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Public Comment Draft

PUBLIC HEALTH ASSESSMENT
Evaluation of Y-12 Mercury Releases

U.S. Department of Energy, Oak Ridge Reservation
Oak Ridge, Anderson County, Tennessee
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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 United States Environmental Protection Agency, U.S.EPA, and the individual states regulate the investigation and clean up of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the U.S.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 environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. The public health assessment program allows the scientists 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. Nevertheless, the public health assessment process is not considered complete until the public health issues at the site are addressed.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by U.S.EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, 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 contacts may result in harmful effects. ATSDR recognizes that children, because of their play activities and their growing bodies, may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high risk groups within the community (such as the elderly, chronically ill, and people engaging in high risk 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 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. When this is so, the report will suggest what further public health actions are needed.

Conclusions: The report presents conclusions about the public health threat, if any, posed by a site. When health threats have been determined for high risk groups (such as children, elderly, chronically ill, and people engaging in high risk practices), they will be summarized in the conclusion section of the report. Ways to stop or reduce exposure will then be recommended in the public health action plan.

ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by U.S.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

ALS	amyotrophic lateral sclerosis
AOEC	Association of Occupational and Environmental Clinics
AT	averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
BMDL	benchmark dose lower limit
BW	body weight
C	concentration
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CEW	Clinton Engineer Works
Colex	column exchange
DGM	dissolved gaseous mercury
DOE	U.S. Department of Energy
ED	exposure duration
EF	exposure frequency
EFPC	East Fork Poplar Creek
Elex	electrical exchange
EMEG	environmental media evaluation guide
FACA	Federal Advisory Committee Act
FAMU	Florida Agricultural and Mechanical University
FDA	U.S. Food and Drug Administration
g/day	grams per day
g/kg/day	grams per kilogram per day
IR	ingestion rate
IRIS	Integrated Risk Information System
kg	kilogram
LOAEL	lowest-observed-adverse-effect level
LTHA	lifetime health advisory
LWBR	Lower Watts Bar Reservoir
m^3	cubic meter
MCLG	maximum contaminant level goal
µg/L	micrograms per liter
MGD	million gallons per day
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/kg/day	milligrams per kilogram per day
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
MRL	minimal risk level
MS	multiple sclerosis
NAS	National Academy of Sciences
NCEH	National Center for Environmental Health
NHANES	National Health and Nutrition Examination Survey
NIOSH	National Institute for Occupational Safety and Health
NOAEL	no-observed-adverse-effect level

NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
ORAU	Oak Ridge Associated Universities
Orex	organic exchange
OREIS	Oak Ridge Environmental Information System
ORHASP	Oak Ridge Health Agreement Steering Panel
ORR	Oak Ridge Reservation
ORRHES	Oak Ridge Reservation Health Effects Subcommittee
OU	operable unit
PCB	polychlorinated biphenyl
PHAWG	Public Health Assessment Work Group
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
RMEG	reference dose media evaluation guide
ROD	Record of Decision
RSL	regional screening level
TDEC	Tennessee Department of Environment and Conservation
TDOH	Tennessee Department of Health
TSCA	Toxic Substances Control Act
TVA	Tennessee Valley Authority
UEFPC	Upper East Fork Poplar Creek
U.S.EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic chemical
χ	chi

I. Summary

I.A. Background

Introduction

The Agency for Toxic Substances and Disease Registry (ATSDR) recognizes you want to know more about past and current exposures to mercury released from the Y-12 Plant at the Oak Ridge Reservation (ORR). We intend that this public health assessment will provide you with the information you need to protect your health.

Mercury in the environment

Mercury occurs naturally in the environment. It occurs in three main forms: elemental mercury, inorganic mercury, and organic mercury. How you are potentially harmed by mercury depends on the form to which you're exposed.

How you are exposed to mercury

The following table identifies the main exposure pathways for the three forms of mercury.

Mercury type	Exposure pathway
Elemental mercury	Breathing in air. About 80% of elemental mercury enters your bloodstream directly from your lungs, and then rapidly spreads to other parts of your body, including the brain and kidneys (ATSDR 1999). The primary health concerns are nervous system and kidney effects.
Inorganic mercury	Eating soil, sediment, surface water, or plants. Typically, less than 10% is absorbed through the stomach and intestines, but it has been reported that up to 40% can be absorbed (ATSDR 1999). Inorganic mercury enters the bloodstream and moves to many different tissues, but will mostly accumulate in the kidneys. The primary health concern is kidney effects.
Organic mercury (methylmercury)	Eating fish. Organic mercury is readily absorbed in the gastrointestinal tract (about 95% absorbed) and can easily enter the bloodstream (ATSDR 1999). It moves rapidly to various tissues and the brain. Developmental effects in children are the primary health concern.

ORR history

In 1942, the federal government established the ORR in Tennessee's Anderson and Roane Counties. ORR was part of the Manhattan Project to research, develop, and produce special nuclear materials for nuclear weapons. Over the years, ORR operations generated a variety of radioactive and nonradioactive wastes. These wastes were released into the environment. In 1989, the U.S. Environmental Protection Agency (U.S. EPA) added the ORR to the National Priorities List. The U.S. Department of Energy (DOE) is cleaning up the ORR under a Federal Facility Agreement with U.S.EPA and the Tennessee Department of Environment and Conservation (TDEC).

Tennessee Department of Health involvement

The Tennessee Department of Health (TDOH) conducted the Oak Ridge Health Studies (1991–1999) to evaluate whether off-site populations were exposed in the past. By contrast, ATSDR's activities since the 1990s have focused on current public health issues related to Superfund cleanup activities of contamination at the site.

1

ATSDR's involvement

ATSDR is the principal federal public health agency charged with evaluating human health effects of exposure to hazardous substances in the environment. Since 1992, ATSDR has responded to requests and addressed health concerns of community members, civic organizations, and other government agencies surrounding ORR.

ATSDR has worked to determine whether levels of environmental contamination at and near the ORR present a public health hazard to surrounding communities. ATSDR has identified and evaluated several public health issues and has worked closely with many parties.

Beginning in 2000, ATSDR scientists expanded on the TDOH efforts. ATSDR reviewed and analyzed TDOH's Phase I and Phase II screening-level evaluation of past exposure (1944 to 1990). ATSDR scientists completed public health assessments on uranium releases from the Y-12 plant (2004), radionuclide releases from White Oak Creek (2006), iodine 131 releases from the X-10 site (2008), ORR-wide polychlorinated biphenyl (PCB) releases (2009), uranium and fluoride releases from the K-25 site (2010), and other topics such as contaminant releases from the Toxic Substances Control Act (TSCA) incinerator (2005) and contaminated off-site groundwater (2006).

In 2007, ATSDR screened current (1990 to 2003) environmental data to identify any other chemicals that required further evaluation. In conducting its public health assessments, ATSDR scientists evaluated and analyzed the information and findings from previous studies and investigations. ATSDR's purpose was to assess the public health implications of past and current exposure.

2

Scope

This public health assessment documents ATSDR's past and current evaluation of mercury releases from the Y-12 plant. Because the Oak Ridge Health Studies evaluated past mercury exposures through 1990, exposures since 1990 are evaluated as "current exposures" in this public health assessment.

I.B. Conclusions for Past Mercury Exposure (1950–1990)

Past exposure to mercury from the air

ATSDR concludes

- In the past (1950–1963), elemental mercury carried from the Y-12 plant by workers into their homes could potentially have harmed their families (especially young children).
- People living in the Wolf Valley area were not harmed from breathing elemental mercury from the Y-12 plant.
- After 1963, the elemental mercury released to the air from the Y-12 plant and elemental mercury vapors released from the East Fork Poplar Creek (EFPC) water did not harm people living off site near the ORR.

ATSDR cannot conclude

- Whether people living off site in Oak Ridge, Scarboro, and along the EFPC floodplain, who in the past breathed elemental mercury released to the air from the Y-12 plant, could have been harmed from 1950 through 1963.
- Whether people living near the EFPC floodplain, who breathed elemental mercury vapors released from the EFPC water from 1950 through 1963, could have been harmed.

Past exposure to mercury from East Fork Poplar Creek (EFPC) surface water

ATSDR concludes

- Children who swallowed water while playing in EFPC for a short period (acute exposure: fewer than 2 weeks) during some weeks in 1956, 1957, and 1958 could potentially have experienced renal (kidney) effects from exposure to inorganic mercury.
- Adults who swallowed water from EFPC for a short time during some weeks in 1958 could also potentially have experienced renal effects.
- People who swallowed water from EFPC for a short time before 1953 or after the summer of 1958 were not harmed from exposure to inorganic mercury.
- People who swallowed water from EFPC over a longer period of time (intermediate and chronic exposures: more than 2 weeks) were not harmed from exposure to inorganic mercury.
- People who swallowed water from EFPC were not harmed from exposure to methylmercury.

ATSDR cannot conclude

- Whether people who swallowed water from EFPC for a short time during 1953, 1954, and 1955 could have been harmed from mercury. .

1

Past exposure to mercury from EFPC soil and sediment

ATSDR concludes

- Children, who played in the EFPC floodplain at the National Oceanic and Atmospheric Administration (NOAA) site and Bruner site before soil removal activities in 1996 and 1997, may have incidentally eaten inorganic mercury in soil that could potentially have caused renal effects. Adults are not expected to have been harmed from inorganic mercury in the soil.
- People who contacted EFPC floodplain soils in the past were not harmed from exposure to methylmercury.

2

Past exposure to mercury from EFPC fish

ATSDR concludes

- Periodically eating fish from EFPC (up to nine meals per year for adults and up to four meals per year for children) in the 1980s did not harm people's health from exposure to methylmercury, including children who ate fish, nursing infants whose mothers ate fish, and fetal exposure from mothers who ate fish.

  Eating nine fish meals per year is a worst case assumption for this non-productive fishing area.

  The estimated methylmercury exposure doses are below ATSDR's and U.S.EPA's health guidelines.

ATSDR cannot conclude

- Whether eating fish from EFPC during the 1950s, 1960s, and 1970s could have harmed people's health from exposure to methylmercury.

Note: Since the1980s there has been a fish consumption advisory due to mercury and PCB contaminated fish.

3

Past exposure to Mercury from Poplar Creek fish

ATSDR concludes

- Children born to or nursing from women who ate 12 fish meals per month (i.e., the maximum consumption rate) from Poplar Creek in the 1970s, 1980s, and 1990 have an increased risk of subtle neurodevelopmental effects from exposure to methylmercury.

  The estimated methylmercury exposure doses from eating Poplar Creek fish approach the methylmercury dose identified by the National Academy of Sciences (NAS) that result in a 5 percent increase in the incidence of abnormal scores on the Boston Naming Test in the Faroe Islands study. The NAS health effect level is consistent with the range identified as the methylmercury benchmark dose lower limit (BMDL05) by the U.S. EPA in the Faroe Islands study.

- Children who ate up to six meals a month (i.e., the maximum consumption rate) of Poplar Creek fish have an increased risk of subtle neurodevelopmental effects.

  The estimated methylmercury doses from eating Poplar Creek fish approach the NAS health effect level, which is associated with subtle neurodevelopmental effects.

- Children born to or nursing from women who ate approximately three meals a month (i.e., the average consumption rate) of Poplar Creek fish in the 1970s, 1980s, and 1990 have a small increased risk of subtle neurodevelopmental effects. Also, children who ate less than two meals a month (i.e., the average consumption rate) of Poplar Creek fish have a small increased risk of neurodevelopmental effects.

  Most of the estimated methylmercury doses for these women and children are below ATSDR's and U.S.EPA's health guidelines for methylmercury and the few doses that are slightly above these health guidelines are not approaching the NAS health effect level for methylmercury, which is associated with subtle neurodevelopmental effects.

ATSDR cannot conclude

- Whether eating fish from Poplar Creek during the 1950s and 1960s could have harmed people's health from methylmercury exposure.

Note: Since the1980s there has been is a fish consumption advisory due to PCB contaminated fish.

Past exposure to mercury from Clinch River fish

ATSDR concludes

- Children born to or nursing from women who ate 12 fish meals per month (three fish meals a week) (i.e., the maximum consumption rate) from the Clinch River in the 1970s, 1980s, and 1990 have a small increased risk of subtle neurodevelopmental effects.

  The estimated methylmercury exposure doses are only slightly above ATSDR's and U.S.EPA's health guidelines for methylmercury and not approaching the NAS health effect level, which is associated with subtle neurodevelopmental effects.

- Children who ate approximately six fish meals a month (i.e., the maximum consumption rate) from the Clinch River have a small increased risk of subtle neurodevelopmental effects.

  The estimated methylmercury exposure doses are only slightly above ATSDR's and U.S.EPA's health guidelines for methylmercury and not approaching the NAS health effect level, which is associated with subtle neurodevelopmental effects.

- Children born to or nursing from women who ate up to three Clinch River

fish meals per month (i.e., the average consumption rate) were not harmed from exposure to methylmercury.

The estimated exposure doses are below ATSDR's and U.S.EPA's health guidelines.

- Children who ate less than two Clinch River fish meals a month (i.e., the average consumption rate) are not at risk of harmful neurodevelopmental effects.

  The estimated exposure doses are below ATSDR's and U.S.EPA's health guidelines.

ATSDR cannot conclude

- Whether eating fish from Clinch River during the 1950s and 1960s could have harmed people's health.

Note: Since the1980s there has been is a fish consumption advisory due to PCB contaminated fish.

1

Past exposure to mercury from Watts Bar Reservoir fish

ATSDR concludes

- Children born to or nursing from women who ate 20 fish meals per month (i.e., the maximum consumption rate) (five fish meals a week) from Watts Bar Reservoir in the 1980s and 1990 have a small increased risk of subtle neurodevelopmental effects.

  The estimated exposure doses are only slightly above U.S.EPA's health guideline and not approaching the NAS health effect level, which is associated with subtle neurodevelopmental effects.

- Children who ate approximately 10 fish meals a month (i.e., the maximum consumption rate) from Watts Bar Reservoir have a small increased risk of subtle neurodevelopmental effects.

  The estimated exposure doses are only slightly above U.S.EPA's health guideline and not approaching the NAS health effect level, which is associated with subtle neurodevelopmental effects.

- Children born to or nursing from women who ate up to five Watts Bar Reservoir fish meals per month (i.e., the average consumption rate) were not harmed from exposure to methylmercury.

  The estimated exposure doses are below ATSDR's and U.S.EPA's health guidelines.

- Children who ate less than three Watts Bar Reservoir fish meals a month (i.e., the average consumption rate) are not at risk of harmful neurodevelopmental effects.

  The estimated exposure doses are below ATSDR's and U.S.EPA's health

guidelines.

ATSDR cannot conclude

- Whether eating fish from Watts Bar Reservoir during the 1950s, 1960s, and 1970s could have harmed people's health.

Note: Since the1980s there has been is a fish consumption advisory due to PCB contaminated fish.

1

Past exposure to mercury from edible plants

ATSDR concludes

- People who ate local produce grown in gardens in the EFPC floodplain or in private gardens that contained mercury-contaminated soils from the floodplain were not harmed from exposure to inorganic mercury.

I.C. Conclusions for Current Exposure (1990–2009)

Current exposure to mercury from EFPC air

ATSDR concludes

- People who breathe the air near the EFPC floodplain are not being harmed from exposure to mercury.

