crops. Heptachlor epoxide was not manufactured—bacteria in the environment form heptachlor epoxide from heptachlor. Ingestion of soil containing heptachlor epoxide is one way the chemical can enter the body. The toxicokinetics (i.e., absorption, distribution, metabolism, and excretion) of heptachlor epoxide is not well studied in humans, however. Animal studies suggest that heptachlor epoxide is primarily stored in adipose tissue (i.e., fat). One animal study reported that the levels of heptachlor epoxide decreased to below detection limits 6 to 8 weeks after exposure (ATSDR 1993a).

ATSDR calculated that a non-pica child is expected to receive a dose of 0.000015 mg/kg/day from exposure to the soil in Scarboro. The oral screening guideline for heptachlor epoxide is based on a study in which liver-to-body weight ratios were significantly increased in animals fed heptachlor epoxide at doses of 0.0125 mg/kg/day for 60 weeks (Dow Chemical Company 1958). Supporting animal studies report no adverse health effects for doses ranging from 0.025 to 0.25 mg/kg/day (EPA 2004a). The estimated dose for non-pica children in Scarboro is well below these health effects levels.

Therefore, ATSDR does not expect that children who incidentally ingest soil from Scarboro would experience adverse health effects from exposure to heptachlor epoxide.

Iron

The calculated dose for adults is below the noncancer screening guideline for iron; therefore, adults are not being exposed to iron at levels of health concern. The calculated doses for both a

pica child and non-pica child were above the acute and chronic noncancer screening guidelines, respectively. Therefore, ATSDR further examined the harmful effect levels reported in the scientific literature and more fully reviewed exposure potential.

Iron is a naturally occurring element in the environment. In fact, it is the fourth most abundant element in the Earth's crust by weight (LANL 2001). The most common iron ore is hematite, which frequently can be seen as black sand along beaches and stream banks. It is hard and brittle, and is usually combined with other metals to form alloys, including steel.

Iron is also an important mineral that assists in the maintenance of basic life functions. It combines with protein and copper to make hemoglobin, which transports oxygen in the blood from the lungs to other parts of the body, including the heart. It also aids in the formation of myoglobin, which supplies oxygen to muscle tissues (ANR 2003). Without sufficient iron, the body cannot produce enough hemoglobin or myoglobin to sustain life. Iron deficiency (anemia) is a condition that occurs when the body does not receive enough iron. NAS's RDA for children is 10 mg/day (FDA 1997). FDA's Reference Daily Intake for iron is 18 mg/day (Kurtzweil 1993).

According to the FDA, doses greater than 200 mg per event could poison or kill a child (FDA 1997). Doses of this magnitude are generally the result of children accidentally ingesting iron pills and not from ingesting iron in soil. Acute iron poisoning has been reported in children less than 6 years of age who have accidentally overdosed on iron-containing supplements for adults. Because iron is not considered to cause harmful health effects in general, toxicological and epidemiological literature is limited.

For comparison, ATSDR calculated a daily consumption from exposure to the iron in soil using a modification of the dose equation (Dose = Conc. x Intake Rate). Exposure to iron in the soil would increase a pica child's daily consumption of iron by 149 mg/day and a non-pica child's daily consumption of iron by 5.1 mg/day. The median daily intake of dietary iron is roughly 11 to 13 mg/day for children 1 to 8 years old and 13 to 20 mg/day for adolescents 9 to 18 years old (NAS 2001). The daily increase in consumption of iron (from ingesting soil) by a non-pica child is within the NAS and FDA recommended intake guidelines, and well below the dose known to induce poisoning (e.g., greater than 200 mg/event). While the daily consumption of iron for a pica child exceeds the NAS and FDA recommended intake guidelines, the daily increase in consumption is not likely to cause a pica child's daily dose to exceed levels known to induce poisoning. Further, to the authors' knowledge, no case of acute iron toxicity has ever occurred as a direct result of soil consumption. The absence of such cases probably reflects the large amount of soil that would have to be ingested combined with the much lower intestinal absorption of iron from soil than from food, and the fact that humans self regulate the body's iron level. Therefore, ATSDR does not expect that children who incidentally ingest the soil or exhibit pica behavior would experience adverse health effects from exposure to iron in Scarboro soil.

Conclusions

None of the soil, sediment, or surface water samples collected from the Scarboro community contained chemicals at levels that are a public health hazard.

VII. Conclusions

ATSDR concludes that current and future exposures to site-related chemicals in soil, sediment, surface water, biota (other than fish), and air pose no apparent public health hazard. “No apparent public health hazard” means that people may be exposed to contaminated media, but that exposure to contamination is not expected to result in adverse health effects. Dioxins pose an indeterminate public health hazard in an unknown fish species due to limited sampling data.

Exposure to mercury, polychlorinated biphenyls (PCBs), uranium, iodine 131, the TSCA incinerator, off-site groundwater, and radiological releases from White Oak Creek will be evaluated in separate public health assessments.

VIII. Recommendations

Because there is very limited dioxin data for fish, ATSDR recommends following the current fish advisories—this behavior reduces exposure to contaminants in fish.

ATSDR recommends working with the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) to communicate the results of this health assessment with the surrounding community and continue those efforts as the public health assessments (chemical-specific and pathway-specific) are developed and completed.

IX. Public Health Action Plan

The public health action plan for the Oak Ridge Reservation (ORR) contains a description of actions taken at the site and those to be taken at the site following the completion of this public health assessment. The purpose of the public health action plan is to ensure that this document not only identifies potential and ongoing public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to harmful substances in the environment. The following public health actions at ORR are completed, ongoing, or planned:

Completed Actions

- In 1991, the Tennessee Department of Health (TDOH) began a two-phase research project to determine whether environmental releases from ORR harmed people who lived nearby. Phase I focused on assessing the feasibility of doing historical dose reconstruction and identifying contaminants that were most likely to have effects on public health. Phase II efforts included full dose reconstruction analyses of iodine 131, mercury, polychlorinated biphenyls (PCBs), and radionuclides, as well as a more detailed health effects screening analysis for releases of uranium and other toxic substances (a summary can be found in the *Oak Ridge Dose Reconstruction Project Summary Report, Volume 7*). Phase II was completed in January 2000.

- In 1992, the U.S. Department of Energy (DOE) conducted a *Background Soil Characterization Project* in the area around Oak Ridge (DOE 1993).

- In 2004, the Agency for Toxic Substances and Disease Registry (ATSDR) released the final ORR Public Health Assessment for Y-12 Uranium Releases.

Ongoing Actions

- ATSDR is conducting PHAs on the releases of uranium and fluorides from the K-25 complex, iodine 131 from X-10, mercury from Y-12, White Oak Creek releases of radionuclides, PCBs, the TSCA incinerator, and off-site groundwater.

- In 1999, ORRHES was created under the guidelines and rules of the Federal Advisory Committee Act to provide a forum for communication and collaboration among citizens and the agencies that are evaluating public health issues and conducting public health activities at ORR. The ORRHES serves as a citizen advisory group to the Centers for Disease Control and Prevention (CDC) and ATSDR and provides recommendations on matters related to public health activities and research at the reservation. It also provides an opportunity for residents to collaborate with agency staff members, to learn more about the public health assessment process and other public health activities, and to help prioritize public health issues and community concerns to be evaluated by ATSDR.

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TABLES

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Table 15. Estimated Exposure Doses for Chemicals in Off-Site Soil Compared to Noncancer Screening Guidelines

Substance Name	*Minimum (ppm)*	*Maximum (ppm)*	*2nd Tier Screening Concentration (ppm)*	*Estimated Exposure Doses (mg/kg/day)*		*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Does the estimated exposure dose exceed the noncancer screening guideline?*	
				child	*adult*			*child*	*adult*
Inorganics									
Arsenic	1	77.3	15	1.8E-04	8.4E-06	0.0003	CMRL	No	No
Cadmium	0.0702	41.3	11	1.3E-04	6.0E-06	0.0002	CMRL	No	No
Chromium	9.4	546§	100	1.2E-03	5.8E-05	0.003	RfD (CrVI)	No	No
Iron	5,790	61,600§	32,000	3.9E-01	1.8E-02	0.3	RfD	Yes	No
Lead	5.3	3,040§	570	7.0E-03	3.3E-04	0.02	Acute LOAEL	No	No
Organics									
Benzidine*	4.0	4.13	1.8	4.1E-05	1.9E-06	0.003	RfD	No	No
Benzo(a)anthracene	0.12	158§	39	*Evaluated for carcinogenic effects (see Table 16)*					
Benzo(a)pyrene	0.14	156§	36	*Evaluated for carcinogenic effects (see Table 16)*					
Benzo(b)fluoranthene	0.29	206§	47	*Evaluated for carcinogenic effects (see Table 16)*					
Benzo(k)fluoranthene	0.17	95.4§	23	*Evaluated for carcinogenic effects (see Table 16)*					
bis(2-Chloroethyl) ether	0.42	4.13	2.6	*Evaluated for carcinogenic effects (see Table 16)*					
Chrysene	0.16	134§	32	*Evaluated for carcinogenic effects (see Table 16)*					
trans-Chlordane	0.096	2.8	1.1	1.3E-05	6.0E-07	0.0006	CMRL (chlordane)	No	No
Dibenzo(a,h)anthracene	0.066	22.7§	7.6	*Evaluated for carcinogenic effects (see Table 16)*					
3,3'-Dichlorobenzidine	0.79	4.13	2.4	*Evaluated for carcinogenic effects (see Table 16)*					
Heptachlor epoxide	0.0096	0.97	0.48	5.8E-06	2.7E-07	0.000013	RfD	No	No
Hexachlorobenzene	0.42	4.13	2.7	3.3E-05	1.5E-06	0.00005	CMRL	No	No
HCDD	2.47E-05	0.000801§	0.00053	*Evaluated for carcinogenic effects (see Table 16)*					
Indeno(1,2,3-cd)pyrene	0.049	4.7§	2.5	*Evaluated for carcinogenic effects (see Table 16)*					
n-Nitroso-di-n-butylamine*	4.0	4.13	1.8	5.1E-05	2.4E-06	0.095	AMRL (n-nitrosodi-n-propylamine)	No	No
n-Nitrosodi-n-propylamine	0.42	0.79	0.63	7.7E-06	3.6E-07	0.095	AMRL	No	No
TCDD	1.98E-08	0.000117§	0.000039	4.8E-10	2.2E-11	1E-09	CMRL	No	No

Doses were calculated using the following formulas:

child dose = (second-tier screening concentration *0.0002 kg/day*291.2 days/year*6 years)/(13 kg*(365 days/year*6 years)) mg/kg/day = milligram per kilogram per day

adult dose = (second-tier screening concentration *0.00005 kg/day*291.2 days/year*30 years)/(70 kg*(365 days/year*30 years)). ppm = parts per million

*Chemical was detected in less than 10% of the samples. The second-tier screening concentration was estimated using 1/2 the detection limit for nondetected samples.

§The maximum concentration was detected in an industrial area (Atomic City Auto Parts) that has since been remediated (i.e., all the contaminated soil has been removed).

The second-tier screening concentrations are rounded. CMRL = chronic minimal risk level (ATSDR) LOAEL = lowest observed adverse effect level (ATSDR)

AMRL = acute minimal risk level (ATSDR) IMRL = intermediate minimal risk level (ATSDR) RfD = reference dose (EPA)

Table 16. Estimated Exposure Doses for Chemicals in Off-Site Soil Compared to Cancer Screening Guidelines

Substance Name	*2nd Tier Screening Conc. (ppm)*	*Estimated Exposure Dose (mg/kg/day)*	*EPA's Oral Cancer Slope Factor $(mg/kg/day)^{-1}$*	*Risk*	*Does the estimated exposure dose exceed the cancer screening guideline? (10^{-4})?*
Inorganics					
Arsenic	15	3.6E-06	1.5	5.4E-06	No
Cadmium	11	*Evaluated for noncarcinogenic effects (see Table 15)*			
Chromium	100	*Evaluated for noncarcinogenic effects (see Table 15)*			
Iron	32,000	*Evaluated for noncarcinogenic effects (see Table 15)*			
Lead	570	*Evaluated for noncarcinogenic effects (see Table 15)*			
Organics					
Benzidine*	1.8	8.3E-07	230	1.9E-04	Yes
Benzo(a)anthracene	39	9.6E-06	0.73	7.0E-06	No
Benzo(a)pyrene	36	8.8E-06	7.3	6.4E-05	No
Benzo(b)fluoranthene	47	1.2E-05	0.73	8.5E-06	No
Benzo(k)fluoranthene	23	5.5E-06	0.073	4.0E-07	No
bis(2-Chloroethyl) ether	2.6	6.3E-07	1.1	7.0E-07	No
Chrysene	32	7.7E-06	0.0073	5.6E-08	No
trans-Chlordane	1.1	2.6E-07	0.35	9.1E-08	No
Dibenzo(a,h)anthracene	7.6	1.8E-06	7.3	1.3E-05	No
3,3'-Dichlorobenzidine	2.4	5.8E-07	0.45	2.6E-07	No
Heptachlor epoxide	0.48	1.2E-07	9.1	1.1E-06	No
Hexachlorobenzene	2.7	6.6E-07	1.6	1.1E-06	No
HCDD	0.00053	1.3E-10	6,200	8.1E-07	No
Indeno(1,2,3-cd)pyrene	2.5	6.0E-07	0.73	4.4E-07	No
n-Nitroso-di-n-butylamine*	1.8	6.0E-07	5.4	3.3E-06	No
n-Nitrosodi-n-propylamine	0.63	1.5E-07	7	1.1E-06	No
TCDD	0.000039	9.6E-12	150,000	1.4E-06	No

Doses were calculated using the following formula:

dose = (second-tier screening concentration*0.00005 kg/day*291.2 days/year*30 years)/(70 kg*(365 days/year*70 years)).

Risk was calculated by multiplying the cancer dose by EPA's oral cancer slope factor.

*Chemical was detected in less than 10% of the samples. The second-tier screening concentration was estimated using 1/2 the detection limit for nondetected samples.