  The concentrations of mercury in all of the EFPC ambient air samples (collected near the areas with the highest level of contamination during the summer) were below the ATSDR comparison value for mercury in air.

Current exposure to mercury from LWBR Air

ATSDR concludes

- People who breathe the air near LWBR are not being harmed from exposure to mercury.

  Even though no Lower Watts Bar Reservoir (LWBR) ambient air samples have been analyzed for mercury concentrations, the occurrence of harmful health effects from exposure to mercury vapor from contaminated soil is not a concern for the LWBR. The mercury contamination accumulated in the sediments of the river channel and is now buried under cleaner sediment. Additionally, the near-shore sediment concentrations in the LWBR are much lower than those found in the EFPC floodplain.

Current exposure to mercury from EFPC Surface Water

ATSDR concludes

- Children who swallow surface water while playing in EFPC are not being harmed from exposure to inorganic mercury. However, there is a bacterial advisory warning people to avoid contact with the water.

  Only one EFPC surface water concentration of mercury was detected slightly above the U.S.EPA's comparison value for mercury. To assess the exposure further, ATSDR evaluated two scenarios: 1) a farm family member's exposure, and 2), a child's exposure if the avoid contact with water (bacterial advisory) warning signs are ignored. The calculated mercury exposure doses for both scenarios were below EPA's health guideline value for chronic exposure.

Current exposure to mercury from Oak Ridge surface water

ATSDR concludes

- People who incidentally swallow surface water from Oak Ridge are not being harmed from exposure to inorganic mercury.

  Only one concentration of mercury in Oak Ridge surface water was higher than U.S.EPA's comparison value. To evaluate the exposure further, ATSDR calculated exposure doses for adults and children using the

maximum concentration detected in Oak Ridge surface water. Both estimated doses were below U.S.EPA's health guideline value for chronic exposure.

1

Current exposure to mercury from Scarboro surface water

ATSDR concludes

- Children who swallow surface water while playing in ditches in Scarboro are not being harmed from exposure to inorganic mercury.

  Mercury has not been detected in any surface water samples collected from the Scarboro community.

2

Current exposure to mercury from LWBR surface water

ATSDR concludes

- People who incidentally swallow surface water from LWBR are not being harmed from exposure to inorganic mercury.

  All of the LWBR surface water samples were below U.S.EPA's comparison value for mercury.

3

Current exposure to mercury from EFPC soil

ATSDR concludes

- Children, who played in the EFPC floodplain at the NOAA and Bruner sites before soil removal activities in 1996 and 1997, may have incidentally eaten inorganic mercury in soil that could potentially have caused renal effects. Adults are not expected to have been harmed.
- People who come in contact with EFPC floodplain soil after cleanup activities are not being harmed from exposure to mercury.

  Floodplain soils with concentrations greater than 400 ppm of mercury were removed in 1996 and 1997. ATSDR evaluated exposure to floodplain soils with up to 400 ppm of mercury and determined that this clean-up level is safe.

Current exposure to mercury from Oak Ridge soil

ATSDR concludes

- People who come in contact with Oak Ridge soil are not being harmed from exposure to mercury.

  Some of the concentrations of mercury in Oak Ridge soil were higher than ATSDR's comparison value. To evaluate the exposure further, ATSDR calculated exposure doses for adults and children using the maximum concentration detected in Oak Ridge soil. Both estimated doses were well below health effect levels.

4

Current exposure to mercury from Scarboro soil

ATSDR concludes

- People who contact Scarboro soil are not being harmed from exposure to inorganic mercury.

  All of the surface soil samples collected in Scarboro were below ATSDR's comparison value.

1

Current exposure to mercury from LWBR soil

ATSDR concludes

- People who contact soil near the LWBR are not being harmed from exposure to inorganic mercury.

  No soil samples have been collected from the LWBR, but the occurrence of harmful health effects from exposure to mercury in soil along the LWBR shoreline is not a concern. ORR operations have not contaminated the soil near LWBR with mercury. The mercury that ORR released into EFPC was transported to the LWBR through Poplar Creek and the Clinch River. That mercury accumulated in the sediments of the LWBR deep river channel, but it was buried under cleaner sediment. Additionally, the near-shore sediment mercury concentrations in the LWBR were much lower than the comparison value for mercury in soil.

Current exposure to mercury from EFPC sediment

ATSDR concludes

- People who contact EFPC sediment are not being harmed from exposure to inorganic mercury.

  Some of the concentrations of mercury in EFPC sediment were higher than ATSDR's comparison value. Thus to assess the exposure further, ATSDR evaluated two scenarios: 1) a farm family member's exposure, and 2) a child's exposure if the avoid contact with water (bacterial advisory) warning signs are ignored. The calculated mercury exposure doses for both scenarios were below U.S.EPA's health guideline value for chronic exposure to inorganic mercury.

2

Current exposure to mercury from Oak Ridge sediment

ATSDR concludes

- People who contact Oak Ridge sediment are not being harmed from exposure to inorganic mercury.

  Some of the concentrations of mercury in Oak Ridge sediment were higher than ATSDR's comparison value. To evaluate the exposure further, ATSDR calculated exposure doses for adults and children using the maximum concentration detected in Oak Ridge sediment. Both the estimated doses were below U.S.EPA's health guideline value for chronic exposure to inorganic mercury.

1

Current exposure to mercury from Scarboro sediment

ATSDR concludes

- People who contact Scarboro sediment are not being harmed from exposure to inorganic mercury.

  The levels of mercury in all of the sediment samples collected in Scarboro were below ATSDR's comparison value for inorganic mercury.

Current exposure to mercury from LWBR sediment

ATSDR concludes

- People who contact LWBR sediment are not being harmed from exposure to inorganic mercury.

  All of the near-shore sediment samples and deep-water sediment samples collected from the LWBR were below ATSDR's comparison value. Still, a few concentrations of mercury in unspecified depth sediment samples were higher than the comparison value. To evaluate further the exposure to sediment, ATSDR calculated exposure doses for adults and children using the maximum concentration detected in LWBR sediment from unspecified depths. Both the estimated doses were below U.S.EPA's health guideline value for chronic exposure to inorganic mercury.

  To prevent unnecessary exposures to workers and the public, ATSDR cautions that the sediments should not be disturbed, removed, or disposed of without careful review by the interagency working group.

2

Current exposure to mercury from EFPC fish and shellfish

ATSDR concludes

- Children born to or nursing from women who ignore the posted warning signs and eat one EFPC fish a month are not at risk of being harmed from exposure to methylmercury. However, eating crayfish from the EFPC floodplain increases the risk of subtle neurodevelopmental effects.

  EFPC is not a productive fishing location, and a *fish consumption advisory* is in place. That anyone is actually eating fish from EFPC is unlikely.

  The estimated methylmercury exposure doses for eating fish are at or below ATSDR's and U.S.EPA's health guidelines. The estimated methylmercury exposure doses for eating crayfish are slightly above the health guidelines but do not approach the NAS health effect level, which is associated with subtle neurodevelopmental effects.

- Children who ignore the posted warning signs and eat one EFPC fish a month have a small increased risk of subtle neurodevelopmental effects. Eating crayfish increases that risk.

  The estimated methylmercury exposure doses for eating fish are slightly above U.S.EPA's health guideline but do not approach the NAS health effect level, which is associated with subtle neurodevelopmental effects.

The estimated methylmercury exposure doses for eating crayfish approach the NAS health effect level.

ATSDR recommends

- Children, pregnant women, and nursing mothers follow the fish consumption advisory for EFPC.

1

Current exposure to mercury from LWBR fish

ATSDR concludes

- Adults and children who eat one LWBR fish meal a month are not at risk of developing harmful effects.

  The estimated methylmercury exposure doses are below ATSDR's and U.S.EPA's health guidelines.

- Children who eat fish from LWBR once a week have a small increased risk of subtle neurodevelopmental effects.

  The estimated methylmercury exposure doses are slightly above ATSDR's and U.S.EPA's health guidelines but do not approach the NAS health effect level, which is associated with subtle neurodevelopmental effects.

People frequently fish in LWBR. But since 1987, fishing advisories have warned people to avoid or limit their consumption of fish due to PCB contamination in the reservoir. ATSDR evaluated three potential exposure scenarios: 1) adults and children eating one fish meal with the average concentration of mercury each month, 2) adults and children eating one fish meal with the average concentration of mercury each week, and 3) adults eating about two fish meals with the average concentration of mercury each week.

- Children born to or nursing from women who eat one or two LWBR fish meals a week have a small increased risk of subtle neurodevelopmental effects.

  Some of the estimated methylmercury exposure doses are slightly above U.S.EPA's health guideline but do not approach the NAS health effect level, which is associated with subtle neurodevelopmental effects.

- Adults and children who eat the edible portion of turtles from LWBR once or twice a week have a small increased risk of subtle neurodevelopmental effects.

  The estimated methylmercury exposure doses are slightly above U.S.EPA's health guideline but do not approach the NAS health effect level, which is associated with subtle neurodevelopmental effects.

ATSDR recommends

- Children, pregnant women, and nursing mothers follow the fish consumption advisory for LWBR.

2

Current

ATSDR concludes

exposure to mercury from EFPC Vegetables

- People who eat beets, kale, or tomatoes grown in the EFPC floodplain are not being harmed from exposure to inorganic mercury.

  Comparison values are not available for screening concentrations detected in edible plants. Thus ATSDR used average concentrations to calculate the estimated inorganic mercury exposure doses and evaluate exposure. ATSDR found that the health effect levels available in the toxicological and epidemiological literature are at least two orders of magnitude higher than the estimated doses for adults and children eating vegetables grown in EFPC gardens. Further, plants tend to store metals such as mercury in a form that is not readily bioavailable to humans.

1

Current exposure to mercury from Oak Ridge Vegetables

ATSDR concludes

- People who eat vegetables from Oak Ridge are not being harmed from exposure to inorganic mercury.

  Within the city of Oak Ridge only four vegetable samples from one garden were collected and analyzed for mercury. Mercury was not detected in any of the samples.

For more information

Call ATSDR toll-free at 1-800-CDC-INFO if you have questions or comments. Ask for information on the Oak Ridge Reservation site. Detailed information about the toxicology of mercury is also available in ATSDR's Toxicological Profile for Mercury at http://www.atsdr.cdc.gov/toxprofiles/tp46.html.

II. Background

II.A. Site Description

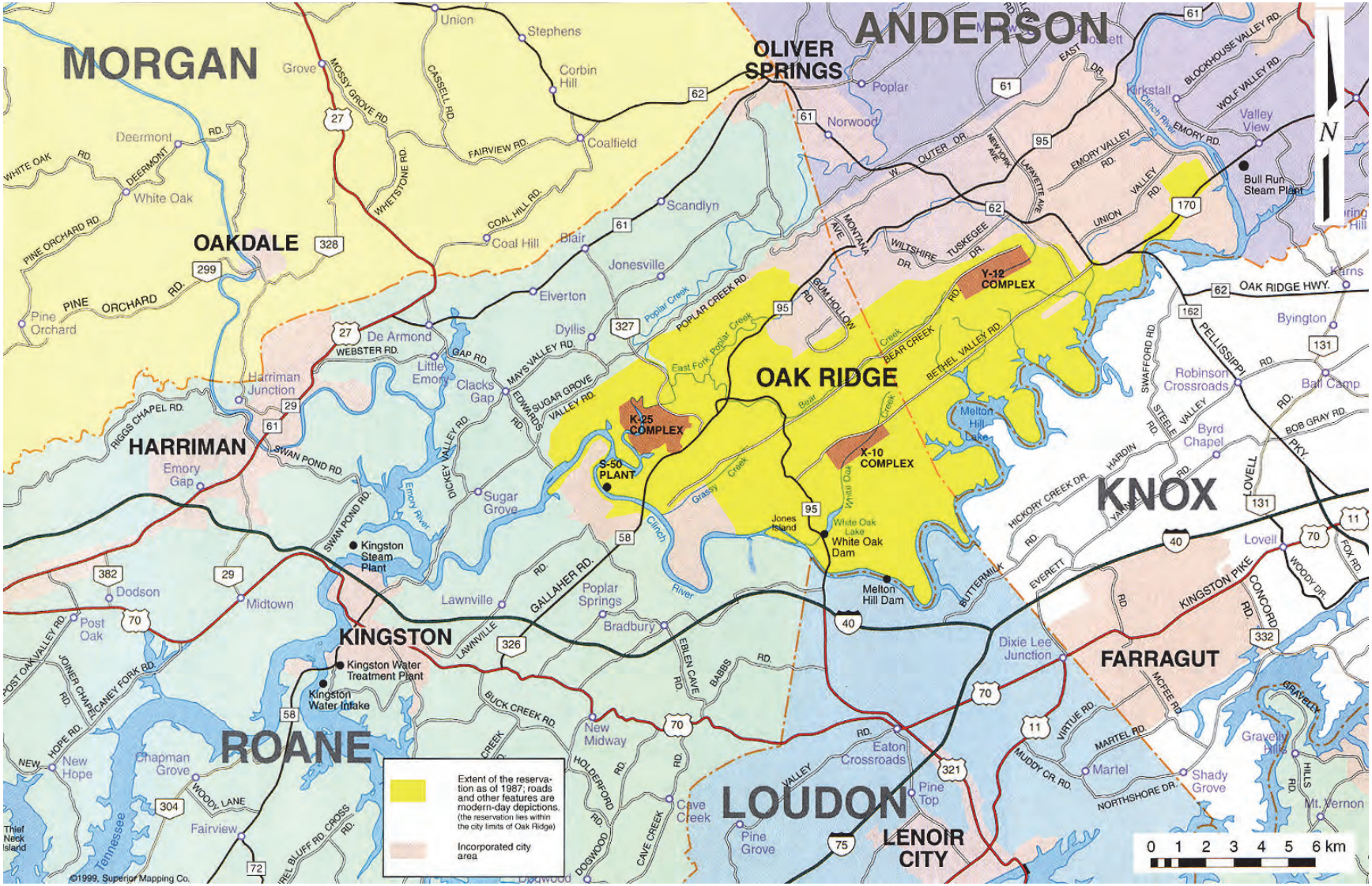
The Oak Ridge Reservation (ORR) is a U.S. Department of Energy (DOE) facility situated on more than 34,000 acres in Anderson and Roane Counties in eastern Tennessee (Figure 1). The Clinch River forms the southern and western boundaries of the ORR, and Poplar Creek and East Fork Poplar Creek (EFPC) drain the property to the north and west (DOE 1997). The ORR was originally part of the Clinton Engineer Works (CEW), which was established by the War Department in 1943[1] as part of the Manhattan Project. The mission of the CEW was 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 site, and the S-50 site to enrich uranium, and the X-10 site to demonstrate processes for producing and separating plutonium (TDOH 2000).

When the federal government established the CEW, the reservation consisted of 58,575 acres. After World War II, the federal government conveyed 24,340 of the original 58,575 acres to various parties, including the city of Oak Ridge and the Tennessee Valley Authority (TVA) (ORNL 2002). DOE continues to control the remaining 34,235 acres (Jacobs Engineering Group 1996; ORNL 2002). Most of the ORR property is within the Oak Ridge city limits (EUWG 1998).

The Y-12 plant is in the eastern end of Bear Creek Valley; it is bordered on the south by Chestnut Ridge and on the north by Bear Creek Road and Pine Ridge (ChemRisk 1999a). The 825-acre Y-12 plant is within the present-day corporate limits of the city of Oak Ridge, about 2 miles south of downtown (ChemRisk 1999a). It is less than a half-mile from the Scarboro community. But Pine Ridge, which rises to about 300 feet above the valley floor, separates the Y-12 plant from the main residential areas of Oak Ridge and hinders the exchange of air between the city and the Y-12 plant (U.S. Weather Bureau 1953). The main Y-12 production area is about 0.6 miles wide and 3.2 miles long and contains roughly 240 principal buildings (ChemRisk 1999b).

[1] The Tennessee project was originally called the Kingston Demolition Range. Land was acquired, trees were cleared, and construction began in the fall of 1942. The name Clinton Engineer Works was officially adopted in early 1943.

Figure 1. Location of the Oak Ridge Reservation



Source: ChemRisk 1999a (with modifications)

II.B. Operational History

The first buildings at the Y-12 plant[2] were built in 1943. They were part of the Manhattan Project's production-scale separation of uranium isotopes for use in the first atomic bomb. In 1950, research and pilot operations began at Y-12 to identify a viable process for large-scale production of enriched lithium for use in hydrogen bombs (ChemRisk 1999a). In 1952, the facilities were converted to fabricate nuclear weapon components (ChemRisk 1999a). 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 dismantling and storage of strategic nuclear materials from retired nuclear weapons systems. In October 2000, oversight of the Y-12 plant passed from the DOE Oak Ridge Operations to the DOE National Nuclear Security Administration. The National Nuclear Security Administration currently uses the Y-12 National Security Complex as the primary storage site for highly enriched uranium. See Figure 2 for a time line of the major processes at the Y-12 plant.

In the early 1950s, the Y-12 plant began separating high-purity lithium 6 from natural lithium to produce enriched lithium 6 deuteride for thermonuclear weapons (i.e., hydrogen bombs) (UCCND 1983a, 1983b). During pilot scale tests conducted between 1950 and 1955, alternate systems to separate lithium isotopes were investigated at Y-12, including Orex (organic exchange), Elex (electrical exchange), and Colex (column exchange) (ChemRisk 1999a). Colex was determined to be the most efficient process for enriching lithium (DOE 1993b). Two of these processes (Elex and Colex) were used in full-scale production, and both processes used large quantities of mercury (ChemRisk 1999a). The Colex process used large quantities of mercury as an extraction solvent (ChemRisk 1999a). Production-level lithium isotopic separation using the Elex process began in August 1953 and ended in 1957. Production using the Colex process began in January 1955 and ended in May 1963.

During the Colex process, lithium isotopes were separated by transferring them between a water-based solution of lithium hydroxide and a solution of lithium in mercury.

These dates are important for assessing mercury releases from the ORR. By far, the highest off-site releases of mercury occurred during these production years. Pilot project investigations resulted in mercury releases to the soil, air, and water before actual production. But those releases were minor—the quantities of materials used were relatively small. And Y-12 mercury releases after 1963 (after the Colex process shut down) came from secondary sources such as mercury spills in buildings and onto soils, mercury rebottling operations, and stripping operations, that is, clean up, tear down, and removal of production equipment. Overall, with the exception of the production years, Y-12 plant post-production activities were only responsible for relatively small mercury releases.

[2] Because this public health assessment focuses on exposure to mercury released from the Y-12 plant, the other main facilities on ORR are not discussed in detail.

Throughout the 1950s and 1960s, six pilot plants, three production facilities, and several auxiliary support facilities used about 24 million pounds of mercury during lithium separation processes (DOE 1993b). Most of the mercury losses to the environment occurred from 1955 to 1962 during the Colex production scale operations (ChemRisk 1999a). Mercury was also used in small quantities in several other operations at the Y-12 plant, at the X-10 site, and at the K-25 site. Still, Task 2[3] found either 1) no evidence that mercury was released from those activities or 2) if it was, that the releases were insignificant—in fact, they were less than 1 percent of the releases from the lithium isotope separation processes at Y-12 (ChemRisk 1999a). In any event, production of enriched lithium stopped in 1962 (Richmond and Auerbach 1983).

Three major efforts have estimated Y-12 mercury releases to water and air:

- In 1977, Y-12 personnel prepared a classified report called the 1977 Mercury Inventory Report.
- In the early 1980s, the Mercury Task Force investigated what was known about mercury use and releases at the Y-12 plant.
- In the 1990s, the Task 2 team revised the previous estimates of mercury releases.

In total, about 73,000 pounds of mercury was released to the air, primarily through building ventilation systems. These ventilation systems were installed in the lithium enrichment facilities to lower the amount of mercury inhaled by the workers (ChemRisk 1999a), and about 280,000 pounds of mercury (or about 12 cubic yards) was also released to EFPC, largely from an early process in which mercury was washed with nitric acid (ChemRisk 1999a).

[3] Task 2 of the Reports of the Oak Ridge Dose Reconstruction, *Mercury Releases from Lithium Enrichment at the Oak Ridge Y-12 Plant—a Reconstruction of Historical Releases and Off-Site Doses and Health Risks* (ChemRisk 1999a) (referred to as the "Task 2 report") describes in greater detail the history of the lithium isotope separation process at the Y-12 plant.

Y-12 Plant Time Line

MAJOR PROCESSES

- Electromagnetic Separation of U-235, 1943-48
- Uranium Chemical Processing and Parts Manufacturing, 1943-present
- Disposal in Boneyard/Burnyard, 1944-72
- Electromagnetic Separation of Stable Isotopes, 1947-90
- ELEX & COLEX Separarting Process for Lithium Isotopes (Using Mercury), 1950-63
- Production of Thorium Weapon Components, 1950-75
- Production of Lithium and Beryllium Weapon Components, 1950-present
- Waste Disposal in S-3 Ponds, 1951-82
- Disposal in Bear Creek Burial Ground, 1954-92
- Waste Disposal in New Hope Pond, 1963-88

ORR ENVIRONMENTAL MONITORING DATA

Surface Water

- 1947-48, Radioactivity, Flourine, Uranium in Clinch River, Poplar Creek
- 1950-present, Radioactivity, Mercury in EFPC, Bear Creek
- 1955-57, Mercury, Manganese in Clinch River, Poplar Creek, EFPC
- 1959-present, Radionuclides, Metals in Clinch River
- 1960-64, Radionuclides, Chemicals in Clinch River, Poplar Creek
- 1971-present, Uranium, Radionuclides, Metals in EFPC, Poplar Creek, Bear Creek
- 1971-90, PCBs in Bear Creek
- 1983, Organics, Priority Pollutants in Bear Creek
- 1983, VOCs, PCBs, Metals in Bear Creek
- 1984, Metals, VOCs, Radioactivity, Radionuclides in Clinch River, EFPC
- 1984-86, Mercury, Organics, in Bear Creek
- 1985, Herbicides, Pesticides, PCBs in Bear Creek
- 1986, Cs-137 in Watts Bar Reservoir
- 1989-90, Metals, Organics, Radionuclides, PCBs, SVOCs, Pesticides, Tritium in Clinch River, Poplar Creek
- 1990, Metals, Organics, Radionuclides, in Melton Hill, Norris, and Watts Bar Reservoir
- 1993, EFPC Remedial Investigation
- 1995-96, Clinch River/Watts Bar Remedial Investigations
- 1998, Radionuclides, metals, organics in Scarboro
- 2001, Radionuclides, metals, VOCs, SVOCs, pesticides, & PCBs in Scarboro

Biota

- 1948-49, Radioactivity Radionuclides in Clinch River Fish
- 1961-present, I-131 and SR-90 in Cows' Milk within 50 miles of ORR
- 1967-present, Mercury, PCBs, Radionuclides, in Clinch River Fish
- 1970-82, Mercury in EFPC, Bear Creek Fish
- 1974-77, Mercury in Clinch River and Poplar Creek Fish
- 1977, Metals, PCBs in Clinch River and Poplar Creek Fish
- 1977-present, Radionuclides in ORR Deer
- 1977-present, Radionuclides in Grass from ORR Perimeter and Remote Stations
- 1979, Metals in Melton Hill Reservoir and Clinch River Fish
- 1982, Mercury in Pasture Grass in EFPC Drainage
- 1982, Mercury in Cow and Horse Grazing on EFPC Floodplain
- 1983, Mercury in EFPC and Bear Creek Frogs and Crayfish
- 1983-87, Mercury in Native Vegetation and Garden Vegetables on EFPC Floodplain
- 1984, Mercury in EFPC and Poplar Creek Turtles
- 1984, Metals, PCBs, Radionuclides in Melton Hill Reservoir, EFPC, Bear Creek, and Clinch River Fish, Frogs, Turtles, and Crayfish
- 1985-present, Metals and Organics in EFPC Fish
- mid-80's, Metals in Deer from the EFPC Floodplain
- 1986, Mercury, PCBs in EFPC Fish
- 1986-89, Metals, Pesticides, PCBs, in Melton Hill and Watts Bar Reservoir Fish
- 1987-present, Radioactivity in Geese
- 1989, Metals, PCBs, Pesticides, SVOCs, Radionuclides in Clinch and Tennessee River Fish
- 1993, EFPC Remedial Investigation
- 1995-96, Clinch River/Watts Bar Remedial Investigations

Sediment

- 1951-66, 77, Radionuclides in Clinch River and Tennessee River
- 1960-64, Organics and Radioactivity in Clinch and Tennessee River
- 1970, Mercury in Melton Hill Reservoir, EFPC, Bear Creek
- 1972, Mercury in EFPC, Bear Creek
- 1973-74, 79, PCBs in Clinch River, EFPC, Poplar Creek
- 1973-82, Metals and PCBs in Melton Hill Reservoir
- 1974-75, Mercury in EFPC
- 1975-present, Metals in Clinch River, EFPC
- 1981-82, Metals in Bear Creek and EFPC
- 1984-86, Metals, Organics, and Radionuclides in Bear Creek
- 1985, Herbicides, Pesticides, and PCBs in Bear Creek
- 1985, Metals, PCBs, Organics, and Radionuclides in Clinch River, Poplar Creek, EFPC, Bear Creek
- 1986, Cs-137 in Watts Bar Reservoir
- 1989-90, Metals, VOCs, SVOCs, PCBs, Pesticides, Tritium, Radionuclides in Clinch River, Poplar Creek
- 1990, Metals, Organics, Radionuclides in Melton Hill, Norris, and Watts Bar Reservoir
- 1993, EFPC Remedial Investigation
- 1995-96, Clinch River/Watts Bar Remedial Investigations
- 1998, Radionuclides, metals, organics in Scarboro
- 2001, Radionuclides, metals, VOCs, SVOCs, pesticides, & PCBs in Scarboro

Soil

- 1949-present, External Gamma Radiation Measurements
- 1959-1968, Routine Aerial Background Surveys
- 1971-present, Radionuclides in Soil at Perimeter and Remote Monitoring Stations
- 1973-74, 1980, 1986, 1989, and 1992, Airborne Gamma Radiation Surveys
- 1978-79, Technetium-99 in Soils near K-25
- 1983-87, Metals, PCBs, and Radionuclides in EFPC Floodplain Soils
- 1984, Radiation Survey of the Oak Ridge Sewer Beltway
- 1989-90, Surface Radiation Exposures to Hunters on ORR
- 1993, EFPC Remedial Investigation
- 1998, Radionuclides, metals, organics in Scarboro
- 2001, Radionuclides, metals, VOCs, SVOCs, pesticides, & PCBs in Scarboro

Air

- 1955-present, Particle Number, Fallout Particle Number, Beta Radioactivity, Beta Radioactivity in Rainwater, Uranium, Nickel, Lead, Chromium, Particulates (nickel, lead, chromium no longer sampled)
- 1963-present, I-131
- 1975-present, Particulate Gamma Emitters, SR-90, uranium, thorium
- 1986-present, Mercury
- 1990-present, Uranium Particulates, Flourides, Particulates
- 1993, EFPC Remedial Investigation

Drinking Water

- 1959-present, Radionuclides in Water from Clinch River Water Intakes
- 1981, 83, Radionuclides, Metals in Residential Well Water
- 1985, Radioactivity in Residential Well Water
- 1986, Radioactivity, Radionuclides, Inorganics in Residential Well Water
- 1986, 89-present, Metals, Organics, Radionuclides in Residential Drinking Water

PUBLIC HEALTH ACTIVITIES AT THE ORR

- 1942-93, Oak Ridge Health Studies Phase 1 Report—Dose Reconstruction Feasibility Study (10/93)
- 1942-90, PCBs, Phase II of Oak Ridge Health Studies Dose Reconstruction Reports (7/99)
- 1944-90, Uranium, Phase II of Oak Ridge Health Studies Dose Reconstruction Reports (7/99)
- 1944-56, White Oak Creek Releases, Phase II of Oak Ridge Health Studies Dose Reconstruction Reports (7/99)
- 1944-56, Iodine 131, Phase II of Oak Ridge Health Studies Dose Reconstruction Reports (7/99)
- 1950-63, Mercury, Phase II of Oak Ridge Health Studies Dose Reconstruction Reports (7/99)
- 1959, 1973, 1980, 1989, 1992, 1997, Aerial Radiological Surveys of the Scarboro Community (1998)
- 1980-92, Health Statistics Review of Mortality Rates (1994)
- 1984, Pilot Survey of Mercury Levels in Oak Ridge (10/85)
- 1985-95, Health Consultation on Lower Watts Bar Reservoir (2/96)
- 1988-90, Health Statistics Review to Address Oak Ridge Physician's Concerns (10/19/92)
- 1990-92, Health Consultation on Y-12 Weapons Plant Chemical Releases into East Fork Poplar Creek (3/93)
- 1992, Review of Clinical Information on Persons Living in or near Oak Ridge, Tennessee (9/92)
- 1995, Health Consultation on Proposed Mercury Clean-Up Levels (1/96)
- 1997, Watts Bar Reservoir Exposure Investigation (3/98)
- 1998, Scarboro Community Health Investigation (7/00)

1944 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

II.C. Remedial and Regulatory History

Over the years, ORR operations released a variety of radioactive and nonradioactive wastes. In 1989, U.S.EPA added ORR to the National Priorities List (NPL) (EPA 2002b). DOE is conducting clean-up activities at the ORR under the Comprehensive Environmental Response, Compensation, and Liability Act[4] and under a Federal Facility Agreement, an Interagency Agreement with the U.S. Environmental Protection Agency (U.S.EPA) and the Tennessee Department of Environment and Conservation (TDEC). U.S.EPA and TDEC, along with the public, help DOE with the details for remedial actions at the ORR. DOE integrates required measures from the Corrective Action sections of the Resource Conservation and Recovery Act (RCRA) with response actions under CERCLA. See Figure 2 for a time line of surface water, biota, sediment, soil, air, and drinking water environmental monitoring data related to activities at the Y-12 plant.

This ORR Federal Facility Agreement was implemented on January 1, 1992. It 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/facts/or/ffa.pdf.