The second-tier screening concentrations are rounded.

mg/kg/day = milligram per kilogram per day

ppm = parts per million

Table 17. Estimated Exposure Doses for Chemicals in Off-Site Sediment Compared to Noncancer Screening Guidelines

Substance Name	*Minimum (ppm)*	*Maximum (ppm)*	*2nd Tier Screening Conc. (ppm)*	*Estimated Exposure Doses (mg/kg/day)*		*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Does the estimated exposure dose exceed the noncancer screening guideline?*	
				child	*adult*			*child*	*adult*
Inorganics									
Arsenic	0.3	432	37	9.3E-06	1.7E-06	0.0003	CMRL	No	No
Cadmium	0.05	98.1	7.3	1.9E-06	3.4E-07	0.0002	CMRL	No	No
Copper	1.1	14,500	650	1.6E-04	3.1E-05	0.04	RfD	No	No
Iron	1,410	113,000	33,000	8.4E-03	1.6E-03	0.3	RfD	No	No
Lead	0.72	1,520	120	3.0E-05	5.6E-06	0.02	Acute LOAEL	No	No
Manganese	140	7,230	2,700	6.8E-04	1.3E-04	0.05	RfD	No	No
Organics									
Aldrin	0.00007	1.8	0.47	1.2E-07	2.2E-08	0.00003	CMRL	No	No
Benzo(a)anthracene	0.011	23.2	2.1	*Evaluated for carcinogenic effects (see Table 18)*					
Benzo(a)pyrene	0.013	30.1	2.5	*Evaluated for carcinogenic effects (see Table 18)*					
Benzo(b)fluoranthene	0.013	42.4	3.1	*Evaluated for carcinogenic effects (see Table 18)*					
Benzo(k)fluoranthene	0.0067	20.5	2.1	*Evaluated for carcinogenic effects (see Table 18)*					
bis(2-Chloroethyl) ether	0.17	3.4	1.4	*Evaluated for carcinogenic effects (see Table 18)*					
cis-Chlordane	0.00025	18	4.6	1.2E-06	2.2E-07	0.0006	CMRL (chlordane)	No	No
trans-Chlordane	0.00024	18	4.6	1.2E-06	2.2E-07	0.0006	CMRL (chlordane)	No	No
DDD, p,p'-	0.00018	4.3	1.1	*Evaluated for carcinogenic effects (see Table 18)*					
DDE, p,p'-	0.00016	4.3	1.1	*Evaluated for carcinogenic effects (see Table 18)*					
DDT, p,p'-	0.00024	4.3	1.1	2.8E-07	5.3E-08	0.0005	RfD	No	No
di(2-Ethylhexyl)phthalate	0.015	256	16	4.1E-06	7.6E-07	0.06	CMRL	No	No
Dibenzo(a,h)anthracene	0.014	4.2	1.4	*Evaluated for carcinogenic effects (see Table 18)*					
3,3'-Dichlorobenzidine	0.22	6.7	2.7	*Evaluated for carcinogenic effects (see Table 18)*					
Dieldrin	0.00015	4.3	1.1	2.9E-07	5.3E-08	0.00005	CMRL	No	No
Heptachlor	0.00007	1.8	0.46	1.2E-07	2.2E-08	0.0005	RfD	No	No
Heptachlor epoxide	0.00044	1.8	0.48	1.2E-07	2.3E-08	0.000013	RfD	No	No
Hexachlorobenzene	0.17	3.4	1.4	3.4E-07	6.4E-08	0.00005	CMRL	No	No
HCH, alpha-	0.0001	1.8	0.48	1.2E-07	2.3E-08	0.008	CMRL	No	No
HCH, beta-	0.00044	1.8	0.48	1.2E-07	2.3E-08	0.0006	IMRL	No	No
HCH, delta-	0.00044	1.8	0.48	1.2E-07	2.3E-08	0.0003	RfD (gamma-HCH)	No	No
HCH, gamma-	0.00022	1.8	0.48	1.2E-07	2.3E-08	0.0003	RfD	No	No
HCDD	6.28E-05	0.000575	0.00068	*Evaluated for carcinogenic effects (see Table 18)*					
Indeno(1,2,3-cd)pyrene	0.017	13.4	1.8	*Evaluated for carcinogenic effects (see Table 18)*					

Table 17. Estimated Exposure Doses for Chemicals in Off-Site Sediment Compared to Noncancer Screening Guidelines (continued)

Substance Name	*Minimum (ppm)*	*Maximum (ppm)*	*2nd Tier Screening Conc. (ppm)*	*Estimated Exposure Doses (mg/kg/day)*		*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Does the estimated exposure dose exceed the noncancer screening guideline?*	
				child	*adult*			*child*	*adult*
n-Nitrosodi-n-propylamine	0.17	3.4	1.4	3.4E-07	6.4E-08	0.095	AMRL	No	No
Pentachlorophenol	0.026	16	6.4	1.6E-06	3.0E-07	0.001	CMRL	No	No
Toxaphene	0.044	43	12	2.9E-06	5.4E-07	0.001	IMRL	No	No

Doses were calculated using the following formulas:

child dose = (second-tier screening concentration*0.0001 kg/day*12 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = (second-tier screening concentration*0.0001 kg/day*12 days/year*30 years)/(70 kg*(365 days/year*30 years)).

The second-tier screening concentrations are rounded.

AMRL = acute minimal risk level (ATSDR)

CMRL = chronic minimal risk level (ATSDR)

IMRL = intermediate minimal risk level (ATSDR)

LOAEL = lowest observed adverse effect level (ATSDR)

mg/kg/day = milligram per kilogram per day

ppm = parts per million

RfD = reference dose (EPA)

Table 18. Estimated Exposure Doses for Chemicals in Off-Site Sediment Compared to Cancer Screening Guidelines

Substance Name	*2nd Tier Screening Conc. (ppm)*	*Estimated Exposure Dose (mg/kg/day)*	*EPA's Oral Cancer Slope Factor $(mg/kg/day)^{-1}$*	*Risk*	*Does the estimated exposure dose exceed the cancer screening guideline? (10^{-4})?*
Inorganics					
Arsenic	37	7.4E-07	1.5	1.1E-06	No
Cadmium	7.3	*Evaluated for noncarcinogenic effects (see Table 17)*			
Copper	650	*Evaluated for noncarcinogenic effects (see Table 17)*			
Iron	33,000	*Evaluated for noncarcinogenic effects (see Table 17)*			
Lead	120	*Evaluated for noncarcinogenic effects (see Table 17)*			
Manganese	2,700	*Evaluated for noncarcinogenic effects (see Table 17)*			
Organics					
Aldrin	0.47	9.5E-09	17	1.6E-07	No
Benzo(a)anthracene	2.1	4.3E-08	0.73	3.1E-08	No
Benzo(a)pyrene	2.5	5.1E-08	7.3	3.7E-07	No
Benzo(b)fluoranthene	3.1	6.3E-08	0.73	4.6E-08	No
Benzo(k)fluoranthene	2.1	4.2E-08	0.073	3.1E-09	No
bis(2-Chloroethyl) ether	1.4	2.7E-08	1.1	3.0E-08	No
cis-Chlordane	4.6	9.3E-08	0.35	3.3E-08	No
trans-Chlordane	4.6	9.3E-08	0.35	3.3E-08	No
DDD, p,p'-	1.1	2.3E-08	0.24	5.5E-09	No
DDE, p,p'-	1.1	2.3E-08	0.34	7.8E-09	No
DDT, p,p'-	1.1	2.3E-08	0.34	7.7E-09	No
di(2-Ethylhexyl)phthalate	16	3.2E-07	0.014	4.5E-09	No
Dibenzo(a,h)anthracene	1.4	2.8E-08	7.3	2.0E-07	No
3,3'-Dichlorobenzidine	2.7	5.4E-08	0.45	2.4E-08	No
Dieldrin	1.1	2.3E-08	16	3.6E-07	No
Heptachlor	0.46	9.3E-09	4.5	4.2E-08	No
Heptachlor epoxide	0.48	9.7E-09	9.1	8.8E-08	No
Hexachlorobenzene	1.4	2.7E-08	1.6	4.4E-08	No
HCH, alpha-	0.48	9.7E-09	6.3	6.1E-08	No
HCH, beta-	0.48	9.7E-09	1.8	1.7E-08	No
HCH, delta-	0.48	9.7E-09	1.3	1.3E-08	No
HCH, gamma-	0.48	9.7E-09	1.3	1.3E-08	No
HCDD	0.00068	1.4E-11	6,200	8.5E-08	No
Indeno(1,2,3-cd)pyrene	1.8	3.5E-08	0.73	2.6E-08	No
n-Nitrosodi-n-propylamine	1.4	2.7E-08	7	1.9E-07	No
Pentachlorophenol	6.4	1.3E-07	0.12	1.5E-08	No
Toxaphene	12	2.3E-07	1.1	2.6E-07	No

Doses were calculated using the following formula:

dose = (second-tier screening concentration*0.0001 kg/day*12 days/year*30 years)/(70 kg*(365 days/year*70 years)).

Risk was calculated by multiplying the cancer dose by EPA's oral cancer slope factor.
The second-tier screening concentrations are rounded.
mg/kg/day = milligram per kilogram per day
ppm = parts per million

Table 19. Estimated Exposure Doses for Chemicals in Off-Site Surface Water Compared to Noncancer Screening Guidelines

Substance Name	*Minimum (ppb)*	*Maximum (ppb)*	*2nd Tier Screening Conc. (ppb)*	*Estimated Exposure Doses (mg/kg/day)*		*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Does the estimated exposure dose exceed the noncancer screening guideline?*	
				child	*adult*			*child*	*adult*
Inorganics									
Aluminum	6.2	21,000	1,400	1.8E-03	3.3E-04	1	RfD	No	No
Ammonia	20	13,000	5,700	7.2E-03	1.3E-03	0.3	IMRL	No	No
Antimony*	0.1	41	49	6.2E-05	1.2E-05	0.0004	RfD	No	No
Arsenic*	0.76	69	40	5.0E-05	9.4E-06	0.0003	CMRL/RfD	No	No
Barium	6.4	250	71.5	9.0E-05	1.7E-05	0.07	RfD	No	No
Beryllium*	0.03	26	1.6	2.0E-06	3.8E-07	0.002	CMRL/RfD	No	No
Boron	3.16	470	77	9.8E-05	1.8E-05	0.09	RfD	No	No
Cadmium*	0.2	13	2.9	3.7E-06	6.8E-07	0.0002	CMRL	No	No
Chlorine	2	1,400	430	5.4E-04	1.0E-04	0.1	RfD	No	No
Chromium	0.25	70	11.5	1.5E-05	2.7E-06	0.003	RfD (CrVI)	No	No
Copper	0.7	381	42	5.4E-05	9.9E-06	0.04	RfD	No	No
Iron	4.8	1,100,000	41,000	5.2E-02	9.7E-03	0.3	RfD	No	No
Lead	0.29	370	28	3.6E-05	6.7E-06	0.02	Acute LOAEL	No	No
Lithium	1.3	4,050	340	4.3E-04	8.1E-05	0.02	RfD	No	No
Manganese	1.07	2,430	220	2.8E-04	5.1E-05	0.05	RfD	No	No
Nickel	0.37	49	10	1.3E-05	2.4E-06	0.02	RfD	No	No
Nitrate	80	52,800	11,000	1.4E-02	2.5E-03	1.6	RfD	No	No
Nitrate and Nitrite	100	47,500	6,300	7.9E-03	1.5E-03	0.1	RfD (nitrite)	No	No
Selenium*	0.97	54	55	6.9E-05	1.3E-05	0.005	CMRL/RfD	No	No
Silver	0.36	61	13	1.6E-05	3.0E-06	0.005	RfD	No	No
Thallium*§	0.5	39	46	5.8E-05	1.1E-05	0.00007	RfD	No	No
Vanadium	0.35	81	14	1.7E-05	3.2E-06	0.007	RfD	No	No
Zinc	0.88	1,270	150	1.9E-04	3.5E-05	0.3	CMRL	No	No
Organics									
Aldrin*	0.0063	0.052	0.07	9.4E-08	1.8E-08	0.00003	CMRL/RfD	No	No
Benzene*	0.3	10	4.6	5.8E-06	1.1E-06	0.003	RfD	No	No
Benzo(a)anthracene*	0.9	10	5.6	*Evaluated for carcinogenic effects (see Table 20)*					
Benzo(a)pyrene*	10	10	5.6	*Evaluated for carcinogenic effects (see Table 20)*					
Benzo(b)fluoranthene*	0.8	17	5.8	*Evaluated for carcinogenic effects (see Table 20)*					
Benzo(k)fluoranthene*	1.2	10	5.6	*Evaluated for carcinogenic effects (see Table 20)*					
Bis(2-chloroethyl) ether*	10	10	5.6	*Evaluated for carcinogenic effects (see Table 20)*					

Table 19. Estimated Exposure Doses for Chemicals in Off-Site Surface Water Compared to Noncancer Screening Guidelines (continued)

Substance Name	*Minimum (ppb)*	*Maximum (ppb)*	*2nd Tier Screening Conc. (ppb)*	*Estimated Exposure Doses (mg/kg/day)*		*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Does the estimated exposure dose exceed the noncancer screening guideline?*	
				child	*adult*			*child*	*adult*
Bromodichloromethane	1	10	3.1	3.9E-06	7.3E-07	0.02	CMRL	No	No
Bromoform*	1	10	4.2	5.3E-06	9.8E-07	0.2	CMRL/RfD	No	No
Carbazole*	10	10	5.3	*Evaluated for carcinogenic effects (see Table 20)*					
Carbon tetrachloride*§	1	10	13	1.7E-05	3.1E-06	0.0007	RfD	No	No
cis-Chlordane*	0.0063	0.5	0.13	*Evaluated for carcinogenic effects (see Table 20)*					
trans-Chlordane*	0.0063	0.5	0.13	*Evaluated for carcinogenic effects (see Table 20)*					
Chlorodibromomethane*	5	10	4.6	5.8E-06	1.1E-06	0.03	CMRL	No	No
Chloroethane*	1.6	34	6.5	8.2E-06	1.5E-06	0.4	RfD	No	No
Chloromethane*	1	10	5.9	*Evaluated for carcinogenic effects (see Table 20)*					
Chrysene*	1	10	5.6	*Evaluated for carcinogenic effects (see Table 20)*					
Dibenzo(a,h)anthracene*	10	10	5.8	*Evaluated for carcinogenic effects (see Table 20)*					
3,3'-Dichlorobenzidine*	10	20	11	*Evaluated for carcinogenic effects (see Table 20)*					
1,2-Dichloroethane*	1	100	9.1	1.1E-05	2.1E-06	0.03	RfD	No	No
1,3-Dichloropropene, cis-*	5	10	4.6	*Evaluated for carcinogenic effects (see Table 20)*					
1,3-Dichloropropene, trans-*	5	10	4.6	*Evaluated for carcinogenic effects (see Table 20)*					
Di(2-ethylhexyl)phthalate	0.6	230	39	4.9E-05	9.1E-06	0.06	CMRL	No	No
Dieldrin*	0.0049	0.1	0.2	1.9E-07	3.6E-08	0.00005	CMRL/RfD	No	No
2,4-Dinitrophenol*	25	50	27	3.4E-05	6.3E-06	0.002	RfD	No	No
4,6-Dinitro-o-cresol*	25	50	26	3.3E-05	6.1E-06	0.0001	RfD	No	No
HCDD	0.000013	0.000013	0.000013	*Evaluated for carcinogenic effects (see Table 20)*					
Heptachlor*	0.0063	0.052	0.07	9.4E-08	1.8E-08	0.0005	RfD	No	No
Heptachlor epoxide*	0.0034	0.052	0.07	9.4E-08	1.8E-08	0.000013	RfD	No	No
Hexachlorobenzene*	10	10	5.6	7.1E-06	1.3E-06	0.00005	CMRL	No	No
Hexachlorobutadiene*	10	10	5.6	7.1E-06	1.3E-06	0.0002	RfD	No	No
alpha-HCH*	0.0063	0.052	0.07	9.4E-08	1.7E-08	0.008	CMRL	No	No
beta-HCH*	0.0063	0.052	0.07	9.4E-08	1.7E-08	0.0006	IMRL	No	No
delta-HCH*	0.0063	0.052	0.07	*Evaluated for carcinogenic effects (see Table 20)*					
Hexachloroethane*	10	10	5.6	7.1E-06	1.3E-06	0.001	RfD	No	No
Indeno(1,2,3-cd)pyrene*	1	10	5.7	*Evaluated for carcinogenic effects (see Table 20)*					
Methoxychlor*	0.063	260	23	2.9E-05	5.5E-06	0.005	RfD	No	No
Methylene chloride	0.5	52	15	1.9E-05	3.5E-06	0.06	CMRL	No	No
2-Nitroaniline*	10	50	27	*Evaluated for carcinogenic effects (see Table 20)*					

Table 19. Estimated Exposure Doses for Chemicals in Off-Site Surface Water Compared to Noncancer Screening Guidelines (continued)

Substance Name	*Minimum (ppb)*	*Maximum (ppb)*	*2nd Tier Screening Conc. (ppb)*	*Estimated Exposure Doses (mg/kg/day)*		*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Does the estimated exposure dose exceed the noncancer screening guideline?*	
				child	*adult*			*child*	*adult*
3-Nitroaniline*	10	50	27	*Evaluated for carcinogenic effects (see Table 20)*					
4-Nitroaniline*	10	50	26	*Evaluated for carcinogenic effects (see Table 20)*					
Nitrobenzene*	10	10	5.6	7.1E-06	1.3E-06	0.0005	RfD	No	No
n-Nitrosodi-n-propylamine*	10	10	5.6	7.1E-06	1.3E-06	0.095	AMRL	No	No
n-Nitrosodiphenylamine*	10	10	5.6	*Evaluated for carcinogenic effects (see Table 20)*					
Pentachlorophenol*	25	50	26			0.001	CMRL	No	No
TCDD	0.00002	0.00002	0.00002	2.5E-11	4.7E-12	1.0E-09	CMRL	No	No
1,1,2,2-Tetrachloroethane*	1	10	4.6	5.8E-06	1.1E-06	0.04	CMRL	No	No
1,1,2-Trichloroethane*	5	10	4.6	5.8E-06	1.1E-06	0.004	RfD	No	No
2,4,6-Trichlorophenol*	10	10	5.6	*Evaluated for carcinogenic effects (see Table 20)*					
Toxaphene*	0.63	5.2	2.7	3.4E-06	6.3E-07	0.001	IMRL	No	No
Trichloroethylene	0.34	23	8.1	1.0E-05	1.9E-06	0.0003	RfD	No	No
Vinyl chloride*	5	10	5.7	7.2E-06	1.3E-06	0.00002	CMRL	No	No

Doses were calculated using the following formulas:

child dose = ((second-tier screening concentration/1,000)*0.5 liters/day*12 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = ((second-tier screening concentration/1,000)*0.5 liters/day*12 days/year*30 years)/(70 kg*(365 days/year*30 years)).

The second-tier screening concentrations are rounded.

*Chemical was detected in less than 10% of the samples. The second-tier screening concentration was estimated using 1/2 the detection limit for nondetected samples.

[§]The thallium and carbon tetrachloride data contained outliers that were three orders of magnitude higher than the second highest concentration. These data points were removed.

CMRL = chronic minimal risk level (ATSDR)

IMRL = intermediate minimal risk level (ATSDR)

LOAEL = lowest observed adverse effect level (ATSDR)

mg/kg/day = milligram per kilogram per day

ppb = parts per billion

RfD = reference dose (EPA)

Table 20. Estimated Exposure Doses for Chemicals in Off-Site Surface Water Compared to Cancer Screening Guidelines

Substance Name	*2nd Tier Screening Conc. (ppb)*	*Estimated Exposure Dose (mg/kg/day)*	*EPA's Oral Cancer Slope Factor $(mg/kg/day)^{-1}$*	*Risk*	*Does the estimated exposure dose exceed the cancer screening guideline? (10^{-4})?*
Inorganics					
Aluminum	1,400	*Evaluated for noncarcinogenic effects (see Table 19)*			
Ammonia	5,700	*Evaluated for noncarcinogenic effects (see Table 19)*			
Antimony*	49	*Evaluated for noncarcinogenic effects (see Table 19)*			
Arsenic*	40	4.0E-06	1.5	6.0E-06	No
Barium	71.5	*Evaluated for noncarcinogenic effects (see Table 19)*			
Beryllium*	1.6	*Evaluated for noncarcinogenic effects (see Table 19)*			
Boron	77	*Evaluated for noncarcinogenic effects (see Table 19)*			
Cadmium*	2.9	*Evaluated for noncarcinogenic effects (see Table 19)*			
Chlorine	430	*Evaluated for noncarcinogenic effects (see Table 19)*			
Chromium	11.5	*Evaluated for noncarcinogenic effects (see Table 19)*			
Copper	42	*Evaluated for noncarcinogenic effects (see Table 19)*			
Iron	41,000	*Evaluated for noncarcinogenic effects (see Table 19)*			
Lead	28	*Evaluated for noncarcinogenic effects (see Table 19)*			
Lithium	340	*Evaluated for noncarcinogenic effects (see Table 19)*			
Manganese	220	*Evaluated for noncarcinogenic effects (see Table 19)*			
Nickel	10	*Evaluated for noncarcinogenic effects (see Table 19)*			
Nitrate	11,000	*Evaluated for noncarcinogenic effects (see Table 19)*			
Nitrate and Nitrite	6,300	*Evaluated for noncarcinogenic effects (see Table 19)*			
Selenium*	55	*Evaluated for noncarcinogenic effects (see Table 19)*			
Silver	13	*Evaluated for noncarcinogenic effects (see Table 19)*			
Thallium*§	46	*Evaluated for noncarcinogenic effects (see Table 19)*			
Vanadium	14	*Evaluated for noncarcinogenic effects (see Table 19)*			
Zinc	150	*Evaluated for noncarcinogenic effects (see Table 19)*			
Organics					
Aldrin*	0.07	7.5E-09	17	1.3E-07	No
Benzene*	4.6	4.6E-07	0.055	2.5E-08	No
Benzo(a)anthracene*	5.6	5.6E-07	0.73	4.1E-07	No
Benzo(a)pyrene*	5.6	5.7E-07	7.3	4.1E-06	No
Benzo(b)fluoranthene*	5.8	5.8E-07	0.73	4.3E-07	No
Benzo(k)fluoranthene*	5.6	5.6E-07	0.073	4.1E-08	No
Bis(2-chloroethyl) ether*	5.6	5.6E-07	1.1	6.2E-07	No
Bromodichloromethane	3.1	3.1E-07	0.062	1.9E-08	No
Bromoform*	4.2	4.2E-07	0.0079	3.3E-09	No
Carbazole*	5.3	5.3E-07	0.02	1.1E-08	No
Carbon tetrachloride*§	13	1.3E-06	0.13	1.7E-07	No
cis-Chlordane*	0.13	*Evaluated for noncarcinogenic effects (see Table 19)*			
trans-Chlordane*	0.13	*Evaluated for noncarcinogenic effects (see Table 19)*			
Chlorodibromomethane*	4.6	6.5E-07	0.0029	1.9E-09	No
Chloroethane*	6.5	5.9E-07	0.013	7.7E-09	No
Chloromethane*	5.9	5.6E-07	0.0073	4.1E-09	No
Chrysene*	5.6	5.8E-07	7.3	4.2E-06	No
Dibenzo(a,h)anthracene*	5.8	1.1E-06	0.45	5.0E-07	No
3,3'-Dichlorobenzidine*	11	9.1E-07	0.091	8.3E-08	No
1,2-Dichloroethane*	9.1	6.5E-07	0.0029	1.9E-09	No

Table 20. Estimated Exposure Doses for Chemicals in Off-Site Surface Water Compared to Cancer Screening Guidelines (continued)

Substance Name	*2nd Tier Screening Conc. (ppb)*	*Estimated Exposure Dose (mg/kg/day)*	*EPA's Oral Cancer Slope Factor $(mg/kg/day)^{-1}$*	*Risk*	*Does the estimated exposure dose exceed the cancer screening guideline? (10^{-4})?*
1,3-Dichloropropene, cis-*	4.6	*Evaluated for noncarcinogenic effects (see Table 19)*			
1,3-Dichloropropene, trans-*	4.6	*Evaluated for noncarcinogenic effects (see Table 19)*			
Di(2-ethylhexyl)phthalate	39	3.9E-06	0.014	5.5E-08	No
Dieldrin*	0.2	1.5E-08	16	2.5E-07	No
2,4-Dinitrophenol*	27	*Evaluated for noncarcinogenic effects (see Table 19)*			
4,6-Dinitro-o-cresol*	26	*Evaluated for noncarcinogenic effects (see Table 19)*			
HCDD	0.000013	1.3E-12	6,200	8.2E-09	No
Heptachlor*	0.07	7.5E-09	4.5	3.4E-08	No
Heptachlor epoxide*	0.07	7.5E-09	9.1	6.8E-08	No
Hexachlorobenzene*	5.6	5.6E-07	1.6	9.0E-07	No
Hexachlorobutadiene*	5.6	5.6E-07	0.078	4.4E-08	No
alpha-HCH*	0.07	7.5E-09	6.3	4.7E-08	No
beta-HCH*	0.07	7.5E-09	1.8	1.3E-08	No
delta-HCH*	0.07	*Evaluated for noncarcinogenic effects (see Table 19)*			
Hexachloroethane*	5.6	5.6E-07	0.014	7.9E-09	No
Indeno(1,2,3-cd)pyrene*	5.7	5.8E-07	0.73	4.2E-07	No
Methoxychlor*	23	*Evaluated for noncarcinogenic effects (see Table 19)*			
Methylene chloride	15	1.5E-06	0.0075	1.1E-08	No
2-Nitroaniline*	27	*Evaluated for noncarcinogenic effects (see Table 19)*			
3-Nitroaniline*	27	*Evaluated for noncarcinogenic effects (see Table 19)*			
4-Nitroaniline*	26	*Evaluated for noncarcinogenic effects (see Table 19)*			
Nitrobenzene*	5.6	*Evaluated for noncarcinogenic effects (see Table 19)*			
N-nitrosodi-n-propylamine*	5.6	5.6E-07	7	4.0E-06	No
N-nitrosodiphenylamine*	5.6	5.6E-07	0.0049	2.8E-09	No
Pentachlorophenol*	26	2.6E-06	0.12	3.1E-07	No
TCDD	0.00002	2.0E-12	150,000	3.0E-07	No
1,1,2,2-Tetrachloroethane*	4.6	4.6E-07	0.2	9.2E-08	No
1,1,2-Trichloroethane*	4.6	4.6E-07	0.057	2.6E-08	No
2,4,6-Trichlorophenol*	5.6	5.6E-07	0.011	6.2E-09	No
Toxaphene*	2.7	2.7E-07	1.1	3.0E-07	No
Trichloroethylene	8.1	8.2E-07	0.4	3.3E-07	No
Vinyl chloride*	5.7	5.8E-07	1.4	8.1E-07	No

Doses were calculated using the following formula:

dose = ((second-tier screening concentration/1,000)*0.5 liters/day*12 days/year*30 years)/(70 kg*(365 days/year*70 years)).

Risk was calculated by multiplying the exposure dose by EPA's oral cancer slope factor.

The second-tier screening concentrations are rounded.

*Chemical was detected in less than 10% of the samples. The second-tier screening concentration was estimated using 1/2 the detection limit for nondetected samples.