But contaminants remain in old ORR waste sites. These sites occupy 5 to 10 percent of the ORR's total area. Abundant rainfall (annual average of 55 inches) and high water tables (for example, 0 to 20 feet below the surface) contribute to leaching of these contaminants, resulting in contaminated surface water, sediment, groundwater, and biota (EUWG 1998). Since 1986 (when initial clean-up activities commenced), DOE has initiated approximately 50 response actions under the Federal Facility Agreement. These actions address contamination and disposal issues on the reservation. The following remedial actions pertain to the Y-12 plant specifically (SAIC 2007):

Upper East Fork Poplar Creek is located entirely on the site. It originates from a spring beneath the Y-12 plant and is initially confined to a human-dug channel and flows through the Y-12 plant along Bear Creek Valley. Contaminants released to the storm drain system commingle and contribute to the surface water contamination. The principal contaminants detected in the surface water are mercury and uranium. The principal contaminants in the sediment are mercury, uranium, and PCBs.

The Upper EFPC Remedial Investigation (RI) report provides a comprehensive overview of historical investigations of mercury fate and transport at the Y-12 plant. Residual mercury remains in soils and storm sewers at Y-12, as well as in Upper EFPC sediments and bank soils. How much residual mercury remains is currently unknown, but the flux of mercury from these various sources is highly variable and dependent on a number of factors (SAIC 2007). Station 17, where Upper EFPC flows into Lower EFPC, has and will continue to monitor Y-12 plant mercury releases. Mercury concentrations at Station 17 have decreased since 1995 (see Figure 3; Bechtel Jacobs 2010; SAIC 2004, 2007).

U.S.EPA, TDEC, and DOE negotiated a Record of Decision (ROD) that selected a number of different source control remedies to control the influx of mercury from the Y-12 plant into Upper EFPC. Major actions include

- The hydraulic isolation of contaminated soils in the West End Mercury Area.

[4] CERCLA, also known as Superfund

- The treatment of the discharge of groundwater into Upper EFPC at Outfall 51.
- The removal of contaminated sediments from storm sewers, Upper EFPC, and Lake Reality.
- Land use controls to prevent consumption of fish from Upper EFPC and to monitor access by workers and the public.
- Surface water monitoring.

The goal is to restore surface water in Upper EFPC to human health recreational risk-based values where Upper EFPC flows into Lower EFPC (DOE 2002; EPA 2002a). Future planned CERCLA actions are expected to achieve the 200 parts per trillion (ppt) performance goal for mercury in surface water at Station 17 (SAIC 2007).

In 2006, a comprehensive Five-Year Review was performed to evaluate baseline conditions in advance of fully implementing the remedy outlined in the Upper EFPC Phase I ROD. The remedy is expected to be protective of human health and the environment upon completion. Until, however, further information is obtained, a human-health protective determination cannot be made (SAIC 2007).

Lower East Fork Poplar Creek flows north from the Y-12 plant off site through a gap in Pine Ridge and into the City of Oak Ridge. Lower EFPC flows through residential and business sections of Oak Ridge to join Poplar Creek, which flows to the Clinch River. Starting in the early 1950s, Lower EFPC was contaminated by releases of mercury and other contaminants.

Lower EFPC RI/FS Conclusions

Mercury was identified as the primary contaminant in floodplain soils, and incidental soil ingestion was identified as the principal exposure route.

No excessive risk associated with mercury in surface water was found. The mercury concentrations were less than drinking water standards, except on occasion near the Y-12 plant.

Shallow groundwater was not being used and is not expected to be used in the future as a drinking water source.

Such limited exposure to contaminated stream channel sediment reduced the human health risk to acceptable levels.

SAIC 2007

The Remedial Investigation/Feasibility Study (RI/FS) for Lower EFPC was completed in 1994. Mercury was identified as the primary contaminant of concern in the floodplain soils (SAIC). The ROD was approved in September 1995, and remediation field activities began in June 1996 (ATSDR et al. 2000). The Remedial Investigation and Proposed Plan (DOE 2001; SAIC 2004) ultimately led to the decision to

- Excavate those floodplain soils with mercury levels higher than 400 parts per million (ppm),
- Dispose of contaminated soils in the Y-12 industrial landfill v (subtitle d landfill),
- Perform confirmatory sampling to ensure that all mercury above this level had been removed, backfill the excavated areas with clean borrow soil and vegetating appropriately, and
- Monitor periodically to ensure the remediation's effectiveness.

The clean-up level of 400 ppm was based on "open" land use; it protects the most sensitive human receptor (children) via inadvertent soil ingestions and dermal contact, and considers the specific form of mercury (mercuric sulfide) present in the EFPC floodplain soil (SAIC 2007). The Agency for Toxic Substances and Disease Registry (ATSDR) evaluated the public health impacts of the 400 ppm clean-up level and concluded that it was protective of public health (ATSDR 1996a):

The excavation of floodplain soils with greater than 400 ppm of mercury was conducted in two phases. From July 8 to September 14, 1996 (Phase I), 4,250 loose cubic meters (m^3) of mercury-contaminated soils were removed from the floodplain near the National Oceanic and Atmospheric Administration (NOAA) Atmospheric Diffusion Laboratory off Illinois Avenue. From March 3 to October 24, 1997 (Phase II), an additional 29,970 loose m^3 of mercury-contaminated soils were removed from the floodplain near the NOAA site and across the Oak Ridge Turnpike from the Bruner's Shopping Center on the Wayne Clark Property (SAIC 1993, 2002a). Confirmatory samples were taken during both phases of the excavation to ensure that the remediated areas were statistically below the clean-up standard (SAIC 1998). Post remediation monitoring (mercury input, stream stability, and fish sampling) was conducted to ensure the excavation's effectiveness (SAIC 2002a).

In 2006, a comprehensive Five Year Review evaluated the protectiveness of the Lower EFPC ROD. The remedy implemented for the Lower EFPC floodplain soil, groundwater, and floodplain remains protective of human health and the environment. A second ROD, the EFPC Surface Water and Creek Bed Sediment ROD, is planned for the future and will investigate media the current ROD did not address (SAIC 2007).

As part of the 2006 Five Year Review, DOE reviewed land use changes along the EFPC floodplain and the exposure factors used in the baseline risk assessment. The evaluation of land use indicated residential use of land adjacent to the Lower EFPC floodplain increased significantly in three locations and was consistent with the future land use projected in the 1994 RI/FS. The only exception was commercial development of the Community Reuse Organization of East Tennessee's (CROET) reindustrialization of the ETTP Parcel ED-1, the Horizon Center. The key exposure factors were the mercuric sulfide bioavailability factor used to develop the 400-ppm clean level and the soil-to-vegetable biotransfer factors used to evaluate the vegetable ingestion pathway. A search of the most current literature revealed no information that might alter the original factors used or that might question the protectiveness of the 400-ppm mercury level in floodplain soil (SAIC 2007).

The review concluded the following potential changes in human health exposure and toxicity information:

- Because mercuric sulfide is stable in soil and has a low potential for biotransfer to plants, the pathway has a lower risk than that calculated in the original baseline risk assessment.
- Dermal exposure to mercuric sulfide has the same risks as those calculated in the original baseline risk assessment.
- Consumption of produce with mercury has the same risks as those calculated in the original baseline risk assessment.

Changes in the Lower EFPC stream channel and floodplain were surveyed annually to evaluate whether erosion of potentially mercury-bearing sediments was occurring and to identify areas where sediment was being deposited in the channel and floodplain. The data indicated little change in erosion, and deposition of mercury above the cleanup level was not occurring (SAIC 2007). Therefore, the floodplain survey was discontinued in 2004.

Since the mid-1980s, mercury concentrations in fish have been increasing at two Lower EFPC locations (SAIC 2007). This raised concerns about the assumptions regarding the importance of upstream industrial sources of mercury relative to floodplain or in-stream sediment sources

(Bechtel Jacobs 2010). Southworth et al. (2010) investigated the sources of mercury to EFPC downstream from the Y-12 plant. They concluded that floodplain sources of mercury have the *potential* to continue contaminating EFPC even if headwater sources are removed, although more investigation is needed (Southworth et al. 2010). The upstream source continues to provide sufficient mercury to account for the concentrations in fish, and will confound the ability to determine the role of floodplain soils and stream sediments as sources until it is substantially reduced (SAIC 2007).

Lower Watts Bar Reservoir (LWBR) stretches from the confluence of the Tennessee River and the Clinch River downstream to the Watts Bar Dam. All surface water and sediment released from the ORR enter the LWBR (DOE 2001; DOE 2003; SAIC 2004). In 1995, a RI/FS revealed that discharges of radioactive, inorganic, and organic pollutants from the ORR contributed to biota, water, and sediment contamination in the LWBR. In September 1995, a ROD identified the following contaminants of concern: 1) mercury, arsenic, PCBs, chlordane, and aldrin in fish; 2) mercury, chromium, zinc, and cadmium in dredged sediments and sediments used for growing food products; and 3) manganese through ingestion of surface water (ATSDR et al. 2000; DOE 2001, 2003; SAIC 2004).

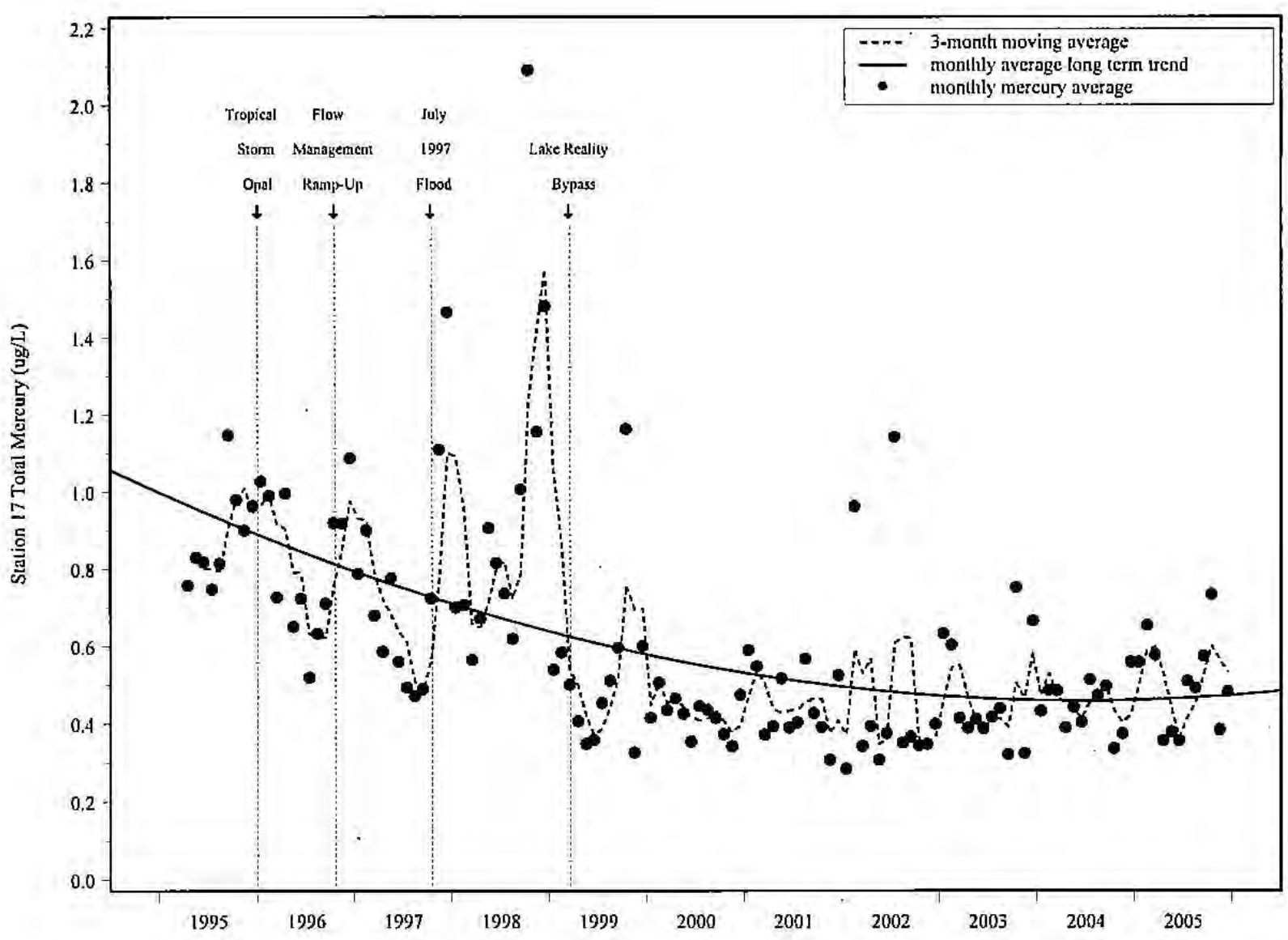
The main source of additional mercury in LWBR is related to current and historical sources from EFPC and the Y-12 plant. But as distances from the EFPC increase, mercury concentrations in fish decrease. As such, mercury concentrations in fish caught in LWBR are 5–10 times lower than fish caught in EFPC (SAIC 2004).

The main threat to public health from the LWBR is related to the consumption of PCB-contaminated fish (ATSDR 1996b, 2009; DOE 2001, 2003; SAIC 2004). The remedial activities selected for the LWBR have included using preexisting institutional controls (e.g., warning signs) to decrease contact with contaminated sediment, fish consumption advisories printed in the *Tennessee Fish Regulations*, and yearly monitoring of biota, sediment, and surface water (ATSDR et al. 2000; DOE 1995c, 2001, 2003; EPA 2002a; SAIC 2004).

In 2006, a comprehensive Five-Year Review evaluated the protectiveness of the LWBR ROD. The Review found that remedies in place under the LWBR ROD for the sediment and surface water remained protective of human health and the environment. Contaminant releases from upstream sources were reduced, which assures continued protection. Also, well-maintained, ROD-required institutional controls remain in place (SAIC 2007).

Further detailed information on remedial and regulatory information at the ORR can be found in *Oak Ridge Health Studies Phase 1 Report: Volume II – Part A – Dose Reconstruction Feasibility Study, Tasks 1 & 2, A Summary of Historical Activities on the Oak Ridge Reservation with Emphasis on Information Concerning Off-Site Emission of Hazardous Material* (ChemRisk 1993a); the *2004 Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Reservation* (SAIC 2004), and *Oak Ridge Reservation Annual Site Reports*. A summary of selected remedies, monitoring, and stewardship requirements for Upper EFPC, Lower EFPC, Bear Creek Valley, and LWBR is provided in Table 1.

Figure 3. Mercury Concentrations at the Confluence of Upper EFPC and Lower EFPC



Source: SAIC 2007

1 **Table 1. Summary of Selected Remedies, Monitoring, and Stewardship Requirements**

Site		*Selected Remedy*	*Monitoring*	*Stewardship Requirements*
Upper EFPC	Mercury Tanks	▪ Removal of mercury-containing sediment and water from three tanks ▪ Two tanks abandoned in place ▪ One tank returned to service	None required	None required
	Plating Shop Container Areas	No further action	None specified	None specified
	Abandoned Nitric Acid Pipeline	No further action	None specified	None specified
	Building 9201-4	Removal of contaminated piping	None specified	None specified
	UEFPC Union Valley	Institutional controls related to groundwater use	None specified	▪ Annual property owner notification ▪ Title searches ▪ License agreements ▪ Water use surveys ▪ Notification to well drillers
	YS-860 Firing Ranges	Excavation, treatment, and disposal of lead-contaminated soil	None specified	None specified
	Y-12 Plant 9822 Sediment Basin and Building 81-10	▪ Removal of contaminated liquid and sediment ▪ Demolition and filling of basin and sump	None specified	None specified
	Y-12 Plant East End VOC Plume	▪ Extract contaminated groundwater from GW-845 ▪ Treat water to reduce VOC concentrations ▪ Discharge treated groundwater into UEFPC upstream of Station 17	▪ Groundwater well sampling ▪ Sampling of effluent from the treatment system	Maintain existing institutional controls such as license agreements with affected property owners to restrict groundwater use

Site		Selected Remedy	Monitoring	Stewardship Requirements
	UEFPC Watershed	▪ Hydraulic isolation ▪ Sediment removal ▪ Treatment of discharges ▪ Land use controls ▪ Surface water monitoring	▪ Surface water sampling ▪ Biota sampling	▪ Property record restrictions, notices ▪ Zoning notices for the western Y-12 area ▪ Continuation of Y-12 access controls, signage, and security patrols ▪ Maintenance of treatment facilities per operating specifications ▪ Continuation of excavation/penetration permit program
Lower EFPC		▪ Excavation of identified floodplain soils containing greater than 400 ppm mercury ▪ Confirmatory sampling ▪ Backfilling and revegetation ▪ Monitoring ▪ Fish bioaccumulation survey ▪ Institutional controls (if needed)	▪ Surface water sampling ▪ Land use survey ▪ Stream channel survey	DOE will monitor to detect any future residential use of shallow groundwater and, if found, to mitigate any risk associated with such use.
LWBR		▪ Institutional controls ▪ Fish consumption advisories ▪ Annual monitoring	▪ Surface water sampling ▪ Sediment sampling ▪ Fish sampling	▪ Maintain existing institutional controls to control potential sediment-disturbing activities ▪ Fish consumption advisories ▪ Participation in the Interagency Working Group

Source: SAIC 2004, 2007
DARA: Disposal Area Remedial Action
EFPC: East Fork Poplar Creek
LWBR: Lower Watts Bar Reservoir
RCRA: Resource Conservation and Recovery Act
UEFPC: Upper East Fork Poplar Creek
VOC: volatile organic chemical

II.D. Site Geology/Hydrogeology

The ORR is in the East Tennessee Valley, part of the Valley and Ridge Province of the Appalachian Mountains. The East Tennessee Valley is bound to the west by the Cumberland Mountains of the Appalachian Plateau Province and to the east by the Smokey Mountains of the Blue Ridge Province. The defining characteristics of the Valley and Ridge Province are the southwest trending series of ridges and valleys due to crustal folding and faulting due to compressive tectonic forces. Differential weathering of the various underlying formations also define the province.

The major hydrologic watersheds associated with the ORR are East Tennessee Technology Park Watershed, Bethel Valley Watershed, Melton Valley Watershed, Bear Creek Valley Watershed, and Upper EFPC Watershed (EUWG 1998).

The majority of information available concerning the geology and hydrogeology of the site indicates that groundwater occurs as shallow flow, with short flow paths to surface water (DOE 2004; MMES 1986; ORNL 1982; SAIC 2004; USGS 1986, 1988, 1989). The fractures and solution cavities—common in this karst region—occur in shallow (0–100 feet deep) bedrock and significantly decrease at depth (>100 feet deep). In the aquitard formations, as much as 95 percent of all groundwater occurs in the shallow zone and discharges into local streams and eventually into the Clinch River. In the aquifer formations—the Knox Aquifer being the most important—solution conduits can make flow paths much deeper and longer along the strike (DOE 2004).

Groundwater beneath the ORR is typically very shallow; approximately 95 percent of it ends up as surface water before leaving the site boundary (DOE 2004).

An extensive interconnection between groundwater and surface water and the ORR groundwater contamination sources are primarily in the shallow subsurface. And core samples have shown that beneath the alluvium at the bottom of the area stream beds a silty-clay horizon likely impedes downward groundwater movement (USGS 1989). The incised meander of the Clinch River in bedrock also represents a major topographic feature that retards groundwater from passing beneath the river (ORNL 1982).

In 2006, ATSDR conducted a public health assessment to evaluate potential community exposures to contaminated groundwater coming from the ORR. ATSDR concluded that no human exposures to contaminated groundwater outside the ORR boundary have occurred in the past, are currently occurring, or are likely to occur in the future. See ATSDR's 2006 *Evaluation of Potential Exposures to Contaminated Off-site Groundwater* at http://www.atsdr.cdc.gov/HAC/oakridge/phact/groundwater/index.html.

II.D.1. Bear Creek and Upper East Fork Poplar Creek Watersheds

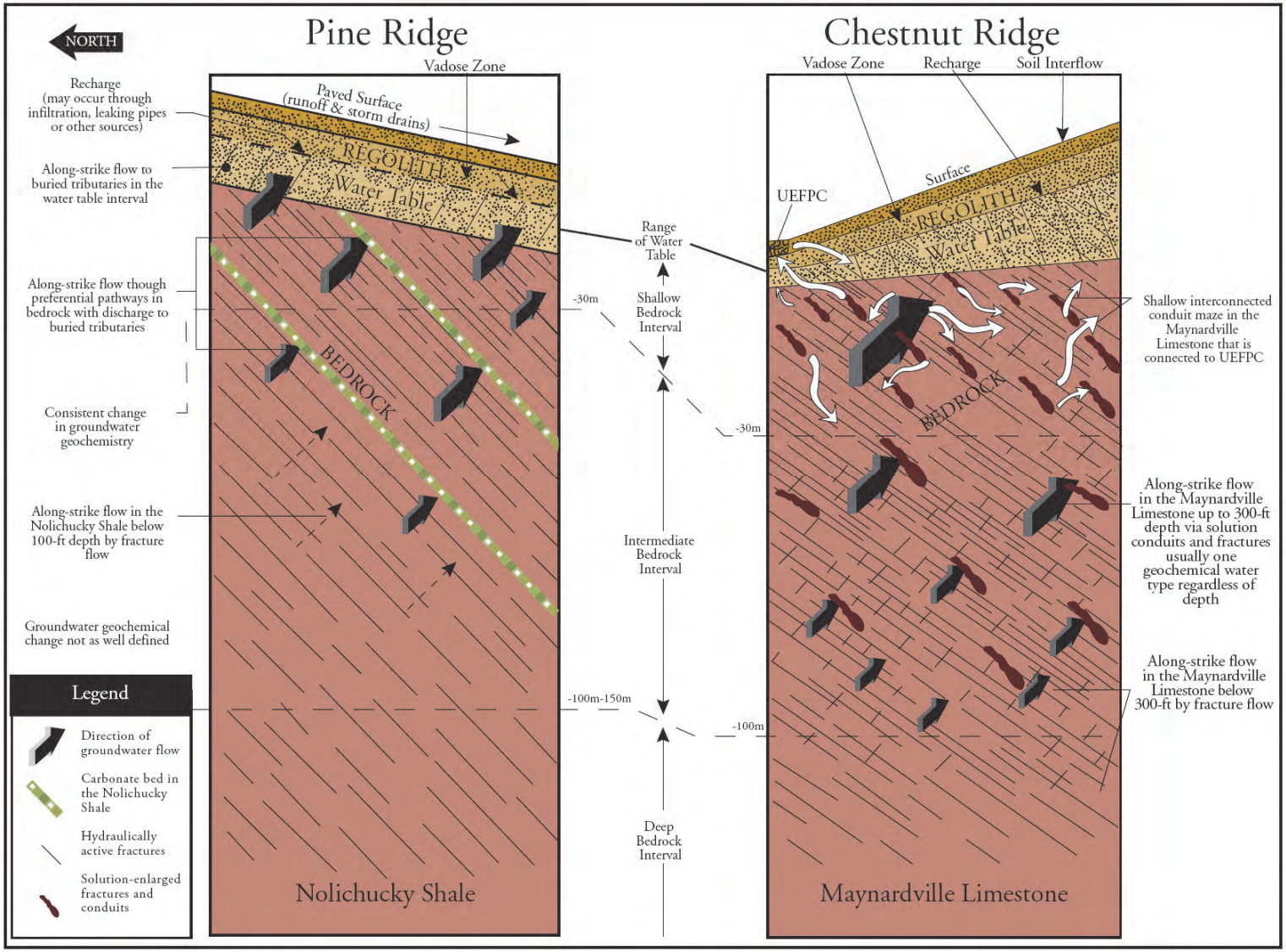
On the ORR, Bear Creek Valley comprises a large portion of the Bear Creek watershed and the Upper EFPC watershed. Bear Creek Valley is bordered by Chestnut Ridge and Pine Ridge. The 825-acre Y-12 plant is in Bear Creek Valley, predominantly in the Upper EFPC watershed. Figure 4 illustrates how groundwater flows along strikes in Pine Ridge and Chestnut Ridge. The southward sloping orientation of the bed planes beneath Pine Ridge prevents groundwater from flowing north toward Scarboro.

As is the case throughout much of the ORR, surface and groundwater are highly interconnected. Gaining and losing reaches of Bear Creek are found along the entire Bear Creek Valley. These reaches are often contamination sources of surface water. As they increase contaminant concentrations in the shallow groundwater, the shallow groundwater increasingly contaminates the reaches. Indeed, several large solution cavities are beneath Bear Creek, which (along certain reaches) serve as a hydraulic drain to the Maynardville Limestone (Lemiski 1994; SAIC 1996).

Groundwater in the Upper EFPC watershed typically flows along strike from west to east in the Maynardville Formation between 100 feet and 400 feet below ground. Groundwater flow direction in this area is also influenced by anthropogenic structures such as pipes, drains, and other underground structures that have created preferential flow paths for contaminated groundwater (SAIC 2005). But the Maynardville Limestone is the primary pathway for contaminant migration off-site from Y-12. Because of its well developed karst-system, groundwater from adjacent formations tends to flow toward the Maynardville Limestone. Because of the high interconnectivity with surface water, groundwater discharges at seeps and springs constitutes much of the base flow of Scarboro Creek and Upper EFPC. Depth to groundwater in this area is between 1 and 4 feet below ground during the winter and between 2 and 7 feet below ground in the summer (USGS 1989).

ATSDR's 2006 *Evaluation of Potential Exposures to Contaminated Off-site Groundwater* provides more detail about the hydrogeology and contamination beneath the Upper EFPC watershed. See http://www.atsdr.cdc.gov/HAC/oakridge/phact/groundwater/index.html.

Figure 4. Cross-sectional Diagram of Pine Ridge and Chestnut Ridge in the Y-12 Vicinity



II.E. Land Use and Natural Resources

Together with the three major DOE installations—the East Tennessee Technology Park (formerly the K-25 site), Oak Ridge National Laboratory (formerly the X-10 site), and the Y-12 National Security Complex (formerly the Y-12 plant)—The ORR currently owns 34,235 acres, occupying about 30 percent of the reservation. In 1980, the remaining 70 percent was established as a National Environmental Research Park to provide protected land for environmental science research and education and to demonstrate that energy technology development can coexist with a quality environment. Over the past several decades large portions of the reservation have grown into full forests. Some of this land includes areas known as "deep forest" that contain ecologically significant flora and fauna; portions of ORR are considered biologically rich (SAIC 2002b).

The ORR also includes 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 the 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. Some residential properties are adjacent to the ORR boundary line. Outside the urban areas, much of the region (about 40 percent) still reflects its historical pattern of farms and small communities (ChemRisk 1993b).

Public access is restricted at the Y-12 plant, which is entirely within the ORR "229 Boundary." Y-12 is "an active production and special nuclear materials management facility [and so] additional security and access limitations apply" (DOE 2002). Out of 1,170 acres in the Upper EFPC area, 800 are currently used for industrial purposes. This acreage includes maintenance facilities, office space, training facilities, change houses, former Oak Ridge National Laboratory Biology Division facilities, waste management facilities, construction contractor support areas, and a high-security portion that supports core National Nuclear Security Administration missions (DOE 2002).

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

Although agriculture (beef and dairy cattle) and forestry had been the two predominant land uses in the area around ORR, both are currently in decline. For many years, milk was produced, bottled, and distributed locally. Corn, tobacco, wheat, and soybeans were the major crops grown in the area. During certain periods hunters seek small game, waterfowl, and deer (ChemRisk 1993b).

EFPC originates from within the Y-12 plant boundary, flows through the city of Oak Ridge for about 12 miles, and ultimately converges with Poplar Creek near the K-25 facility (DOE 1989). A number of small tributaries flow into the creek and support some small aquatic life. While people do not use the streams on the reservation, they do have access downstream from the reservation. The area through which the Lower EFPC flows has many uses, but they can be grouped into five major categories: residential, commercial, agricultural, open land, and DOE-owned (DOE 1995b). Land use changes were evaluated during the 2006 Five Year Review

(SAIC 2007). Much of the land along the creek remains undeveloped; however, residential use of land *adjacent* to the Lower EFPC floodplain has increased in the following three locations:

- Development along Wiltshire Drive (approximately 24 parcels, with 12 adjacent to the floodplain).
- Jackson Crossing (approximately 30 parcels, with 6 adjacent to the floodplain).
- Southwood (many residential parcels, with almost half adjacent to the floodplain).

EFPC appears too shallow for swimming, although some areas, particularly those near the confluence with Poplar Creek, are deep enough for wading and fishing. TDEC issued a fishing advisory for EFPC that warns the public to avoid eating fish from the creek because of mercury and PCB contamination. They also have an advisory to avoid contact with the water due to bacterial contamination. The presence of bacteria in the water affects the public's ability to safely swim, wade, and fish in streams and reservoirs. According to TDEC, bacterial sources include failing septic tanks, collection system failure, failing animal waste systems, or urban runoff. In 1992, some of the advisory signs along the creek were replaced and additional signs posted to warn the public about contaminated surface water and fish (TDEC 1992). The state reviews and updates postings along EFPC to address exposure to surface water and fish. Postings warning about the presence of bacteria may be removed in the future; however, postings warning of contamination in fish will remain (SAIC 2007).

Fish Advisories for Waterways Near the ORR

Tennessee River

Catfish, striped bass, and hybrid (striped bass-white bass) bass should not be eaten due to elevated levels of PCBs. Children, pregnant women, and nursing mothers should not consume white bass, sauger, carp, smallmouth buffalo, and largemouth bass, but other people can safely consume one meal per month of these species.

Clinch River

Striped bass should not be eaten due to elevated levels of PCBs. Children, pregnant women, and nursing mothers should not consume catfish and sauger, but other people can safely consume one meal per month of these species.

East Fork Poplar Creek

No fish should be eaten due to elevated mercury and PCB levels. Avoid contact with the water due to bacterial contamination.

For the advisories, see http://www.tennessee.gov/environment/wpc/publications/pdf/advisories.pdf.