[§]The thallium and carbon tetrachloride data contained outliers that were three orders of magnitude higher than the second highest concentration. These data points were removed.

mg/kg/day = milligram per kilogram per day

ppb = parts per billion

Table 21. Estimated Exposure Doses for Chemicals in Fish Caught in EFPC Compared to Noncancer Screening Guidelines

Substance name	*Species*	*Minimum (ppm)*	*Maximum (ppm)*	*2nd Tier Screening Conc. (ppm)*	*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Subsistence Estimated Exposure Doses (mg/kg/day)*		*Does the subsistence estimated exposure dose exceed the noncancer screening guideline?*		*Recreational Estimated Exposure Doses (mg/kg/day)*		*Does the recreational estimated exposure dose exceed the noncancer screening guideline?*	
							child	*adult*	*child*	*adult*	*child*	*adult*	*child*	*adult*
Inorganics														
Arsenic	Crayfish	0.2557	0.5122	0.51	0.0003	CMRL	7.9E-04	4.7E-04	Yes	Yes	1.2E-04	5.8E-05	No	No
Arsenic	Sunfish spp.	0.0484	0.1721	0.12	0.0003	CMRL	2.6E-04	1.5E-04	No	No	3.8E-05	1.9E-05	No	No
Cadmium	Crayfish	2.1588	3.7445	3.7	0.0002	CMRL	5.7E-03	3.4E-03	Yes	Yes	8.5E-04	4.2E-04	Yes	Yes
Cadmium	Sunfish spp.	0.3654	1.8589	1.7	0.0002	CMRL	2.7E-03	1.6E-03	Yes	Yes	4.0E-04	2.0E-04	Yes	No
Chromium	Crayfish	0.3473	3.2609	2.9	0.003	RfD	4.4E-03	2.7E-03	Yes	No	6.6E-04	3.3E-04	No	No
Chromium	Sunfish spp.	0.1997	0.7746	0.64	0.003	RfD	9.8E-04	5.9E-04	No	No	1.5E-04	7.3E-05	No	No
Organics														
Aldrin	Sunfish spp.	ND	ND	ND	0.00003	CMRL	ND	ND	No	No	ND	ND	No	No
Aldrin	Crayfish	0.00099	0.0012	0.0012	0.00003	CMRL	1.9E-06	1.2E-06	No	No	2.9E-07	1.4E-07	No	No
Benzo(a)pyrene	Sunfish spp.	ND	ND	ND	NA	NA	ND	ND	No	No	ND	ND	No	No
Benzo(a)pyrene	Crayfish	0.0023	0.041	0.033	*Evaluated for carcinogenic effects (see Table 22)*									
Dibenzo(a,h) anthracene	Sunfish spp.	ND	ND	ND	NA	NA	ND	ND	No	No	ND	ND	No	No
Dibenzo(a,h) anthracene	Crayfish	0.0011	0.047	0.037	*Evaluated for carcinogenic effects (see Table 22)*									
Dieldrin	Crayfish	0.002	0.0049	0.0052	0.00005	CMRL	7.9E-06	4.8E-06	No	No	1.2E-06	5.9E-07	No	No
Dieldrin	Sunfish spp.	0.0065	0.079	0.066	0.00005	CMRL	1.0E-04	6.1E-05	Yes	Yes	1.5E-05	7.5E-06	No	No
alpha-HCH	Sunfish spp.	ND	ND	ND	0.008	CMRL	ND	ND	No	No	ND	ND	No	No
alpha-HCH	Crayfish	0.0016	0.0057	0.0053	0.008	CMRL	8.2E-06	5.0E-06	No	No	1.2E-06	6.1E-07	No	No
Heptachlor epoxide	Crayfish	0.00027	0.0027	0.0027	0.000013	RfD	4.1E-06	2.5E-06	No	No	6.2E-07	3.1E-07	No	No
Heptachlor epoxide	Sunfish spp.	0.0021	0.08	0.068	0.000013	RfD	1.0E-04	6.3E-05	Yes	Yes	1.6E-05	7.7E-06	Yes	No
Toxaphene	Crayfish	ND	ND	ND	0.001	IMRL	ND	ND	No	No	ND	ND	No	No
Toxaphene	Sunfish spp.	ND	ND	ND	0.001	IMRL	ND	ND	No	No	ND	ND	No	No

Noncancer subsistence-level doses were calculated using the following formulas:

child dose = (second-tier screening concentration*0.02 kg/day*365 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = (second-tier screening concentration*0.065 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*30 years)).

Table 21. Estimated Exposure Doses for Chemicals in Fish Caught in EFPC Compared to Noncancer Screening Guidelines (continued)

Noncancer recreational-level doses were calculated using the following formulas:

child dose = (second-tier screening concentration*0.003 kg/day*365 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = (second-tier screening concentration*0.008 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*30 years)).

The second-tier screening concentrations are rounded.

CMRL = chronic minimal risk level (ATSDR)
EFPC = East Fork Poplar Creek
IMRL = intermediate minimal risk level (ATSDR)
mg/kg/day = milligram per kilogram per day
NA = not available
ND = not detected
ppm = parts per million
RfD = reference dose (EPA)
spp = species
Unknown = “unknown aquatic animal”

Table 22. Estimated Exposure Doses for Chemicals in Fish Caught in the EFPC River Compared to Cancer Screening Guidelines

Substance name	*Species*	*2nd Tier Screening Conc. (ppm)*	*EPA's Oral Cancer Slope Factor (mg/kg/day)$^{-1}$*	*Estimated Exposure Dose (mg/kg/day)*		*Risk*		*Does the estimated exposure dose exceed the cancer screening guideline? (10^{-4})?*	
				Subsistence	*Recreational*	*Subsistence*	*Recreational*	*Subsistence*	*Recreational*
Inorganics									
Arsenic	Crayfish	0.51	1.5	2.0E-04	2.5E-05	3.0E-04	3.7E-05	Yes	No
Arsenic	Sunfish spp.	0.12	1.5	6.6E-05	8.1E-06	9.9E-05	1.2E-05	No	No
Cadmium	Crayfish	3.7	*Evaluated for noncarcinogenic effects (see Table 21)*						
Cadmium	Sunfish spp.	1.7	*Evaluated for noncarcinogenic effects (see Table 21)*						
Chromium	Crayfish	2.9	*Evaluated for noncarcinogenic effects (see Table 21)*						
Chromium	Sunfish spp.	0.64	*Evaluated for noncarcinogenic effects (see Table 21)*						
Organics									
Aldrin	Sunfish spp.	ND	17	ND	ND	ND	ND	No	No
Aldrin	Crayfish	0.0012	17	4.9E-07	6.1E-08	8.4E-06	1.0E-06	No	No
Benzo(a)pyrene	Sunfish spp.	ND	7.3	ND	ND	ND	ND	No	No
Benzo(a)pyrene	Crayfish	0.033	7.3	1.3E-05	1.6E-06	9.6E-05	1.2E-05	No	No
Dibenzo(a,h)anthracene	Sunfish spp.	ND	7.3	ND	ND	ND	ND	No	No
Dibenzo(a,h)anthracene	Crayfish	0.037	7.3	1.5E-05	1.8E-06	1.1E-04	1.3E-05	Yes	No
Dieldrin	Crayfish	0.0052	16	2.1E-06	2.5E-07	3.3E-05	4.0E-06	No	No
Dieldrin	Sunfish spp.	0.066	16	2.6E-05	3.2E-06	4.2E-04	5.2E-05	Yes	No
alpha-HCH	Sunfish spp.	ND	6.3	ND	ND	ND	ND	No	No
alpha-HCH	Crayfish	0.0053	6.3	2.1E-06	2.6E-07	1.3E-05	1.6E-06	No	No
Heptachlor epoxide	Crayfish	0.0027	9.1	1.1E-06	1.3E-07	9.7E-06	1.2E-06	No	No
Heptachlor epoxide	Sunfish spp.	0.068	9.1	2.7E-05	3.3E-06	2.5E-04	3.0E-05	Yes	No
Toxaphene	Crayfish	ND	1.1	ND	ND	ND	ND	No	No
Toxaphene	Sunfish spp.	ND	1.1	ND	ND	ND	ND	No	No

Cancer subsistence-level doses were calculated using the following formula:

dose = (second-tier screening concentration*0.065 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*70 years)).

Cancer recreational-level doses were calculated using the following formula:

dose = (second-tier screening concentration*0.008 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*70 years)).

The second-tier screening concentrations are rounded.

EFPC = East Fork Poplar Creek
mg/kg/day = milligram per kilogram per day
ND = not detected
ppm = parts per million
Unknown aquatic = "unknown aquatic animal"

Table 23. Estimated Exposure Doses for Chemicals in Fish Caught in the Clinch River Compared to Noncancer Screening Guidelines

Substance Name	*Species*	*Minimum (ppm)*	*Maximum (ppm)*	*2nd Tier Screening Conc. (ppm)*	*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Subsistence Estimated Exposure Doses (mg/kg/day)*		*Does the subsistence estimated exposure dose exceed the noncancer screening guideline?*		*Recreational Estimated Exposure Doses (mg/kg/day)*		*Does the recreational estimated exposure dose exceed the noncancer screening guideline?*	
							child	*adult*	*child*	*adult*	*child*	*adult*	*child*	*adult*
Inorganics														
Arsenic	Catfish	0.64	0.64	0.64	0.0003	CMRL	9.8E-04	5.9E-04	Yes	Yes	1.5E-04	7.3E-05	No	No
Arsenic	Sunfish spp.	0.018	1.1	0.79	0.0003	CMRL	1.2E-03	7.4E-04	Yes	Yes	1.8E-04	9.0E-05	No	No
Arsenic	Bass spp.	0.14	0.45	0.37	0.0003	CMRL	5.7E-04	3.4E-04	Yes	Yes	8.5E-05	4.2E-05	No	No
Cadmium	Sunfish spp.	ND	ND	ND	0.0002	CMRL	ND	ND	No	No	ND	ND	No	No
Cadmium	Catfish	ND	ND	ND	0.0002	CMRL	ND	ND	No	No	ND	ND	No	No
Cadmium	Bass spp.	ND	ND	ND	0.0002	CMRL	ND	ND	No	No	ND	ND	No	No
Chromium	Bass spp.	ND	ND	ND	0.003	RfD	ND	ND	No	No	ND	ND	No	No
Chromium	Catfish	0.12	0.406	0.47	0.003	RfD	7.2E-04	4.3E-04	No	No	1.1E-04	5.3E-05	No	No
Chromium	Sunfish spp.	0.044	0.822	0.38	0.003	RfD	5.8E-04	3.5E-04	No	No	8.7E-05	4.3E-05	No	No
Thallium	Bass spp.	ND	ND	ND	0.00007	RfD	ND	ND	No	No	ND	ND	No	No
Thallium	Catfish	0.0025	0.029	0.035	0.00007	RfD	5.3E-05	3.2E-05	No	No	8.0E-06	3.9E-06	No	No
Thallium	Sunfish spp.	0.0035	0.0075	0.0068	0.00007	RfD	1.0E-05	6.3E-06	No	No	1.6E-06	7.7E-07	No	No
Organics														
Aldrin	Bass spp.	0.0027	0.0027	0.0027	0.00003	CMRL	4.2E-06	2.5E-06	No	No	6.2E-07	3.1E-07	No	No
Aldrin	Catfish	0.013	0.013	0.013	0.00003	CMRL	2.0E-05	1.2E-05	No	No	3.0E-06	1.5E-06	No	No
Aldrin	Sunfish spp.	0.033	0.051	0.047	0.00003	CMRL	7.3E-05	4.4E-05	Yes	Yes	1.1E-05	5.4E-06	No	No
Dieldrin	Bass spp.	0.00097	0.015	0.0093	0.00005	CMRL	1.4E-05	8.6E-06	No	No	2.1E-06	1.1E-06	No	No
Dieldrin	Catfish	0.00047	0.027	0.021	0.00005	CMRL	3.2E-05	1.9E-05	No	No	4.8E-06	2.4E-06	No	No
Dieldrin	Sunfish spp.	0.0005	0.102	0.085	0.00005	CMRL	1.3E-04	7.9E-05	Yes	Yes	2.0E-05	9.8E-06	No	No
alpha-HCH	Bass spp.	0.0002	0.0014	0.0016	0.008	CMRL	2.5E-06	1.5E-06	No	No	3.8E-07	1.9E-07	No	No
alpha-HCH	Catfish	0.00045	0.013	0.016	0.008	CMRL	2.4E-05	1.4E-05	No	No	3.6E-06	1.8E-06	No	No
alpha-HCH	Sunfish spp.	0.033	0.051	0.047	0.008	CMRL	7.3E-05	4.4E-05	No	No	1.1E-05	5.4E-06	No	No
Heptachlor epoxide	Bass spp.	0.0016	0.008	0.0062	0.000013	RfD	9.5E-06	5.7E-06	No	No	1.4E-06	7.1E-07	No	No
Heptachlor epoxide	Catfish	0.00052	0.013	0.0098	0.000013	RfD	1.5E-05	9.1E-06	Yes	No	2.3E-06	1.1E-06	No	No
Heptachlor epoxide	Sunfish spp.	0.0006	0.051	0.051	0.000013	RfD	7.9E-05	4.8E-05	Yes	Yes	1.2E-05	5.9E-06	No	No

Table 23. Estimated Exposure Doses for Chemicals in Fish Caught in the Clinch River Compared to Noncancer Screening Guidelines (continued)

Substance Name	*Species*	*Minimum (ppm)*	*Maximum (ppm)*	*2nd Tier Screening Conc. (ppm)*	*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Subsistence Estimated Exposure Doses (mg/kg/day)*		*Does the subsistence estimated exposure dose exceed the noncancer screening guideline?*		*Recreational Estimated Exposure Doses (mg/kg/day)*		*Does the recreational estimated exposure dose exceed the noncancer screening guideline?*	
							child	*adult*	*child*	*adult*	*child*	*adult*	*child*	*adult*
Toxaphene	Bass spp.	ND	ND	ND	0.001	IMRL	ND	ND	No	No	ND	ND	No	No
Toxaphene	Catfish	0.2	0.2	0.2	0.001	IMRL	3.1E-04	1.9E-04	No	No	4.6E-05	2.3E-05	No	No
Toxaphene	Sunfish spp.	0.656	1.024	0.94	0.001	IMRL	1.5E-03	8.8E-04	Yes	No	2.2E-04	1.1E-04	No	No

Noncancer subsistence-level doses were calculated using the following formulas:

child dose = (second-tier screening concentration*0.02 kg/day*365 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = (second-tier screening concentration*0.065 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*30 years)).

Noncancer recreational-level doses were calculated using the following formulas:

child dose = (second-tier screening concentration*0.003 kg/day*365 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = (second-tier screening concentration*0.008 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*30 years)).

The second-tier screening concentrations are rounded.