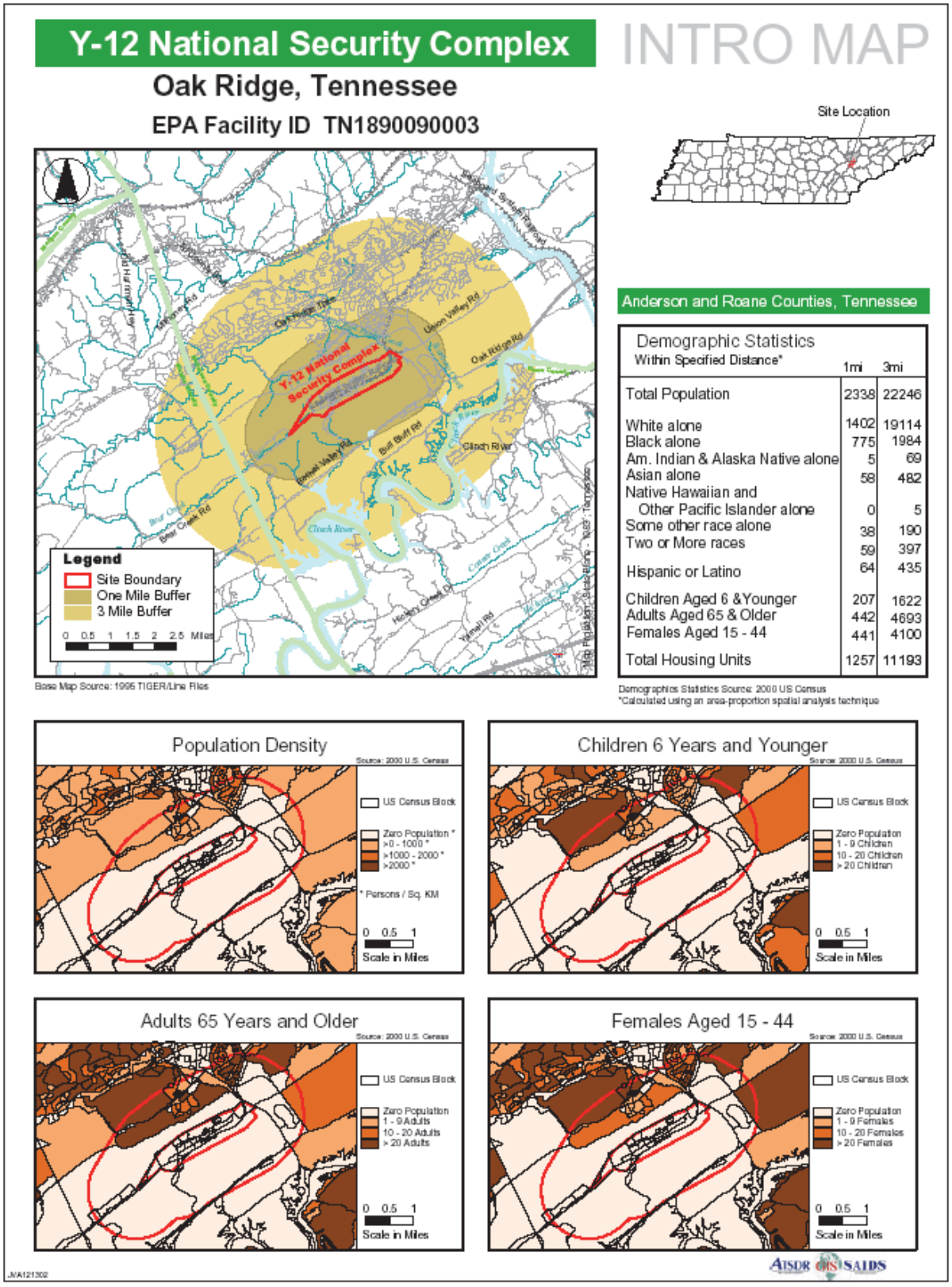
The LWBR is downstream of the ORR and extends from the confluence of the Clinch and Tennessee Rivers to the Watts Bar Dam (DOE 1995a). The waters of the reservoir supply domestic water (although LWBR is not a direct source of drinking water), industrial water, and irrigation for plants and livestock (DOE 1995c). The area around LWBR is forested or agricultural, with moderate residential development and little industrial development (DOE 2003). The public has access to the LWBR, which it uses for recreational purposes such as boating, swimming, fishing, skiing, and shoreline activities (DOE 1996, 2003). The LWBR area comprises over 47 recreational parks and facilities (including marinas, resorts, and golf courses) (TVA 1990). In the early 1990s, the total annual visitor-days were estimated at over 1 million, with the area from the Watts Bar Dam upstream to Kingston receiving the most visits (TVA 1987, 1990). TDEC issued a fishing advisory that warns the public to avoid or limit how much fish from the LWBR they eat because of elevated levels of PCBs (ORNL and Jacobs Engineering Group 1995; SAIC 2004).

II.F. Demographics

The Y-12 mercury releases study area consists of two separate areas, with distinct exposures and communities. The first area surrounds EFPC, which runs through the city of Oak Ridge. The

communities evaluated in this area live within the city of Oak Ridge, including the Scarboro community and the communities living along the EFPC floodplain. The city of Oak Ridge is in Anderson County. The second area evaluated surrounds the LWBR. Harriman, Kingston, Rockwood, and Spring City are the four main cities within the reservoir area. Harriman, Kingston, and Rockwood are in Roane County, and Spring City is in Rhea County. Meigs County is also in the area that surrounds LWBR and, therefore, is also in the study area. Figure 5 provides the current demographics for a 1-mile and 3-mile radius of the Y-12 plant.

Figure 5. Demographics for a 1-Mile and 3-Mile Radius of the Y 12 Plant



II.F.1. Counties within the Y-12 Mercury Releases Study Area

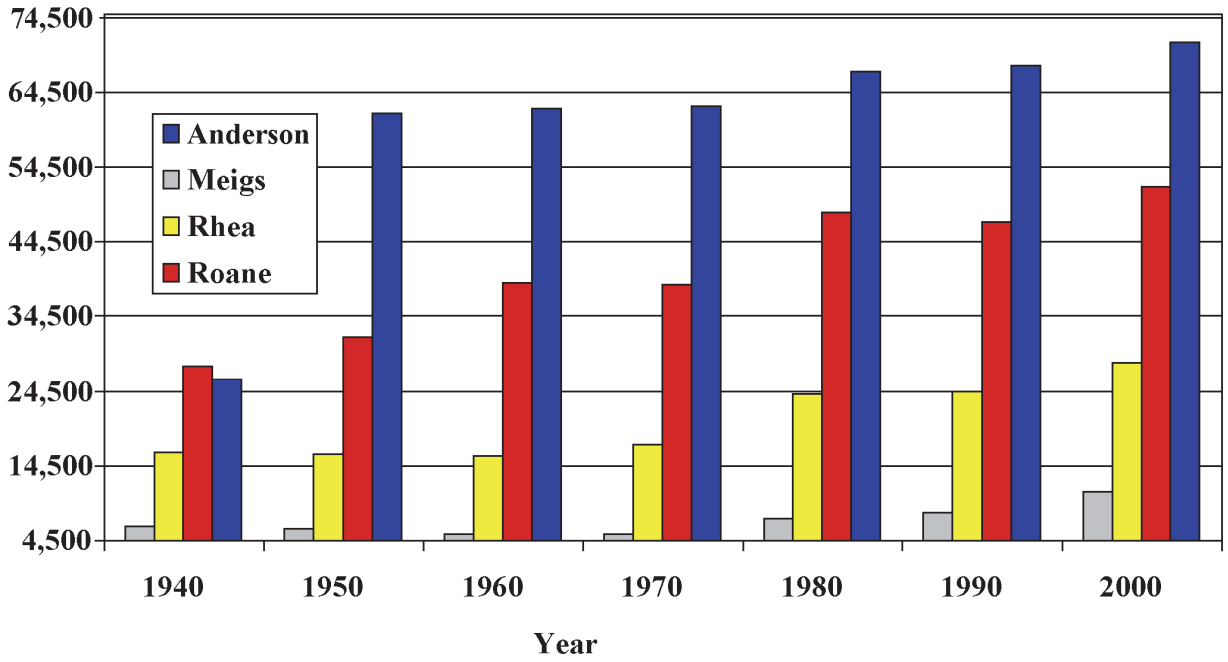
Since 1940, the populations of Anderson, Roane, Rhea, and Meigs Counties have all grown by about 50 percent (U.S. Census Bureau 1940–2000). Table 2 shows the population for these counties over that 60-year period, and Figure 6 shows the population distribution for the counties over that same period.

Table 2. Populations of Anderson, Roane, Rhea, and Meigs 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
Roane County	27,795	31,665	39,133	38,881	48,425	47,227	51,910
Rhea County	16,353	16,041	15,863	17,202	24,235	24,344	28,400
Meigs County	6,393	6,080	5,160	5,219	7,431	8,033	11,086

Source: U.S. Census Bureau 1940–2000

Figure 6. Population Distribution of Anderson, Roane, Rhea, and Meigs Counties from 1940 to 2000



Source: U.S. Census Bureau 1940–2000

Anderson County

From 1940 to 1950, as people came to build and operate the new Y-12 facilities, the Anderson County population more than doubled: from 26,504 to 59,407. Over the next 50 years, the county grew steadily at the more modest rate of 20 percent to 71,330 in the year 2000 (U.S. Census Bureau 1940–2000). Figure 6 shows the pattern of growth. As of 2000, most residents worked in management, professional, and related fields. Anderson County has 66,593 whites, 2,766 African

Americans, and 828 persons of other races. Most residents are between 40 and 44 years old, with a median age of 39.9 (U.S. Census Bureau 2000).

Roane County

Over this same 60-year period, the Roane County population has grown by 86.8 percent, as shown in Table 2 (U.S. Census Bureau 1940–2000). The population declined slightly from 1960 to 1970, and between 1980 and 1990 (East Tennessee Development District 1995; U.S. Census Bureau 1960, 1970, 1980, 1993). The county population grew during the remaining time and reached a population of 51,910 in 2000. Figure 6 shows the population distribution of the county over time (East Tennessee Development District 1995; U.S. Census Bureau 1940–2000).

Most of Roane County's 2000 persons are white (49,440); the rest are African American (1,409) and other races (1,061) (U.S. Census Bureau 2000). Since the 1970s, the median age of Roane County residents has increased from 32.1 to 40.7, suggesting that the county population is aging (East Tennessee Development District 1995; U.S. Census Bureau 1993, 2000). The X-10 site and the K-25 site are both within Roane County (East Tennessee Development District 1995; Jacobs EM Team 1997). Primarily because of these two facilities, between 1940 and 1990 manufacturing was the dominant occupation for Roane County residents (East Tennessee Development District 1995; U.S. Census Bureau 1993).

Rhea County

The population of Rhea County declined between 1940 and 1960, but has increased steadily since the 1960s (see Table 2 and Figure 6). The largest increase (40.9 percent) was between 1970 and 1980, when the number of residents increased from 17,202 to 24,235. Over the past 60 years, the population of Rhea County has increased by nearly 75 percent (U.S. Census Bureau 1940–2000). As of 2000, most residents worked in the manufacturing industry. Rhea County has 27,097 whites, 580 African Americans, and 723 persons of other races. Most residents are between the ages of 35 and 44, with a median age of 37.2 (U.S. Census Bureau 2000).

Meigs County

Between 1940 and 1960, the population of Meigs County decreased. But the population has nearly doubled since then—from 5,160 to 11,086 (46.5 percent) (see Table 2 and Figure 6). The largest percentage increase in population occurred between 1970 and 1980, when the number of residents grew from 5,219 to 7,431 (42.4 percent). Since 1940, the population of Meigs County has grown by almost 60 percent (U.S. Census Bureau 1940–2000). As of 2000, most residents worked in the manufacturing industry. The Meigs County population is comprised of 10,826 whites, 138 African Americans, and 122 persons of other races. Most residents are between the ages of 35 and 44, and the median age is 36.7 (U.S. Census Bureau 2000).

II.F.2. Cities within the Y-12 Mercury Releases Study Area

Oak Ridge

In 1942, the city of Oak Ridge, Tennessee, was established in Anderson County for the 13,000 persons who were expected to work at the ORR (Friday and Turner 2001). By July 1944, the population of Oak Ridge had increased to 50,000. The Oak Ridge population peaked in 1945 at approximately 75,000 and declined to 30,229 by 1950 (see Table 3) (Oak Ridge Comprehensive Plan 1988). For the last three census years (1980, 1990, 2000) the city population has been

between 27,000 and 28,000. 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 one of the largest population centers in the area (ChemRisk 1993b).

Table 3. Population of Oak Ridge from 1942 to 2000

	1942	*1944*	*1945*	*1950*	*1960*	*1970*	*1980*	*1990*	*2000*
Oak Ridge	13,000	50,000	75,000	30,229	27,169	28,319	27,662	27,310	27,387

Sources: ChemRisk 1993b; Oak Ridge Comprehensive Plan 1988; U.S. Census Bureau 1940–2000

From 1940 to 1960, the city of Oak Ridge had a higher proportion of working age people and fewer seniors than the rest of Tennessee (ChemRisk 1993b). Since 1960, however, the resident population under age 35 and over age 55 has increased, while the population of children under age 16 has declined (Oak Ridge Comprehensive Plan 1988). The education level of Oak Ridge citizens is dramatically higher than in surrounding areas; Oak Ridge boasts one of the highest per capita PhD ratios of any city in the United States (Oak Ridge Comprehensive Plan 1988).

Scarboro

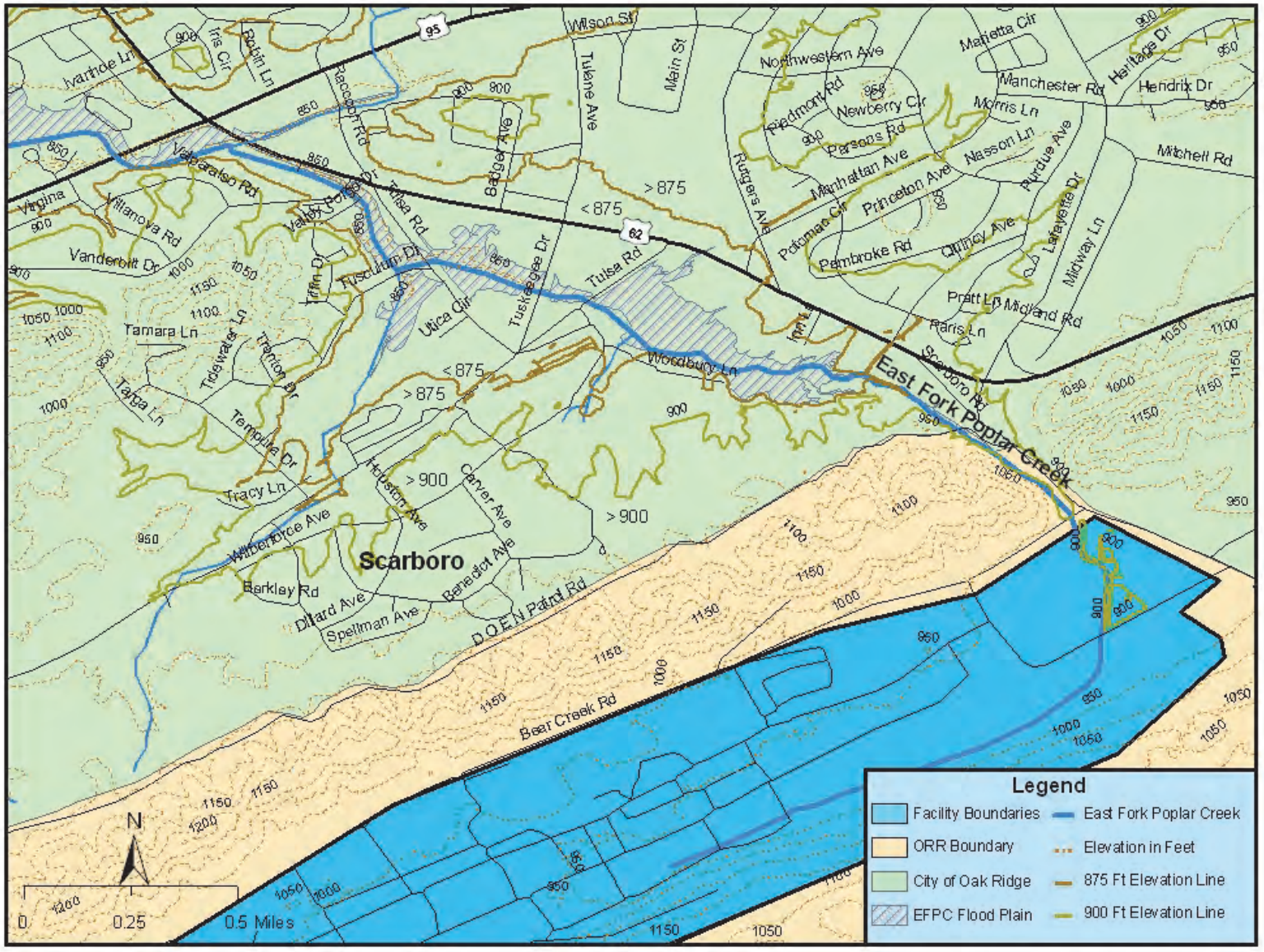
The Scarboro community is within the city of Oak Ridge, outside of the EFPC floodplain (see Figure 7). It's about a half mile from the Y-12 plant and is separated from the Y-12 plant by Pine Ridge. Before 1950, the area was known as the Gamble Valley Trailer Camp, and the population was predominantly white. In 1950, Scarboro was established to provide single-family homes, duplexes, apartments, and an elementary school to African American Oak Ridge residents (Friday and Turner 2001). To this day, Scarboro remains predominantly African American (94 percent) (Friday and Turner 2001).

In the fall of 1999, the Joint Center for Political and Economic Studies conducted a survey of the broader Scarboro community (Friday and Turner 2001). The staff identified 380 residences, of which 326 were occupied. About 266 persons responded to the survey (82 percent). The report generated from the survey is one of the few sources of detailed information available on the Scarboro community (Friday and Turner 2001).

The Scarboro community is aging—the average respondent is almost 53 years old. Only 36 percent of participating households reported having at least one member between the ages of 18 and 34 years. About half of the households reported having one senior citizen or more, while only 23 percent of the surveyed households reported having children. Additionally, 39 percent of respondents were retired. As of 1999, the average length of residence in Scarboro was 29 years. But many (82 percent) of the young adult residents (18–30 years old) moved to Scarboro after 1994. For additional details, see the *Scarboro Community Assessment Report* (Friday and Turner 2001).

1

Figure 7. Surface Elevation for Scarboro



2

EFPC Floodplain

The EFPC floodplain surrounds EFPC. Using available information, researchers found that over the history of the ORR, approximately 10 farms were located in the floodplain (ChemRisk 1999a). The Task 2 team estimated that the total population size between 1940 and 1990 was between 40 and 200 persons—the number in any given year was estimated to be between 10 and 50 (ChemRisk 1999a).

Harriman

The city of Harriman is located along Roane County's Emory River, in to the west of the ORR (see Figure 1). As seen in Table 4 and Figure 8, the population of Harriman peaked between 1970 and 1980 (8,734 and 8,303, respectively) and has continued to decline since (East Tennessee Development District 1995; U.S. Census Bureau 1940–2000). The median age of the population is 40.5 years; about 40 percent of the residents are between the ages of 25 and 54 (U.S. Census Bureau 2000). About 90 percent of the population is white, 7.4 percent is African America, and a small percentage is persons of other races (U.S. Census Bureau 2000). In 1990, Harriman had more minority residents than any other city in Roane County (8.6 percent of the population; East Tennessee Development District 1995). In 1969, 18 of the 29 manufacturing plants in Roane County were located within the city of Harriman. By 1990, however, only 15 of 35 manufacturing plants were in Harriman (East Tennessee Development District 1995). As of 2000, manufacturing was Harriman's leading industry.

Kingston

The City of Kingston is in Roane County, at the confluence of the Clinch River and the Tennessee River, southwest of the ORR (see Figure 1). The population of Kingston has grown steadily from 1940 to 2000, except for a 0.2 percent decrease between 1980 and 1990 (see Table 4 and Figure 8) (East Tennessee Development District 1995; U.S. Census Bureau 1940–2000). The median age of the population is 41.6 years. About 40 percent of the residents are between the ages of 25 and 54, with the greatest portion between 45 and 54 years of age (U.S. Census Bureau 2000). The majority of the population is white (93.8 percent), 3.6 percent are African American, and a small percentage consists of persons of other races (U.S. Census 2000). Since 1990, the greatest portion of residents (26.2 percent) has been employed in the professional services field (East Tennessee Development District 1995; U.S. Census Bureau 2000).

Rockwood

Rockwood is situated to the southwest of ORR, northwest of the confluence of the Clinch and Tennessee Rivers, also in Roane County. As seen in Table 4 and Figure 8, the city experienced steady growth between 1940 and 2000, except for slight declines that occurred between 1960 and 1970, and between 1980 and 1990 (East Tennessee Development District 1995; U.S. Census Bureau 1940–2000). As of 2000, the median age was 42 years. About 38 percent of the population is between the ages of 25 and 54 (U.S. Census Bureau 2000). The majority of the population is white (92.9 percent), about 5.4 percent are African American, and a small percentage are persons of other races (U.S. Census Bureau 2000). The largest percentage of residents is employed in the manufacturing field. In 1969, 10 out of 29 manufacturing plants in Roane County were located in Rockwood; by 1990, Rockwood had 13 out of the 35 manufacturing plants in the county (East Tennessee Development District 1995).

Spring City

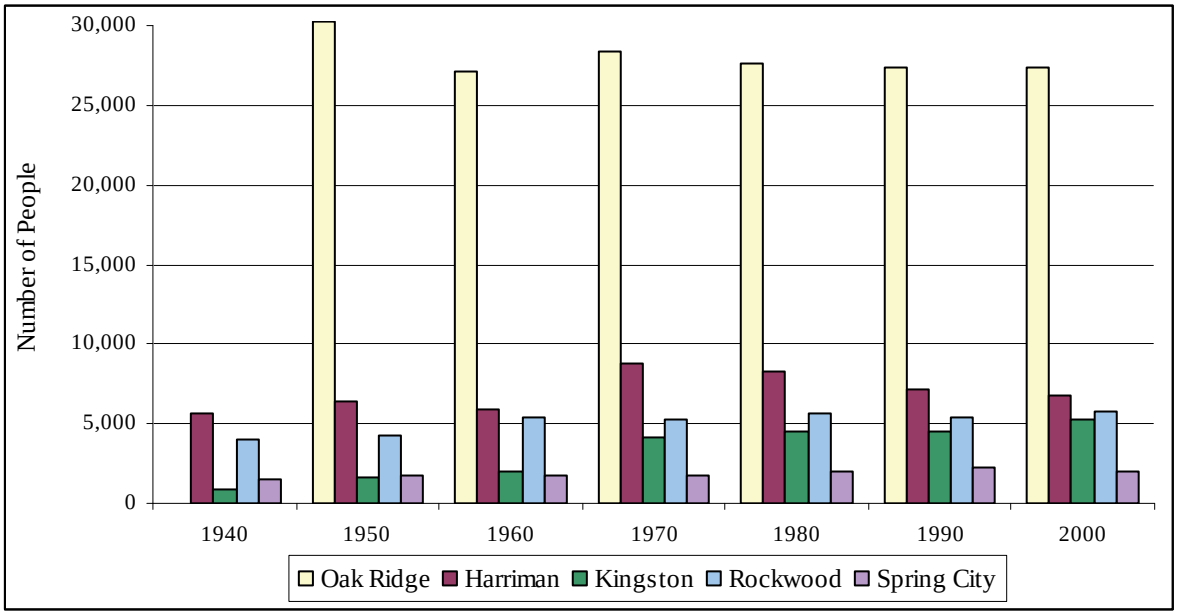
Spring City is in Rhea County along the Tennessee River, south of the confluence with the Clinch River and north of the Watts Bar Dam. Between 1940 and 2000, the Spring City population remained relatively steady, with the number of residents slowly increasing by about 25 percent (see Table 4 and Figure 8). The largest percent increase in population was seen between 1980 and 1990, followed by the largest decrease between 1990 and 2000 (U.S. Census Bureau 1940–2000). The median age of the population is 44 years. About 36 percent of the residents are between the ages of 25 and 54, with the greatest portion between 35 and 44 years of age (U.S. Census Bureau 2000). The majority of the population is white (94.5 percent), 4.5 percent are African American, and a small percentage consists of persons of other races (U.S. Census 2000). As of 2000, the largest percentage (31.6 percent) of residents worked in the manufacturing industry (U.S. Census Bureau 2000).

Table 4. Population of Harriman, Kingston, Rockwood, and Spring City from 1940 to 2000

City	*1940*	*1950*	*1960*	*1970*	*1980*	*1990*	*2000*
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
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: East Tennessee Development District 1995; U.S. Census Bureau 1940–2000

Figure 8. Population of Oak Ridge, Harriman, Kingston, Rockwood, and Spring City from 1940 to 2000



Sources: East Tennessee Development District 1995; U.S. Census Bureau 1940–2000

II.F.3. Summary of Public Health Activities Pertaining to Y-12 Mercury Releases

This section describes the public health activities that pertain to Y-12 mercury releases. Several additional public health activities conducted at the ORR by ATSDR, the Tennessee Department of Health (TDOH), and other agencies are described in Appendix B. Summary of Other Public Health Activities. See Figure 2 for a time line of public health activities related to the Y-12 plant.

II.F.4. ATSDR

Since 1992, ATSDR has addressed health concerns of community members, civic organizations, and other government agencies. ATSDR has worked to determine whether levels of environmental contamination at and near the 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 local, state, and federal environmental and health agencies. While the TDOH conducted the Oak Ridge Health Studies to evaluate whether off-site populations have experienced exposures in the *past* (1944–1990), ATSDR's activities in the 1990s focused on *current* public health issues current at that time to prevent duplication of the state's efforts. The ATSDR ORR Web site (http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html) highlights ATSDR's major public health activities at the ORR. The following paragraphs highlight major public health activities conducted by ATSDR that pertain to Y-12 mercury releases.

Health Consultation on Y-12 Weapons Plant Chemical Releases Into East Fork Poplar Creek, April 1993. This health consultation provided DOE with advice on current public health issues related to past and present chemical releases into the creek from the Y-12 plant. Before finalizing its remedial investigation and feasibility study on EFPC, DOE implemented many of ATSDR's recommendations. The EFPC Phase Ia data evaluated for this health consultation indicate that the creek's soil, sediment, groundwater, surface water, air, and fish are contaminated with various chemicals. ATSDR reached the following public health conclusions:

- Soil and sediments in certain locations along the EFPC floodplain are contaminated with levels of mercury that pose a public health concern.
- Fish in the creek contain levels of mercury and PCBs that pose a moderately increased risk of adverse health effects to people who eat fish frequently over long periods of time.
- Shallow groundwater in a few areas along the EFPC floodplain contains metals at levels of public health concern; however, this shallow groundwater is not used for drinking or other domestic purposes.

Other contaminants found in soil, sediment, surface water, and fish were not detected at levels that could make people ill. In summary, among other recommendations, ATSDR advised continuation of the EFPC fish advisory with posting of signs, especially at the confluence of Poplar Creek (ATSDR 1993b). Access this public health consultation at http://www.atsdr.cdc.gov/HAC/PHA/efork1/y12_toc.html. A brief summarizing the health consultation is provided in Appendix C. Summary Briefs and Factsheets.

ATSDR Science Panel Meeting on the Bioavailability of Mercury in Soil, August 1995. The purpose of the science panel was to identify methods and strategies that would enable health assessors to develop data-supported, site-specific estimates of the bioavailability of inorganic

mercury and other metals (arsenic and lead) from soils. The panel consisted of private consultants and academicians internationally known for their metal bioavailability research. Experts from ATSDR, the Centers for Disease Control and Prevention (CDC), U.S.EPA, and the National Institute for Environmental Health Science also participated. ATSDR used information obtained from the panel meeting to evaluate the EFPC clean-up level. ATSDR also used the findings to characterize and evaluate soil containing mercury at other waste sites. Three technical papers and an ATSDR overview paper on the findings of the panel meeting were published in the International Journal of Risk Analysis in 1997 (Volume 17:5).

Health Consultation on Proposed Mercury Clean Up Levels, January 1996. In response to a request from community members and the City of Oak Ridge, ATSDR evaluated the public health effects of DOE's clean-up levels of 180 milligrams per kilogram (mg/kg) and 400 mg/kg of mercury in the EFPC floodplain soil. ATSDR concluded that both clean-up levels would be protective of public health and would pose no health threat to adults or children (ATSDR 1996a). Access this public health consultation at http://www.atsdr.cdc.gov/HAC/PHA/efork2/oak_toc.html. Note: Floodplain soils with mercury concentrations greater than 400 ppm were remediated in 1996 and 1997 (SAIC 1993, 2002a).

Watts Bar Reservoir Exposure Investigation, March 1998. In following up on the findings of previous studies and investigations of the Watts Bar Reservoir, including Feasibility of Epidemiologic Studies by the TDOH, ATSDR conducted the exposure investigation in cooperation with the TDOH and the Roane County Health Department. The 1996 exposure investigation was conducted to measure actual PCB and mercury levels in people consuming moderate to large amounts of fish and turtles from the Watts Bar Reservoir. The investigation also was to determine whether these people were exposed to high levels of PCBs and mercury.

ATSDR published the following three major findings:

- The exposure investigation participants' serum PCB levels and blood mercury levels were very similar to levels found in the general population.
- Five of the 116 people tested (4 percent) had PCB levels higher than 20 micrograms per liter (μg/L) or parts per billion (ppb), which is considered to be an elevated level of total PCBs. Of the five participants who exceeded 20 μg/L, four had levels of 20–30 μg/L. One participant had a serum PCB level of 103.8 μg/L—higher than the general population distribution.
- Only 1 of 116 participants had an elevated blood mercury level. The participants' blood mercury levels were very similar to levels found in the general population (ATSDR 1998).

A brief summarizing the exposure investigation is provided in Appendix C. Summary Briefs and Factsheets.

Where Can I Obtain More Information on ATSDR's Activities at the ORR?

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 in the following three ways:

1. Visit one of the records repositories. Copies of ATSDR's publications on the ORR, along with publications from other agencies, can be viewed in records repositories at public libraries and the DOE Information Center (located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee; 865-241-4780). For directions to these repositories, please contact ATSDR at 1-800-CDC-INFO (1-800-232-4636).
2. Visit the ATSDR or ORRHES Web sites. These Web sites include past publications, schedules of future events, and other materials. ATSDR's ORR Web 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, 1-800-CDC-INFO (1-800-232-4636).