CMRL = chronic minimal risk level (ATSDR)
IMRL = intermediate minimal risk level (ATSDR)
mg/kg/day = milligram per kilogram per day
ND = not detected
ppm = parts per million
RfD = reference dose (EPA)
spp = species

Table 24. Estimated Exposure Doses for Chemicals in Fish Caught in the Clinch River Compared to Cancer Screening Guidelines

Substance Name	*Species*	*2nd Tier Screening Conc. (ppm)*	*EPA's Oral Cancer Slope Factor (mg/kg/day)$^{-1}$*	*Estimated Exposure Dose (mg/kg/day)*		*Risk*		*Does the estimated exposure dose exceed the cancer screening guideline? (10^{-4})?*	
				Subsistence	*Recreational*	*Subsistence*	*Recreational*	*Subsistence*	*Recreational*
Inorganics									
Arsenic	Catfish	0.64	1.5	2.5E-04	3.1E-05	3.8E-04	4.7E-05	Yes	No
Arsenic	Sunfish spp.	0.79	1.5	3.2E-04	3.9E-05	4.7E-04	5.8E-05	Yes	No
Arsenic	Bass spp.	0.37	1.5	1.5E-04	1.8E-05	2.2E-04	2.7E-05	Yes	No
Cadmium	Sunfish spp.	ND	NA	ND	ND	ND	ND	No	No
Cadmium	Catfish	ND	NA	ND	ND	ND	ND	No	No
Cadmium	Bass spp.	ND	NA	ND	ND	ND	ND	No	No
Chromium	Bass spp.	ND	NA	ND	ND	ND	ND	No	No
Chromium	Catfish	0.47	*Evaluated for noncarcinogenic effects (see Table 23)*						
Chromium	Sunfish spp.	0.38	*Evaluated for noncarcinogenic effects (see Table 23)*						
Thallium	Bass spp.	ND	NA	ND	ND	ND	ND	No	No
Thallium	Catfish	0.035	*Evaluated for noncarcinogenic effects (see Table 23)*						
Thallium	Sunfish spp.	0.0068	*Evaluated for noncarcinogenic effects (see Table 23)*						
Organics									
Aldrin	Bass spp.	0.0027	17	1.1E-06	1.3E-07	1.8E-05	2.2E-06	No	No
Aldrin	Catfish	0.013	17	5.2E-06	6.4E-07	8.8E-05	1.1E-05	No	No
Aldrin	Sunfish spp.	0.051	17	1.9E-05	2.3E-06	3.2E-04	3.9E-05	Yes	No
Dieldrin	Bass spp.	0.015	16	3.7E-06	4.5E-07	5.9E-05	7.3E-06	No	No
Dieldrin	Catfish	0.027	16	8.3E-06	1.0E-06	1.3E-04	1.6E-05	Yes	No
Dieldrin	Sunfish spp.	0.102	16	3.4E-05	4.2E-06	5.4E-04	6.7E-05	Yes	No
alpha-HCH	Bass spp.	0.0014	6.3	6.6E-07	8.1E-08	4.1E-06	5.1E-07	No	No
alpha-HCH	Catfish	0.013	6.3	6.2E-06	7.6E-07	3.9E-05	4.8E-06	No	No
alpha-HCH	Sunfish spp.	0.051	6.3	1.9E-05	2.3E-06	1.2E-04	1.5E-05	Yes	No
Heptachlor epoxide	Bass spp.	0.008	9.1	2.5E-06	3.0E-07	2.2E-05	2.8E-06	No	No
Heptachlor epoxide	Catfish	0.013	9.1	3.9E-06	4.8E-07	3.5E-05	4.4E-06	No	No
Heptachlor epoxide	Sunfish spp.	0.051	9.1	2.0E-05	2.5E-06	1.9E-04	2.3E-05	Yes	No
Toxaphene	Bass spp.	ND	1.1	ND	ND	ND	ND	No	No
Toxaphene	Catfish	0.2	1.1	8.0E-05	9.8E-06	8.8E-05	1.1E-05	No	No
Toxaphene	Sunfish spp.	1.024	1.1	3.8E-04	4.6E-05	4.1E-04	5.1E-05	Yes	No

Table 24. Estimated Exposure Doses for Chemicals in Fish Caught in the Clinch River Compared to Cancer Screening Guidelines
(continued)

Cancer subsistence-level doses were calculated using the following formula:
dose = (second-tier screening concentration*0.065 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*70 years)).
Cancer recreational-level doses were calculated using the following formula:
dose = (second-tier screening concentration*0.008 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*70 years)).
The second-tier screening concentrations are rounded.
mg/kg/day = milligram per kilogram per day
NA = not available
ND = not detected
ppm = parts per million
spp = species

Table 25. Estimated Exposure Doses for Chemicals in Fish Caught in WBR Compared to Noncancer Screening Guidelines

Substance Name	*Species*	*Minimum (ppm)*	*Maximum (ppm)*	*2nd Tier Screening Conc. (ppm)*	*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Subsistence Estimated Exposure Doses (mg/kg/day)*		*Does the subsistence estimated exposure dose exceed the noncancer screening guideline?*		*Recreational Estimated Exposure Doses (mg/kg/day)*		*Does the recreational estimated exposure dose exceed the noncancer screening guideline?*	
							child	*adult*	*child*	*adult*	*child*	*adult*	*child*	*adult*
Inorganics														
Arsenic	Catfish	0.012	1.1	0.66	0.0003	CMRL	1.0E-03	6.1E-04	Yes	Yes	1.5E-04	7.5E-05	No	No
Arsenic	Unknown	0.1	0.46	0.30	0.0003	CMRL	4.6E-04	2.8E-04	Yes	No	6.9E-05	3.4E-05	No	No
Arsenic	Bass spp.	0.008	0.32	0.26	0.0003	CMRL	3.9E-04	2.4E-04	Yes	No	5.9E-05	2.9E-05	No	No
Arsenic	Sunfish spp.	0.006	0.83	0.32	0.0003	CMRL	4.9E-04	3.0E-04	Yes	No	7.4E-05	3.7E-05	No	No
Cadmium	Catfish	ND	ND	ND	0.0002	CMRL	ND	ND	No	No	ND	ND	No	No
Cadmium	Sunfish spp.	ND	ND	ND	0.0002	CMRL	ND	ND	No	No	ND	ND	No	No
Cadmium	Unknown	0.05	0.06	0.062	0.0002	CMRL	9.5E-05	5.8E-05	No	No	1.4E-05	7.1E-06	No	No
Chromium	Catfish	0.043	0.28	0.33	0.003	RfD	5.1E-04	3.1E-04	No	No	7.6E-05	3.8E-05	No	No
Chromium	Sunfish spp.	0.12	0.8	0.46	0.003	RfD	7.0E-04	4.2E-04	No	No	1.1E-04	5.2E-05	No	No
Chromium	Unknown	0.1	44.6	16	0.003	RfD	2.5E-02	1.5E-02	Yes	Yes	3.7E-03	1.8E-03	Yes	No
Thallium	Catfish	0.0025	0.006	0.0067	0.00007	RfD	1.0E-05	6.2E-06	No	No	1.6E-06	7.7E-07	No	No
Thallium	Sunfish spp.	0.0045	0.022	0.014	0.00007	RfD	2.2E-05	1.3E-05	No	No	3.2E-06	1.6E-06	No	No
Organics														
Aldrin	Unknown	ND	ND	ND	0.00003	CMRL	ND	ND	No	No	ND	ND	No	No
Aldrin	Sunfish spp.	0.0056	0.048	0.049	0.00003	CMRL	7.5E-05	4.5E-05	Yes	Yes	1.1E-05	5.6E-06	No	No
Aldrin	Catfish	0.00083	0.018	0.013	0.00003	CMRL	2.0E-05	1.2E-05	No	No	3.0E-06	1.5E-06	No	No
Aldrin	Bass spp.	0.00054	0.014	0.009	0.00003	CMRL	1.4E-05	8.4E-06	No	No	2.1E-06	1.0E-06	No	No
Dieldrin	Unknown	ND	ND	ND	0.00005	CMRL	ND	ND	No	No	ND	ND	No	No
Dieldrin	Sunfish spp.	0.00148	0.096	0.079	0.00005	CMRL	1.2E-04	7.3E-05	Yes	Yes	1.8E-05	9.0E-06	No	No
Dieldrin	Catfish	0.00044	0.036	0.018	0.00005	CMRL	2.7E-05	1.6E-05	No	No	4.1E-06	2.0E-06	No	No
Dieldrin	Bass spp.	0.0005	0.03	0.013	0.00005	CMRL	2.0E-05	1.2E-05	No	No	3.0E-06	1.5E-06	No	No
alpha-HCH	Unknown	ND	ND	ND	0.008	CMRL	ND	ND	No	No	ND	ND	No	No
alpha-HCH	Catfish	0.01	0.01	0.01	0.008	CMRL	1.5E-05	9.3E-06	No	No	2.3E-06	1.1E-06	No	No
alpha-HCH	Bass spp.	0.01	0.02	0.022	0.008	CMRL	3.4E-05	2.0E-05	No	No	5.1E-06	2.5E-06	No	No
alpha-HCH	Sunfish spp.	0.0056	0.048	0.049	0.008	CMRL	7.5E-05	4.5E-05	No	No	1.1E-05	5.6E-06	No	No

Table 25. Estimated Exposure Doses for Chemicals in Fish Caught in WBR Compared to Noncancer Screening Guidelines (continued)

Substance Name	*Species*	*Minimum (ppm)*	*Maximum (ppm)*	*2nd Tier Screening Conc. (ppm)*	*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Subsistence Estimated Exposure Doses (mg/kg/day)*		*Does the subsistence estimated exposure dose exceed the noncancer screening guideline?*		*Recreational Estimated Exposure Doses (mg/kg/day)*		*Does the recreational estimated exposure dose exceed the noncancer screening guideline?*	
							child	*adult*	*child*	*adult*	*child*	*adult*	*child*	*adult*
Heptachlor epoxide	Unknown	ND	ND	ND	0.000013	RfD	ND	ND	No	No	ND	ND	No	No
Heptachlor epoxide	Sunfish spp.	0.0013	0.048	0.048	0.000013	RfD	7.4E-05	4.5E-05	Yes	Yes	1.1E-05	5.5E-06	No	No
Heptachlor epoxide	Catfish	0.0012	0.018	0.0096	0.000013	RfD	1.5E-05	8.9E-06	Yes	No	2.2E-06	1.1E-06	No	No
Heptachlor epoxide	Bass spp.	0.00044	0.016	0.007	0.000013	RfD	1.1E-05	6.5E-06	No	No	1.6E-06	8.0E-07	No	No
TCDD	Unknown	8.7E-06	8.7E-06	9E-06	1E-09	CMRL	1.3E-08	8.1E-09	Yes	Yes	2.0E-09	9.9E-10	Yes	No
Toxaphene	Bass spp.	0.24	0.24	0.24	0.001	IMRL	3.7E-04	2.2E-04	No	No	5.5E-05	2.7E-05	No	No
Toxaphene	Catfish	0.12	0.28	0.31	0.001	IMRL	4.8E-04	2.9E-04	No	No	7.2E-05	3.6E-05	No	No
Toxaphene	Sunfish spp.	0.088	0.96	0.98	0.001	IMRL	1.5E-03	9.1E-04	Yes	No	2.3E-04	1.1E-04	No	No

Noncancer subsistence-level doses were calculated using the following formulas:

child dose = (second-tier screening concentration*0.02 kg/day*365 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = (second-tier screening concentration*0.065 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*30 years)).

Noncancer recreational-level doses were calculated using the following formulas:

child dose = (second-tier screening concentration*0.003 kg/day*365 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = (second-tier screening concentration*0.008 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*30 years)).

The second-tier screening concentrations are rounded.

CMRL = chronic minimal risk level (ATSDR)
IMRL = intermediate minimal risk level (ATSDR)
mg/kg/day = milligram per kilogram per day
ND = not detected
ppm = parts per million
RfD = reference dose (EPA)
spp = species
WBR = Watts Bar Reservoir
Unknown = “unknown aquatic animal”

Table 26. Estimated Exposure Doses for Chemicals in Fish Caught in the WBR Compared to Cancer Screening Guidelines

Substance Name	*Species*	*2nd Tier Screening Conc. (ppm)*	*EPA's Oral Cancer Slope Factor (mg/kg/day)$^{-1}$*	*Estimated Exposure Dose (mg/kg/day)*		*Risk*		*Does the estimated exposure dose exceed the cancer screening guideline? (10^{-4})?*	
				Subsistence	*Recreational*	*Subsistence*	*Recreational*	*Subsistence*	*Recreational*
Inorganics									
Arsenic	Catfish	0.66	1.5	2.6E-04	3.2E-05	3.9E-04	4.8E-05	Yes	No
Arsenic	Unknown aquatic	0.30	1.5	1.2E-04	1.5E-05	1.8E-04	2.2E-05	Yes	No
Arsenic	Bass spp.	0.26	1.5	1.0E-04	1.3E-05	1.5E-04	1.9E-05	Yes	No
Arsenic	Sunfish spp.	0.32	1.5	1.3E-04	1.6E-05	1.9E-04	2.4E-05	Yes	No
Cadmium	Catfish	ND	NA	ND	ND	ND	ND	No	No
Cadmium	Sunfish spp.	ND	NA	ND	ND	ND	ND	No	No
Cadmium	Unknown aquatic	0.062	*Evaluated for noncarcinogenic effects (see Table 25)*						
Chromium	Catfish	0.33	*Evaluated for noncarcinogenic effects (see Table 25)*						
Chromium	Sunfish spp.	0.46	*Evaluated for noncarcinogenic effects (see Table 25)*						
Chromium	Unknown aquatic	16	*Evaluated for noncarcinogenic effects (see Table 25)*						
Thallium	Catfish	0.0067	*Evaluated for noncarcinogenic effects (see Table 25)*						
Thallium	Sunfish spp.	0.014	*Evaluated for noncarcinogenic effects (see Table 25)*						
Organics									
Aldrin	Unknown aquatic	ND	17	ND	ND	ND	ND	No	No
Aldrin	Sunfish spp.	0.049	17	1.9E-05	2.4E-06	3.3E-04	4.0E-05	Yes	No
Aldrin	Catfish	0.013	17	5.2E-06	6.3E-07	8.8E-05	1.1E-05	No	No
Aldrin	Bass spp.	0.009	17	3.6E-06	4.4E-07	6.1E-05	7.5E-06	No	No
Dieldrin	Unknown aquatic	ND	16	ND	ND	ND	ND	No	No
Dieldrin	Sunfish spp.	0.079	16	3.1E-05	3.9E-06	5.0E-04	6.2E-05	Yes	No
Dieldrin	Catfish	0.018	16	7.1E-06	8.7E-07	1.1E-04	1.4E-05	Yes	No
Dieldrin	Bass spp.	0.013	16	5.2E-06	6.3E-07	8.2E-05	1.0E-05	No	No
alpha-HCH	Unknown aquatic	ND	6.3	ND	ND	ND	ND	No	No
alpha-HCH	Catfish	0.01	6.3	4.0E-06	4.9E-07	2.5E-05	3.1E-06	No	No
alpha-HCH	Bass spp.	0.022	6.3	8.8E-06	1.1E-06	5.5E-05	6.8E-06	No	No
alpha-HCH	Sunfish spp.	0.049	6.3	1.9E-05	2.4E-06	1.2E-04	1.5E-05	Yes	No
Heptachlor epoxide	Unknown aquatic	ND	9.1	ND	ND	ND	ND	No	No
Heptachlor epoxide	Sunfish spp.	0.048	9.1	1.9E-05	2.4E-06	1.7E-04	2.1E-05	Yes	No
Heptachlor epoxide	Catfish	0.0096	9.1	3.8E-06	4.7E-07	3.5E-05	4.3E-06	No	No
Heptachlor epoxide	Bass spp.	0.007	9.1	2.8E-06	3.4E-07	2.5E-05	3.1E-06	No	No

Table 26. Estimated Exposure Doses for Chemicals in Fish Caught in the WBR Compared to Cancer Screening Guidelines (continued)

Substance Name	*Species*	*2nd Tier Screening Conc. (ppm)*	*EPA's Oral Cancer Slope Factor (mg/kg/day)$^{-1}$*	*Estimated Exposure Dose (mg/kg/day)*		*Risk*		*Does the estimated exposure dose exceed the cancer screening guideline? (10^{-4})?*	
				Subsistence	*Recreational*	*Subsistence*	*Recreational*	*Subsistence*	*Recreational*
TCDD	Unknown aquatic	9E-06	150,000	3.5E-09	4.3E-10	5.2E-04	6.4E-05	Yes	No
Toxaphene	Bass spp.	0.24	1.1	9.6E-05	1.2E-05	1.1E-04	1.3E-05	Yes	No
Toxaphene	Catfish	0.31	1.1	1.2E-04	1.5E-05	1.4E-04	1.7E-05	Yes	No
Toxaphene	Sunfish spp.	0.98	1.1	3.9E-04	4.8E-05	4.3E-04	5.3E-05	Yes	No

Cancer subsistence-level doses were calculated using the following formula:

adult dose = (second-tier screening concentration*0.065 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*70 years)).

Cancer recreational-level doses were calculated using the following formula:

adult dose = (second-tier screening concentration*0.008 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*70 years)).

The second-tier screening concentrations are rounded.

mg/kg/day = milligram per kilogram per day
NA = not available
ND = not detected
ppm = parts per million
spp = species
WBR = Watts Bar Reservoir
Unknown aquatic = "unknown aquatic animal"

Table 27. Estimated Exposure Doses for Chemicals in Fish Caught On Site Compared to Noncancer Screening Guidelines

Substance name	*Species*	*Minimum (ppm)*	*Maximum (ppm)*	*2nd Tier Screening Conc. (ppm)*	*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Subsistence Estimated Exposure Doses (mg/kg/day)*		*Does the subsistence estimated exposure dose exceed the noncancer screening guideline?*		*Recreational Estimated Exposure Doses (mg/kg/day)*		*Does the recreational estimated exposure dose exceed the noncancer screening guideline?*	
							child	*adult*	*child*	*adult*	*child*	*adult*	*child*	*adult*
Inorganics														
Arsenic	Creek chub	0.0855	0.112	0.11	0.0003	CMRL	1.7E-04	1.0E-04	No	No	2.5E-05	1.3E-05	No	No
Arsenic	Crayfish	0.2196	0.2749	0.28	0.0003	CMRL	4.2E-04	2.6E-04	Yes	No	6.4E-05	3.1E-05	No	No
Arsenic	Unknown	0.137	0.39	0.38	0.0003	CMRL	5.8E-04	3.5E-04	Yes	Yes	8.8E-05	4.3E-05	No	No
Arsenic	Sunfish spp.	0.026	1.3	0.44	0.0003	CMRL	6.7E-04	4.1E-04	Yes	Yes	1.0E-04	5.0E-05	No	No
Arsenic	Bass spp.	0.045	0.96	0.34	0.0003	CMRL	5.3E-04	3.2E-04	Yes	Yes	7.9E-05	3.9E-05	No	No
Cadmium	Creek chub	0.529	1.11	1.2	0.0002	CMRL	1.8E-03	1.1E-03	Yes	Yes	2.7E-04	1.3E-04	Yes	No
Cadmium	Crayfish	1.9136	2.3827	2.4	0.0002	CMRL	3.6E-03	2.2E-03	Yes	Yes	5.4E-04	2.7E-04	Yes	Yes
Cadmium	Bass spp.	0.028	0.8282	0.63	0.0002	CMRL	9.7E-04	5.9E-04	Yes	Yes	1.5E-04	7.2E-05	No	No
Cadmium	Sunfish spp.	0.0416	1.9608	1.6	0.0002	CMRL	2.4E-03	1.5E-03	Yes	Yes	3.7E-04	1.8E-04	Yes	No
Cadmium	Unknown	0.12	1.8	1.4	0.0002	CMRL	2.2E-03	1.3E-03	Yes	Yes	3.3E-04	1.6E-04	Yes	No
Chromium	Creek chub	0.242	0.356	0.35	0.003	RfD	5.4E-04	3.3E-04	No	No	8.1E-05	4.0E-05	No	No
Chromium	Crayfish	0.5469	1.3066	1.3	0.003	RfD	1.9E-03	1.2E-03	No	No	2.9E-04	1.4E-04	No	No
Chromium	Bass spp.	0.12	2.1	1.5	0.003	RfD	2.2E-03	1.3E-03	No	No	3.3E-04	1.7E-04	No	No
Chromium	Unknown	0.27	0.69	0.61	0.003	RfD	9.4E-04	5.7E-04	No	No	1.4E-04	7.0E-05	No	No
Chromium	Sunfish spp.	0.062	0.7173	0.43	0.003	RfD	6.6E-04	4.0E-04	No	No	9.9E-05	4.9E-05	No	No
Thallium	Creek chub	ND	ND	ND	0.00007	RfD	ND	ND	No	No	ND	ND	No	No
Thallium	Unknown	0.01	0.024	0.027	0.00007	RfD	4.1E-05	2.5E-05	No	No	6.2E-06	3.1E-06	No	No
Thallium	Bass spp.	0.005	0.049	0.058	0.00007	RfD	8.9E-05	5.4E-05	Yes	No	1.3E-05	6.6E-06	No	No
Thallium	Sunfish spp.	0.009	9.2	4.1	0.00007	RfD	6.3E-03	3.8E-03	Yes	Yes	9.5E-04	4.7E-04	Yes	Yes
Organics														
Aldrin	Crayfish	ND	ND	ND	0.00003	CMRL	ND	ND	No	No	ND	ND	No	No
Aldrin	Catfish	0.0023	0.0055	0.0062	0.00003	CMRL	9.5E-06	5.7E-06	No	No	1.4E-06	7.0E-07	No	No
Aldrin	Bass spp.	0.00039	0.0042	0.0039	0.00003	CMRL	6.0E-06	3.6E-06	No	No	8.9E-07	4.4E-07	No	No
Aldrin	Sunfish spp.	0.033	0.042	0.043	0.00003	CMRL	6.5E-05	3.9E-05	Yes	Yes	9.8E-06	4.9E-06	No	No
Benzo(a)pyrene	Sunfish spp.	0.00041	0.00041	0.0004	*Evaluated for carcinogenic effects (see Table 28)*									

Table 27. Estimated Exposure Doses for Chemicals in Fish Caught On Site Compared to Noncancer Screening Guidelines (continued)

Substance name	*Species*	*Minimum (ppm)*	*Maximum (ppm)*	*2nd Tier Screening Conc. (ppm)*	*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Subsistence Estimated Exposure Doses (mg/kg/day)*		*Does the subsistence estimated exposure dose exceed the noncancer screening guideline?*		*Recreational Estimated Exposure Doses (mg/kg/day)*		*Does the recreational estimated exposure dose exceed the noncancer screening guideline?*	
							child	*adult*	*child*	*adult*	*child*	*adult*	*child*	*adult*
Benzo(a)pyrene	Catfish	0.033	0.033	0.033	*Evaluated for carcinogenic effects (see Table 28)*									
Benzo(a)pyrene	Crayfish	0.0042	0.0071	0.0077	*Evaluated for carcinogenic effects (see Table 28)*									
Dibenzo(a,h)anthracene	Catfish	0.033	0.033	0.033	*Evaluated for carcinogenic effects (see Table 28)*									
Dibenzo(a,h)anthracene	Sunfish spp.	0.0056	0.0056	0.0056	*Evaluated for carcinogenic effects (see Table 28)*									
Dibenzo(a,h)anthracene	Crayfish	0.00093	0.0013	0.0014	*Evaluated for carcinogenic effects (see Table 28)*									
Dieldrin	Crayfish	0.0082	0.011	0.012	0.00005	CMRL	1.8E-05	1.1E-05	No	No	2.7E-06	1.3E-06	No	No
Dieldrin	Catfish	0.0012	0.028	0.023	0.00005	CMRL	3.5E-05	2.1E-05	No	No	5.3E-06	2.6E-06	No	No
Dieldrin	Bass spp.	0.00081	0.11	0.069	0.00005	CMRL	1.1E-04	6.4E-05	Yes	Yes	1.6E-05	7.8E-06	No	No
Dieldrin	Sunfish spp.	0.011	0.083	0.085	0.00005	CMRL	1.3E-04	7.9E-05	Yes	Yes	2.0E-05	9.7E-06	No	No
alpha-HCH	Crayfish	ND	ND	ND	0.008	CMRL	ND	ND	No	No	ND	ND	No	No
alpha-HCH	Catfish	ND	ND	ND	0.008	CMRL	ND	ND	No	No	ND	ND	No	No
alpha-HCH	Bass spp.	ND	ND	ND	0.008	CMRL	ND	ND	No	No	ND	ND	No	No
alpha-HCH	Sunfish spp.	0.0026	0.042	0.048	0.008	CMRL	7.4E-05	4.5E-05	No	No	1.1E-05	5.5E-06	No	No
Heptachlor epoxide	Crayfish	0.0016	0.0042	0.0047	0.000013	RfD	7.3E-06	4.4E-06	No	No	1.1E-06	5.4E-07	No	No
Heptachlor epoxide	Bass spp.	0.00057	0.011	0.0084	0.000013	RfD	1.3E-05	7.8E-06	No	No	1.9E-06	9.6E-07	No	No
Heptachlor epoxide	Catfish	0.0019	0.02	0.016	0.000013	RfD	2.4E-05	1.4E-05	Yes	Yes	3.6E-06	1.8E-06	No	No
Heptachlor epoxide	Sunfish spp.	0.0006	0.073	0.053	0.000013	RfD	8.2E-05	4.9E-05	Yes	Yes	1.2E-05	6.1E-06	No	No
Toxaphene	Catfish	ND	ND	ND	0.001	IMRL	ND	ND	No	No	ND	ND	No	No
Toxaphene	Crayfish	ND	ND	ND	0.001	IMRL	ND	ND	No	No	ND	ND	No	No
Toxaphene	Bass spp.	1.9	1.9	1.9	0.001	IMRL	2.9E-03	1.8E-03	Yes	Yes	4.4E-04	2.2E-04	No	No
Toxaphene	Sunfish spp.	0.656	0.832	0.85	0.001	IMRL	1.3E-03	7.9E-04	Yes	No	2.0E-04	9.7E-05	No	No

Noncancer subsistence-level doses were calculated using the following formulas:

child dose = (second-tier screening concentration*0.02 kg/day*365 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = (second-tier screening concentration*0.065 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*30 years)).

Noncancer recreational-level doses were calculated using the following formulas:

child dose = (second-tier screening concentration*0.003 kg/day*365 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = (second-tier screening concentration*0.008 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*30 years)).

Table 27. Estimated Exposure Doses for Chemicals in Fish Caught On Site Compared to Noncancer Screening Guidelines (continued)

The second-tier screening concentrations are rounded.
CMRL = chronic minimal risk level (ATSDR)
IMRL = intermediate minimal risk level (ATSDR)
mg/kg/day = milligram per kilogram per day
ND = not detected
ppm = parts per million
RfD = reference dose (EPA)
spp = species
Unknown = “unknown aquatic animal”

Table 28. Estimated Exposure Doses for Chemicals in Fish Caught On Site Compared to Cancer Screening Guidelines

Substance name	*Species*	*2nd Tier Screening Conc. (ppm)*	*EPA's Oral Cancer Slope Factor (mg/kg/day)$^{-1}$*	*Estimated Exposure Dose (mg/kg/day)*		*Risk*		*Does the estimated exposure dose exceed the cancer screening guideline? (10^{-4})?*	
				Subsistence	*Recreational*	*Subsistence*	*Recreational*	*Subsistence*	*Recreational*
Inorganics									
Arsenic	Creek chub	0.11	1.5	4.4E-05	5.4E-06	6.6E-05	8.1E-06	No	No
Arsenic	Crayfish	0.28	1.5	1.1E-04	1.3E-05	1.6E-04	2.0E-05	Yes	No
Arsenic	Unknown aquatic	0.38	1.5	1.5E-04	1.9E-05	2.3E-04	2.8E-05	Yes	No
Arsenic	Sunfish spp.	0.44	1.5	1.7E-04	2.1E-05	2.6E-04	3.2E-05	Yes	No
Arsenic	Bass spp.	0.34	1.5	1.4E-04	1.7E-05	2.0E-04	2.5E-05	Yes	No
Cadmium	Creek chub	1.2	*Evaluated for noncarcinogenic effects (see Table 27)*						
Cadmium	Crayfish	2.4	*Evaluated for noncarcinogenic effects (see Table 27)*						
Cadmium	Bass spp.	0.63	*Evaluated for noncarcinogenic effects (see Table 27)*						
Cadmium	Sunfish spp.	1.6	*Evaluated for noncarcinogenic effects (see Table 27)*						
Cadmium	Unknown aquatic	1.4	*Evaluated for noncarcinogenic effects (see Table 27)*						
Chromium	Creek chub	0.35	*Evaluated for noncarcinogenic effects (see Table 27)*						
Chromium	Crayfish	1.3	*Evaluated for noncarcinogenic effects (see Table 27)*						
Chromium	Bass spp.	1.5	*Evaluated for noncarcinogenic effects (see Table 27)*						
Chromium	Unknown aquatic	0.61	*Evaluated for noncarcinogenic effects (see Table 27)*						
Chromium	Sunfish spp.	0.43	*Evaluated for noncarcinogenic effects (see Table 27)*						
Thallium	Creek chub	ND	NA	ND	ND	ND	ND	No	No
Thallium	Unknown aquatic	0.027	*Evaluated for noncarcinogenic effects (see Table 27)*						
Thallium	Bass spp.	0.058	*Evaluated for noncarcinogenic effects (see Table 27)*						
Thallium	Sunfish spp.	4.1	*Evaluated for noncarcinogenic effects (see Table 27)*						
Organics									
Aldrin	Crayfish	ND	17	ND	ND	ND	ND	No	No
Aldrin	Catfish	0.0062	17	2.5E-06	3.0E-07	4.2E-05	5.1E-06	No	No
Aldrin	Bass spp.	0.0039	17	1.5E-06	1.9E-07	2.6E-05	3.2E-06	No	No
Aldrin	Sunfish spp.	0.043	17	1.7E-05	2.1E-06	2.9E-04	3.5E-05	Yes	No
Benzo(a)pyrene	Sunfish spp.	0.0004	7.3	1.6E-07	2.0E-08	1.2E-06	1.5E-07	No	No
Benzo(a)pyrene	Catfish	0.033	7.3	1.3E-05	1.6E-06	9.6E-05	1.2E-05	No	No
Benzo(a)pyrene	Crayfish	0.0077	7.3	3.1E-06	3.8E-07	2.2E-05	2.8E-06	No	No
Dibenzo(a,h)anthracene	Catfish	0.033	7.3	1.3E-05	1.6E-06	9.6E-05	1.2E-05	No	No
Dibenzo(a,h)anthracene	Sunfish spp.	0.0056	7.3	2.2E-06	2.7E-07	1.6E-05	2.0E-06	No	No

Table 28. Estimated Exposure Doses for Chemicals in Fish Caught On Site Compared to Cancer Screening Guidelines (continued)

Substance name	*Species*	*2nd Tier Screening Conc. (ppm)*	*EPA's Oral Cancer Slope Factor $(mg/kg/day)^{-1}$*	*Estimated Exposure Dose (mg/kg/day)*		*Risk*		*Does the estimated exposure dose exceed the cancer screening guideline? (10^{-4})?*	
				Subsistence	*Recreational*	*Subsistence*	*Recreational*	*Subsistence*	*Recreational*
Dibenzo(a,h)anthracene	Crayfish	0.0014	7.3	5.5E-07	6.7E-08	4.0E-06	4.9E-07	No	No
Dieldrin	Crayfish	0.012	16	4.6E-06	5.7E-07	7.4E-05	9.1E-06	No	No
Dieldrin	Catfish	0.023	16	9.2E-06	1.1E-06	1.5E-04	1.8E-05	Yes	No
Dieldrin	Bass spp.	0.069	16	2.7E-05	3.4E-06	4.4E-04	5.4E-05	Yes	No
Dieldrin	Sunfish spp.	0.085	16	3.4E-05	4.2E-06	5.4E-04	6.7E-05	Yes	No
alpha-HCH	Crayfish	ND	6.3	ND	ND	ND	ND	No	No
alpha-HCH	Catfish	ND	6.3	ND	ND	ND	ND	No	No
alpha-HCH	Bass spp.	ND	6.3	ND	ND	ND	ND	No	No
alpha-HCH	Sunfish spp.	0.048	6.3	1.9E-05	2.4E-06	1.2E-04	1.5E-05	Yes	No
Heptachlor epoxide	Crayfish	0.0047	9.1	1.9E-06	2.3E-07	1.7E-05	2.1E-06	No	No
Heptachlor epoxide	Bass spp.	0.0084	9.1	3.3E-06	4.1E-07	3.0E-05	3.7E-06	No	No
Heptachlor epoxide	Catfish	0.016	9.1	6.2E-06	7.6E-07	5.7E-05	7.0E-06	No	No
Heptachlor epoxide	Sunfish spp.	0.053	9.1	2.1E-05	2.6E-06	1.9E-04	2.4E-05	Yes	No
Toxaphene	Catfish	ND	1.1	ND	ND	ND	ND	No	No
Toxaphene	Crayfish	ND	1.1	ND	ND	ND	ND	No	No
Toxaphene	Bass spp.	1.9	1.1	7.6E-04	9.3E-05	8.3E-04	1.0E-04	Yes	Yes
Toxaphene	Sunfish spp.	0.85	1.1	3.4E-04	4.1E-05	3.7E-04	4.6E-05	Yes	No

Cancer subsistence-level doses were calculated using the following formula:

dose = (second-tier screening concentration*0.065 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*70 years)).

Cancer recreational-level doses were calculated using the following formula:

dose = (second-tier screening concentration*0.008 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*70 years)).

The second-tier screening concentrations are rounded.

mg/kg/day = milligram per kilogram per day

NA = not available

ND = not detected

ppm = parts per million

spp = species

Unknown aquatic = "unknown aquatic animal"

Table 29. Estimated Exposure Doses for Chemicals in Game Species Caught On Site Compared to Noncancer Screening Guidelines

Substance Name	*Species*	*Minimum (ppm)*	*Maximum (ppm)*	*2nd Tier Screening Conc. (ppm)*	*Estimated Exposure Doses (mg/kg/day)*		*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Does the estimated exposure dose exceed the noncancer screening guideline?*	
					child	*adult*			*child*	*adult*
Inorganics										
Aluminum	Unknown terrestrial animal	0.0987	15,300	10,400	8.0E-01	3.0E-01	1	RfD	No	No
Antimony	Unknown terrestrial animal	0.0224	14.3	12	8.9E-04	3.3E-04	0.0004	RfD	Yes	No
Cadmium	Canadian goose	0.41	3.2	2.5	1.9E-04	7.2E-05	0.0002	CMRL	No	No
Cadmium	Unknown aquatic bird	1.53	7.21	7.1	5.5E-04	2.0E-04	0.0002	CMRL	Yes	Yes
Cadmium	Unknown terrestrial animal	0.0033	32.4	13	9.7E-04	3.6E-04	0.0002	CMRL	Yes	Yes
Cadmium	Unknown terrestrial bird	ND	ND	ND	ND	ND	0.0002	CMRL	ND	ND
Cadmium	Wood duck	ND	ND	ND	ND	ND	0.0002	CMRL	ND	ND
Iron	Unknown terrestrial animal	0.6878	36,200	18,000	1.4E+00	5.1E-01	0.3	RfD	Yes	Yes
Manganese	Unknown terrestrial animal	0.291	10,200	4,000	3.1E-01	1.1E-01	0.14	RfD	Yes	No
Manganese	Unknown terrestrial bird	0.36	0.5	0.53	4.1E-05	1.5E-05	0.14	RfD	No	No
Thallium	Unknown terrestrial animal	0.93	2.9	2.6	2.0E-04	7.5E-05	0.00007	RfD	Yes	Yes
Organics										
4,6-Dinitro-o-cresol	Unknown terrestrial animal	3.5	3.5	3.5	2.7E-04	1.0E-04	0.0001	RfD	Yes	No
2,4-Dinitrophenol	Unknown terrestrial animal	3.5	75	82	6.3E-03	2.3E-03	0.002	RfD	Yes	Yes

Noncancer doses were calculated using the following formulas:

child dose = (second-tier screening concentration*0.001 kg/day*365 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = (second-tier screening concentration*0.002 kg/day*365 days/year*30 years)/(70 kg*(365 days/year*30 years)).

The second-tier screening concentrations are rounded.

CMRL = chronic minimal risk level (ATSDR)

mg/kg/day = milligram per kilogram per day

ND = not detected

ppm = parts per million

RfD = reference dose (EPA)

All chemicals detected in game species caught on site were evaluated for noncarcinogenic effects only—cancer screening guidelines are not available for these chemicals.

Table 30. Estimated Exposure Doses for Chemicals in Vegetation Species Collected Off Site Compared to Noncancer Screening Guidelines

Substance Name	*Species*	*Minimum (ppm)*	*Maximum (ppm)*	*2nd Tier Screening Conc. (ppm)*	*Estimated Exposure Doses (mg/kg/day)*		*Noncancer Screening Guideline (mg/kg/day)*	*Source*	*Does the estimated exposure dose exceed the noncancer screening guideline?*	
					child	*adult*			*child*	*adult*
Inorganics										
Arsenic	Beets	0.0702	0.0702	0.07	1.1E-04	1.1E-04	0.0003	CMRL	No	No
Arsenic	Kale	0.0341	5.3428	3.0	4.8E-03	4.8E-03	0.0003	CMRL	Yes	Yes
Arsenic	Tomato	0.4371	3.6404	2.6	4.2E-03	4.2E-03	0.0003	CMRL	Yes	Yes
Arsenic	Unknown terrestrial plant	ND	ND	ND	ND	ND	0.0003	CMRL	ND	ND
Cadmium	Beets	0.6857	0.6857	0.69	1.1E-03	1.1E-03	0.0002	CMRL	Yes	Yes
Cadmium	Kale	0.2332	1.5643	1.0	1.7E-03	1.7E-03	0.0002	CMRL	Yes	Yes
Cadmium	Tomato	0.1084	2.7098	2.0	3.3E-03	3.3E-03	0.0002	CMRL	Yes	Yes
Cadmium	Unknown terrestrial plant	ND	ND	ND	ND	ND	0.0002	CMRL	ND	ND
Chromium	Beets	0.1446	0.5144	0.52	8.3E-04	8.3E-04	0.003	RfD	No	No
Chromium	Kale	0.061	24.446	16	2.6E-02	2.6E-02	0.003	RfD	Yes	Yes
Chromium	Tomato	0.0472	30.296	21	3.4E-02	3.4E-02	0.003	RfD	Yes	Yes
Chromium	Unknown terrestrial plant	0.3437	0.3437	0.34	5.5E-04	5.5E-04	0.003	RfD	No	No

Noncancer doses were calculated using the following formulas:

child dose = (second-tier screening concentration*0.0016 kg/kg/day*365 days/year*6 years)/(365 days/year*6 years))

adult dose = (second-tier screening concentration*0.0016 kg/kg/day*365 days/year*30 years)/(365 days/year*30 years)).

The second-tier screening concentrations are rounded.

CMRL = chronic minimal risk level (ATSDR)

mg/kg/day = milligram per kilogram per day

ND = not detected

ppm = parts per million

RfD = reference dose (EPA)

Table 31. Estimated Exposure Doses for Chemicals in Vegetation Species Collected Off Site Compared to Cancer Screening Guidelines

Substance Name	*Species*	*2nd Tier Screening Conc. (ppm)*	*Estimated Exposure Dose (mg/kg/day)*	*EPA's Oral Cancer Slope Factor $(mg/kg/day)^{-1}$*	*Risk*	*Does the estimated exposure dose exceed the cancer screening guideline? (10^{-4})?*
Inorganics						
Arsenic	Beets	0.07	4.8E-05	1.5	7.2E-05	No
Arsenic	Kale	3	2.1E-03	1.5	3.1E-03	Yes
Arsenic	Tomato	2.6	1.8E-03	1.5	2.7E-03	Yes
Arsenic	Unknown terrestrial plant	ND	ND	1.5	ND	No
Cadmium	Beets	0.69	*Evaluated for noncarcinogenic effects (see Table 30)*			
Cadmium	Kale	1	*Evaluated for noncarcinogenic effects (see Table 30)*			
Cadmium	Tomato	2	*Evaluated for noncarcinogenic effects (see Table 30)*			
Cadmium	Unknown terrestrial plant	ND	ND	NA	ND	No
Chromium	Beets	0.52	*Evaluated for noncarcinogenic effects (see Table 30)*			
Chromium	Kale	16	*Evaluated for noncarcinogenic effects (see Table 30)*			
Chromium	Tomato	21	*Evaluated for noncarcinogenic effects (see Table 30)*			
Chromium	Unknown terrestrial plant	0.34	*Evaluated for noncarcinogenic effects (see Table 30)*			

Cancer doses were calculated using the following formula:

dose = (second-tier screening concentration*0.0016 kg/kg/day*365 days/year*30 years)/(365 days/year*70 years)).

Risk was calculated by multiplying the cancer dose by EPA's oral cancer slope factor.

The second-tier screening concentrations are rounded.

mg/kg/day = milligram per kilogram per day

NA = not available

ND = not detected

ppm = parts per million

Table 32. Chemicals Detected at Air Monitoring Stations

Substance	*Minimum (μ/m^3)*	*Maximum (μ/m^3)*	*Average (μ/m^3)*	*2nd Tier Screening Conc. (μ/m^3)*	*Number of Times Detected*	*Sample Total*	*Percent Detected*	*Comparison Value (μ/m^3)*	*Source*	*Maximum above CV?*	*2nd tier screening conc. above CV?*	*Number of times above CV*
Inorganics												
Arsenic	0.000001	0.00685	0.00056	0.00134	132	224	59%	0.0002	CREG	Yes	Yes	98
Beryllium	0.00001	0.00002	0.00001	0.00001	5	219	2%	0.0004	CREG	No	No	0
Cadmium	0.00004	0.00376	0.00065	0.00129	241	241	100%	0.0006	CREG	Yes	Yes	88
Chromium	0.00000	0.04560	0.00128	0.00565	179	219	82%	0.00008	CREG (CrVI)	Yes	Yes	161
Lead	0.00001	0.00888	0.00347	0.00535	242	243	100%	1.5	NAAQS	No	No	0

There are discrepancies between OREIS and DOE's Annual Reports for some of the air monitoring data. The highest values were used in this evaluation.
CREG = cancer risk evaluation guide
CV = comparison value
EMEG = environmental medial evaluation guide
μ/m^3 = micrograms per cubic meter
NAAQS = National Ambient Air Quality Standard

Table 33. Chemicals Detected in the Soil in the Scarboro Community

Substance	*Minimum (ppm)*	*Maximum (ppm)*	*Average (ppm)*	*Number of Times Detected*	*Sample Total*	*Comparison Value (ppm)*	*Source*	*Maximum above CV?*
Inorganics								
Aluminum	8,530	32,900	17,000	13	16	100,000	IEMEG	No
Antimony	0.0383	0.113	0.076	6	16	20	RMEG	No
Arsenic	1	6.39	4.0	13	16	0.5	CREG	Yes
Barium	36.6	206	95	13	16	4,000	RMEG	No
Beryllium	0.509	1.35	0.80	13	16	100	CEMEG	No
Cadmium	0.0702	0.57	0.38	13	16	10	CEMEG	No
Chromium	13.8	26.6	20	13	16	200	RMEG (CrVI)	No
Cobalt	4.7	60	14	13	16	500	IEMEG	No
Copper	13.3	44.3	22	13	16	2,000	IEMEG	No
Iron	14,900	29,700	21,000	13	16	23,000	Residential RBC	Yes
Lead	5.3	130	45	13	16	400	Soil Screening Level	No
Manganese	122	1,930	760	13	16	3,000	RMEG	No
Nickel	9.42	60.9	16	13	16	1,000	IEMEG	No
Selenium	1.46	1.87	1.7	3	16	300	CEMEG	No
Silver	0.39	0.39	0.39	2	16	300	RMEG	No
Thallium	0.287	0.377	0.34	6	16	5.5	Residential RBC	No
Vanadium	17.7	35.6	26	13	16	200	IEMEG	No
Zinc	24.8	153	74	13	16	20,000	CEMEG	No
Organics								
Acetone	0.0098	0.0098	0.0098	1	16	5,000	RMEG	No
Benzoic acid	0.0824	0.123	0.017	4	24	200,000	RMEG	No
Bromoform	0.0019	0.0025	0.0022	4	16	90	CREG	No
cis-Chlordane	0.011	1.7	0.86	4	16	2	CREG (chlordane)	No
DDE, p,p'-	0.0017	0.0017	0.0017	2	16	2	CREG	No
DDT, p,p'-	0.002	0.002	0.002	2	16	2	CREG	No
Fluoranthene	0.074	0.0824	0.10	4	16	2,000	RMEG	No
gamma-Chlordane	0.012	2.8	1.4	4	16	2	CREG (chlordane)	Yes

Table 33. Chemicals Detected in the Soil in the Scarboro Community (continued)

Substance	*Minimum (ppm)*	*Maximum (ppm)*	*Average (ppm)*	*Number of Times Detected*	*Sample Total*	*Comparison Value (ppm)*	*Source*	*Maximum above CV?*
Heptachlor	0.013	0.19	0.13	3	16	0.2	CREG	No
Heptachlor epoxide	0.011	0.97	0.65	3	16	0.08	CREG	Yes
Pyrene	0.068	0.068	0.068	1	16	2,000	RMEG	No

Essential nutrients (calcium, magnesium, potassium, and sodium) are not included in the table.
CEMEG = chronic environmental medial evaluation guide
CREG = cancer risk evaluation guide
CV = comparison value
IEMEG = intermediate environmental medial evaluation guide
ppm = parts per million
RBC = risk-based concentration

Table 34. Chemicals Detected in the Sediment in the Scarboro Community

Substance	*Minimum (ppm)*	*Maximum (ppm)*	*Average (ppm)*	*Number of Times Detected*	*Sample Total*	*Comparison Value (ppm)*	*Source*	*Maximum above CV?*
Inorganics								
Aluminum	5,830	21,000	10,000	4	5	100,000	IEMEG	No
Antimony	0.0507	0.0949	0.073	2	5	20	RMEG	No
Arsenic	1.62	5.17	3.7	4	5	0.5	CREG	Yes
Barium	76.4	91.4	81	4	5	4,000	RMEG	No
Beryllium	0.576	0.977	0.75	4	5	100	CEMEG	No
Cadmium	0.124	0.29	0.22	4	5	10	CEMEG	No
Chromium	14.3	26.6	20.6	4	5	200	RMEG (CrVI)	No
Cobalt	7.91	15	9.8	4	5	500	IEMEG	No
Copper	7.29	17.4	10	4	5	2,000	IEMEG	No
Iron	12,500	23,900	20,700	4	5	23,000	Residential RBC	Yes
Lead	9	101	32.5	4	5	400	Soil Screening Level	No
Manganese	542	680	590	4	5	3,000	RMEG	No
Nickel	9.3	16.1	11	4	5	1,000	IEMEG	No
Selenium	0.936	1.13	1.03	2	5	300	CEMEG	No
Thallium	0.23	0.31	0.27	2	5	5.5	Residential RBC	No
Vanadium	15.7	33	23	4	5	200	IEMEG	No
Zinc	51.7	94	74	4	5	20,000	CEMEG	No
Organics								
Benzoic acid	0.206	0.206	0.206	1	8	200,000	RMEG	No
Bromoform	0.0022	0.0022	0.0022	1	5	90	CREG	No
cis-Chlordane	0.0005	0.002	0.0015	3	5	2	CREG (chlordane)	No
Di-n-butyl phthalate	0.54	0.54	0.54	1	5	5,000	RMEG	No
gamma-Chlordane	0.00075	0.0017	0.0014	3	5	2	CREG (chlordane)	No

Essential nutrients (calcium, magnesium, potassium, and sodium) are not included in the table.
CEMEG = chronic environmental medial evaluation guide
CREG = cancer risk evaluation guide
CV = comparison value
IEMEG = intermediate environmental medial evaluation guide
ppm = parts per million
RBC = risk-based concentration

Table 35. Chemicals Detected in the Surface Water in the Scarboro Community

Substance	*Minimum (ppb)*	*Maximum (ppb)*	*Average (ppb)*	*Number of Times Detected*	*Sample Total*	*Comparison Value (ppb)*	*Source*	*Maximum above CV?*
Inorganics								
Aluminum	261	1,640	798	4	5	20,000	IEMEG	No
Antimony	0.21	0.21	0.21	1	5	4	RMEG	No
Arsenic	0.83	0.88	0.86	2	5	0.023	CREG	Yes
Barium	17.6	106	68	4	5	700	RMEG	No
Beryllium	0.06	0.06	0.06	2	5	20	CEMEG	No
Chromium	2.36	2.56	2.46	2	5	100	LTHA	No
Cobalt	0.36	0.96	0.8	4	5	100	IEMEG	No
Copper	1.83	3.16	2.5	2	5	300	IEMEG	No
Iron	565	1,160	765	4	5	10,950	RBC	No
Lead	0.48	1.06	0.77	2	5	0	MCLG	Yes
Manganese	39.4	292	170	4	5	500	RMEG	No
Nickel	1.87	2.73	2.3	2	5	100	LTHA	No
Selenium	2.04	2.04	2.04	1	5	50	CEMEG	No
Silver	0.105	0.14	0.12	2	5	50	RMEG	No
Vanadium	1.87	2.48	2.2	2	5	30	IEMEG	No
Zinc	3.93	12.4	8.2	2	5	3,000	CEMEG	No
Organics								
Butyl benzyl phthalate	15.8	15.8	15.8	1	5	2,000	RMEG	No
Di-n-butyl phthalate	11.7	31.4	21.5	2	9	1,000	RMEG	No
Toluene	5	5	5	1	5	200	IEMEG	No

Essential nutrients (calcium, magnesium, potassium, and sodium) are not included in the table.

CEMEG = chronic environmental medial evaluation guide for drinking water
CREG = cancer risk evaluation guide for drinking water
CV = comparison value
IEMEG = intermediate environmental medial evaluation guide for drinking water
LTHA = lifetime health advisory for drinking water
MCLG = maximum contaminant level goal for drinking water
ppb = parts per billion
RBC = risk-based concentration for tap water

Table 36. Estimated Exposure Doses for Chemicals in Scarboro Compared to Noncancer Screening Guidelines

Substance Name	*Maximum Concentration (ppm)*	*2nd Tier Screening Conc. (ppm)*	*Estimated Exposure Doses (mg/kg/day)*			*Acute Screening Guideline (mg/kg/day)*	*Source*	*Chronic Screening Guideline (mg/k/day)*	*Source*	*Does the estimated exposure dose exceed the noncancer screening guideline?*		
			pica	*child*	*adult*					*pica*	*child*	*adult*
Surface Soil												
Arsenic	6.39	6.03	4.6E-04	7.4E-05	3.4E-06	0.005	AMRL	0.0003	CMRL	No	No	No
gamma-Chlordane	2.8	3.01	2.0E-04	3.7E-05	1.7E-06	0.001	Acute MRL (chlordane)	0.0006	CMRL	No	No	No
Heptachlor epoxide	0.97	1.20	6.9E-05	1.5E-05	6.9E-07	0.008	Tox Profile*	0.000013	RfD	No	Yes	No
Iron	29,700	25,600	149 mg/day	3.1E-01	1.5E-02	10 mg/day	RDA	0.3	RfD	Yes	Yes	No
Sediment												
Arsenic	5.17	5.25	N/A	1.3E-06	2.5E-07	N/A	N/A	0.0003	CMRL	N/A	No	No
Iron	23,900	26,200	N/A	6.6E-03	1.2E-03	N/A	N/A	0.3	RfD	N/A	No	No
Surface Water												
Arsenic	0.88	0.0009	N/A	1.1E-06	2.1E-07	N/A	N/A	0.0003	CMRL	N/A	No	No
Lead	1,160	0.0012	N/A	1.5E-06	2.8E-07	N/A	N/A	0.02	Acute LOAEL	N/A	No	No

Soil doses were calculated using the following formulas:

pica dose = (maximum concentration*0.005 kg/day*52 days/year*3 years)/(10 kg*(365 days/year*3 years))

child dose = (second-tier screening concentration*0.0002 kg/day*291.2 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = (second-tier screening concentration*0.00005 kg/day*291.2 days/year*30 years)/(70 kg*(365 days/year*30 years))

Sediment doses were calculated using the following formulas:

child dose = (second-tier screening concentration*0.0001 kg/day*12 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = (second-tier screening concentration*0.0001 kg/day*12 days/year*30 years)/(70 kg*(365 days/year*30 years))

Surface water doses were calculated using the following formulas:

child dose = (second-tier screening concentration*0.5 L/day*12 days/year*6 years)/(13 kg*(365 days/year*6 years))

adult dose = (second-tier screening concentration*0. 5 L/day*12 days/year*30 years)/(70 kg*(365 days/year*30 years))

* The acute screening guideline was derived from limited acute toxicological data available in ATSDR's Toxicological Profile. A safety factor of 1,000 was applied. These acute screening guidelines should be considered unofficial and are for use in this health assessment only.

AMRL = acute minimal risk level
CMRL = chronic minimal risk level
LOAEL = lowest-observed-adverse-effect level
mg/kg/day = milligram per kilogram per day
N/A = not applicable
ppm = parts per million
RDA = Recommended Dietary Allowance
RfD = reference dose

Table 37. Estimated Exposure Doses for Chemicals in Scarboro Compared to Cancer Screening Guidelines

Substance	*2nd Tier Screening Concentration (ppm)*	*Estimated Lifetime Exposure Dose (mg/kg/day)*	*EPA's Oral Cancer Slope Factor (mg/kg/day)$^{-1}$*	*Risk*	*Does the estimated exposure dose exceed the cancer screening guideline (10^{-4})?*
Surface Soil					
Arsenic	6.03	1.5E-06	1.5	2.2E-06	No
gamma-Chlordane	3.01	7.4E-07	0.35	2.6E-07	No
Heptachlor epoxide	1.20	2.9E-07	9.1	2.7E-06	No
Iron	25,600	*Evaluated for noncarcinogenic effects (see* Table 36*)*			
Sediment					
Arsenic	5.25	1.1E-07	1.5	1.6E-07	No
Iron	26,200	*Evaluated for noncarcinogenic effects (see* Table 36*)*			
Surface Water					
Arsenic	0.0009	9.0E-08	1.5	1.3E-07	No
Lead	0.0012	*Evaluated for noncarcinogenic effects (see* Table 36*)*			

Soil doses were calculated using the following formula:

lifetime dose = (second-tier screening concentration*0.00005 kg/day*291.2 days/year*70 years)/(70 kg*(365 days/year*70 years))

Sediment doses were calculated using the following formula:

lifetime dose = (second-tier screening concentration*0.0001 kg/day*12 days/year*70 years)/(70 kg*(365 days/year*70 years))

Surface water doses were calculated using the following formula:

lifetime dose = (second-tier screening concentration*0.5 L/day*12 days/year*70 years)/(70 kg*(365 days/year*70 years))

Risk was calculated by multiplying the exposure dose by EPA's oral cancer slope factor.

mg/kg/day = milligram per kilogram per day

ppm = parts per million

Table 38. Chemicals Detected in Scarboro, Without Screening Guidelines

Substance Name	*Average Concentration (ppm)*	*Highest Dose (mg/kg/day)*	*Screening Guideline*	*Screening Guideline Source*	*Does the dose/concentration exceed the screening guideline?*
Soil					
Acetic acid	0.012	1.4E-07	40,000–80,000 ppm	Vinegar	No
alpha-Pinene	0.045	5.5E-07	37.5 mg/kg/day lowest NOAEL	EPA: Federal Register [FR Doc. 98-31063] (11/19/1998)	No
Benzene ethanamine	0.0088	1.1E-07	0.1 mg/kg/day	FDA – amphetamine pediatric dose of 10 mg/tablet	No
Cyclotetrasiloxane	0.043	5.3E-07	NJ value	Data QA/QC	No—presumptive evidence/estimated value
Sediment					
Acetic acid	0.011	2.7E-09	40,000–80,000 ppm	Vinegar	No
Cyclotetrasiloxane	0.027	6.9E-09	NJ value	Data QA/QC	No—presumptive evidence/estimated value
Dodacane	0.0074	1.9E-09	NJ value	Data QA/QC	No—presumptive evidence/estimated value

The average concentrations are rounded.
Highest doses were calculated using the following formula:

non-pica child dose = (average concentration*0.0002 kg/day*291.2 days/year*6 years)/(13 kg*(365 days/year*6 years))

child dose = (average concentration*0.0001 kg/day*12 days/year*6 years)/(13 kg*(365 days/year*6 years))
mg/kg/day = milligram per kilogram per day
ppm = parts per million

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