II.F.5. TDOH

Oak Ridge Health Studies. In 1991, DOE and the state of Tennessee entered into the Tennessee Oversight Agreement, which allowed the TDOH to undertake a two-phase independent state research project to determine whether past environmental releases from ORR operations harmed people who lived nearby (ChemRisk 1999d; ORHASP 1999). Access all the technical reports produced for the TDOH Oak Ridge Health Studies at http://health.state.tn.us/ceds/oakridge/oridge.htmlhttps://www.orau.gov/cedr/.

Phase I. 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 the ORR. The objective of the study was to determine the quantity, quality, and potential usefulness of the available information and data on these past releases and subsequent exposure pathways. Phase I of the health studies began in May 1992 and was completed in September 1993.

The findings of the Phase I Dose Reconstruction Feasibility Study indicated that a significant amount of information was available. Researchers could use this information to reconstruct the past releases and potential off-site exposure doses for four hazardous substances that may have been responsible for adverse health effects. These four substances include 1) radioactive iodine releases associated with radioactive lanthanum processing at the X-10 site from 1944 through 1956; 2) mercury releases associated with lithium separation and enrichment operations at the Y-12 plant from 1950 through 1963; 3) PCBs in fish from EFPC, the Clinch River, and the Watts Bar Reservoir; and 4) radionuclides from White Oak Creek associated with various chemical separation activities at the X-10 site from 1943 through the 1960s. A brief summarizing the Phase I Feasibility Study is provided in Appendix C. Summary Briefs and Factsheets.

Phase II (also referred to as the Oak Ridge Dose Reconstruction). Phase II of the health studies conducted at Oak Ridge began in mid-1994 and was completed in early 1999. Phase II was primarily a dose reconstruction study focusing on past releases of radioactive iodine, mercury, radionuclides from White Oak Creek, 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 Phase I had not fully characterized. The following paragraphs describe the significant findings for each of the substances evaluated.

Radioactive iodine releases were associated with radioactive lanthanum processing at the X-10 site from 1944 through 1956. Results indicate that children who were born in the area in the early 1950s and who drank milk produced by cows or goats living in their yards had an increased risk of developing thyroid cancer. The report stated that children living within a 25-mile radius of Oak Ridge were likely to have had an increased risk of more than 1 in 10,000 of developing thyroid cancer.

The study evaluated mercury releases associated with lithium separation and enrichment operations at the Y-12 plant from 1950 through 1963. Results indicate that depending on their activities, persons living in the area during the years that mercury releases were highest (mid-1950s to early 1960s) may have received annual average doses of mercury exceeding the U.S.EPA reference dose (RfD) (ChemRisk 1999a). A brief summarizing this study is provided in Appendix C. Summary Briefs and Factsheets.

Radionuclides associated with various chemical separation activities at the X-10 site from 1943 through the 1960s were released into White Oak Creek. Studied were eight radionuclides (cesium 137, ruthenium 106, strontium 90, cobalt 60, cerium 144, zirconium 95, niobium 95, and iodine 131) deemed more likely than others to carry significant risks. The results indicate that the releases caused small increases in the radiation dose of those who ate fish from the Clinch River near the mouth of White Oak Creek. The dose reconstruction scientists estimated that a male who ate up to 130 meals of fish from the mouth of White Oak Creek every year for 50 years (worst-case scenario) would face an excess cancer risk ranging from 4 to 350 in 100,000. The risk from eating fish goes down proportionately for those who eat fewer fish and for those who eat fish taken farther downstream.

U.S.EPA's reference dose is an estimate of the largest amount of a substance that a person can take in on a daily basis over their lifetime without experiencing adverse health effects.

Additional studies were conducted on PCBs in fish from EFPC, the Clinch River, and the Watts Bar Reservoir. TDOH concluded that persons who consumed large amounts of fish from the Clinch River and the LWBR were at risk of noncancer effects of PCBs. The studies also concluded that three or fewer additional cases of cancer could have resulted from eating Clinch River and Watts Bar Reservoir fish (carcinogenic risks ranged from 1 in 1,000,000 to 2 in 10,000; ChemRisk 1999c). Because, however, the estimates and modeling are conservative, "the actual risks and expected number of cases are likely to be smaller and could be zero" (ChemRisk 1999c). To reduce the uncertainty, TDOH also made recommendations for further study.

Uranium was released from various large-scale uranium operations, primarily uranium processing and machining operations at the Y-12 plant and uranium enrichment operations at the K-25 and S-50 plants. Because uranium was not initially given high priority as a contaminant of concern, a Level II screening assessment for all uranium releases was performed. Preliminary screening indices were slightly below the decision guide of one chance in 10,000, which indicated that more work may be needed to characterize better the uranium releases and the possible heath risk (ChemRisk 1999b).

Pilot Survey. In the fall of 1983, TDOH developed an interim soil mercury concentration for use in environmental management decisions. CDC reviewed the methodology for the interim mercury level in soil. CDC then recommended a pilot survey to determine whether populations with the highest risk for mercury exposure had elevated mercury body burdens. In June and July 1984, a pilot survey was conducted to document human body levels of inorganic mercury. The

survey focused on residents of Oak Ridge with the highest potential for mercury exposure from contaminated soil and fish. The survey also examined whether exposure to mercury-contaminated soil and fish constituted an immediate health risk to the Oak Ridge population. The results of the pilot survey, released in October 1985, suggested that Oak Ridge, Tennessee residents and workers were not likely at increased risk for significantly high mercury levels. Mercury concentrations in hair and urine samples were below levels associated with known health effects (Rowley et al. 1985).

II.F.6. Florida Agricultural and Mechanical University (FAMU)

Scarboro Community Environmental Study. In 1998, soil, sediment, and surface water were sampled in the Scarboro community to address community concerns about environmental monitoring in the Scarboro neighborhood. The analytical component of the study was conducted by the Environmental Sciences Institute at Florida Agricultural and Mechanical University (FAMU) and its contractual partners at the Environmental Radioactivity Measurement Facility at Florida State University and the Bureau of Laboratories of the Florida Department of Environmental Protection, and by DOE subcontractors in the Neutron Activation Analysis Group at the Oak Ridge National Laboratory.

Organic compounds were only detected in one of the samples tested. This same sample also contained lead and zinc at concentrations twice as high as those found in the Background Soil Characterization Project (DOE 1993a). Mercury was found within the range given in the Background Soil Characterization Project, and about 10 percent of the soil samples showed evidence of uranium 235, which is associated with uranium enrichment. The final Scarboro community Environmental Study was released in September 22, 1998, during a Scarboro community meeting (FAMU 1998). A brief summarizing this study is provided in Appendix C. Summary Briefs and Factsheets.

II.F.7. U.S.EPA

Scarboro Community Environmental Sampling Validation Study. In 2001, U.S.EPA's Science and Ecosystem Division Enforcement Investigation Branch collected soil, sediment, and surface water samples from the Scarboro community to respond to community concerns, identify data gaps, and validate the sampling performed by FAMU in 1998 (FAMU 1998). A final report was released in April 2003 (EPA 2003). U.S.EPA concluded that the results support the sampling performed by FAMU in 1998, and that the residents of Scarboro are not currently exposed to harmful levels of substances in the soil, sediment, or surface water. A brief summarizing this study is provided in Appendix C. Summary Briefs and Factsheets.

II.F.8. DOE

Mercury Inventory Report, 1977. DOE asked Union Carbide to reconstruct the historical mercury inventory at the Y-12 plant from 1950 through 1977. Two employees spent 2 weeks gathering information from documents and employee interviews. The classified report indicated that 550,000 pounds of mercury had been spilled or lost to the environment, and about 1.9 million pounds were unaccounted for (ChemRisk 1999a).

Mercury Task Force, 1983. In May 1983, the Y-12 plant manager appointed the Mercury Task Force to collect historical data (1950–1983) on mercury accountability, study mercury salvage and recovery, and summarize mercury effects on worker health and the environment. The task

force consisted of employees who were not involved in operations when most mercury exposures to workers and losses to the environment occurred. The classified report represents the official statement of mercury releases from the Y-12 plant (ChemRisk 1999a).

Federal Facility Agreement, 1992. DOE is conducting clean-up activities at the ORR under a Federal Facility Agreement—a legally binding agreement between DOE, U.S.EPA, and TDEC. The agreement was finalized on January 1, 1992, to establish timetables, procedures, and documentation for remediation actions at ORR. Under the Federal Facility Agreement, DOE, U.S.EPA, and TDEC have conducted RI/FSs on the Lower EFPC Operable Unit (OU), the LWBR OU, and the Clinch River/Poplar Creek OU. All of these OUs were placed on the NPL in December 1989; under CERCLA an RI/FS is required for all sites on the NPL (ATSDR et al. 2000). The Federal Facility Agreement is available online at http://www.bechteljacobs.com/facts/or/ffa.pdf.

Lower East Fork Poplar Creek Remedial Investigation/Feasibility Study, 1994. The purpose of the RI/FS was to assess contamination (primarily mercury-contaminated floodplain soils) resulting from releases since 1950 from the Y-12 plant. The objectives of the study were to determine the extent of contamination of the EFPC floodplain, to develop a baseline risk analysis based on the level of contaminants, and to determine whether remedial action was required (ATSDR et al. 2000).

The findings indicated that portions of the floodplain were contaminated with mercury. Also, floodplain soil with mercury concentrations of more than 400 ppm would constitute an unacceptable risk to human health and the environment. Drawing on these findings, the 1995 ROD called for remedial action. The remedial action included

- Excavation of four areas of the floodplain where soils had mercury concentrations of more than 400 ppm;
- Confirmatory sampling during excavation activities to document the removal;
- Disposal of contaminated soil into a landfill at the Y-12 plant under a special waste permit;
- Backfilling of excavated areas, including a 0.6-acre wetland, with clean borrow soil; and
- Revegetation of the affected areas.

A small area next to the NOAA site was not remediated. The area underneath the Dean Stallings Ford automobile dealership parking lot was filled. But it still contains mercury above 400 ppm. DOE annually visits the lot to ensure that the land use has not changed (SAIC 2007).

Remediation field activities began in June 1996 and were completed in October 1997 (ATSDR et al. 2000).

Lower Watts Bar Reservoir Remedial Investigation/Feasibility Study, March 1995. The purpose of the RI/FS was to assess the level of contamination in the Watts Bar Reservoir, to create a baseline risk analysis based on the contaminant levels, and to establish whether remedial action was necessary. The findings of the remedial investigation suggested that biota, sediment, and water at the Watts Bar Reservoir were contaminated with metals, radionuclides, and organic compounds. The baseline risk analysis suggested that protective standards for environmental and human health would not be reached if deep channel sediments permeated with cesium 137 were dredged and placed in a residential area, and if people consumed moderate to high quantities of fish that contained increased levels of PCBs (ATSDR et al. 2000).

Using the RI/FS results, a ROD was prepared and finalized in September 1995. The ROD mandated that DOE use controls to prevent adverse effects from exposure to contaminants in the Watts Bar Reservoir. These controls included TDEC-administered fish consumption advisories, ongoing monitoring, and controlling activities that could disturb sediment (ATSDR et al. 2000; DOE 1995c).

Clinch River/Poplar Creek Remedial Investigation/Feasibility Study, March 1996. The purpose of the RI/FS was to examine the past and present releases to off-site surface water and to establish whether remedial action was necessary (ATSDR et al. 2000). The RI/FS found two main hazards associated with the Clinch River/Poplar Creek OU: 1) exposure to chromium, cesium 137, mercury, and arsenic located in deep sediment within the main river channel, and 2) exposure to mercury, chlordane, PCBs, and arsenic in fish tissue (DOE 1997).

A baseline risk assessment was conducted. It suggested that consumption of certain fish contaminated with PCBs posed the greatest risk to public health. Fish contaminated with chlordane, mercury, and arsenic presented possible health risks as well. The assessment also determined that the consumption of any type of fish in Poplar Creek posed a health risk, as did bass from the Clinch River below Melton Hill Dam. The risk assessment further determined that contaminants in the buried sediments in the deep-water river channel would only present a health risk if they were dredged; there is no current exposure to these sediments (DOE 1997).

Again using the results of the RI/FS, another ROD was finalized in September 1997 (DOE 1997). This ROD recommended (DOE 1997, 2001; SAIC 2004):

- Fish consumption advisories,
- Controls on activities that could disrupt sediment,
- Yearly monitoring of fish, sediment, surface water, and turtles, and
- Surveys to assess the value of fish consumption advisories.

In February 1998, a Remedial Action Report was approved. This report recommended that monitoring for surface water, fish, sediment, and turtles in the Clinch River/Poplar Creek OU (ATSDR et al. 2000).

Oak Ridge Environmental Information System (OREIS), April 1999. Because of the availability of an abundance of environmental data for the ORR, DOE created an electronic data management system to integrate all of the data into a single database, facilitating public and government access to environmental operations data while 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 on compliance, environmental restoration, and surveillance activities. Information from all key surveillance activities and environmental monitoring efforts is entered into OREIS, which include but are not limited to studies of the Clinch River embayment and the Lower Watts Bar, as well as annual site summary reports. As new studies are completed, the environmental data are entered as well.

Upper East Fork Poplar Creek Record of Decision for Phase I Interim Source Control Actions, May 2002. The ROD selected a number of different source control remedies to control the influx of mercury from the Y-12 plant into Upper EFPC. The major actions are

- Hydraulic isolation of the West End Mercury Area (e.g., capping contaminated soils);

- Removal of contaminated sediments from storm sewers, Upper EFPC, and Lake Reality;
- Treatment of discharge from Outfall 51;
- Temporary water treatment;
- Land use controls to prevent consumption of fish from Upper EFPC and to monitor access by workers and the public; and
- Monitoring of surface water.

The remedial action's goal is to reduce the mass flux of mercury to Upper EFPC. Specifically, 200 ppt is the performance goal for mercury in surface water at Station 17, Building 9201-2 effluent discharge point, Outfall 550, and Outfall 551 (SAIC 2007).

2006 Remediation Effectiveness Report/Second Reservation-wide CERCLA Five-Year Review, February 2007. DOE conducted the second ORR-wide Five Year Review in 2006. Five Year Reviews are required at all post-Superfund Amendments and Reauthorization Act (SARA) sites that still have hazardous substances remaining above levels that allow for unlimited use and unrestricted exposures. The purpose is to report on completed and ongoing CERCLA actions and to determine whether the remedy at each site is protective of human health and the environment. Because many of the CERCLA decisions on the ORR fall within this definition, the ORR as a whole is subject to Five Year Reviews indefinitely. This Five Year Review assesses an important set of key, off-site completed remedial actions (e.g., LWBR, Clinch River/Poplar Creek, and Lower EFPC) and reviews the effects and progress of two major watershed RODs (the Phase I ROD for Bear Creek Valley and the Interim Record of Decision for Melton Valley) (SAIC 2007).

III. Evaluation of Environmental Contamination and Potential Exposure Pathways

III.A. Introduction

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

- Y-12 plant uranium releases (2004);
- White Oak Creek radionuclide releases (2006);
- Site-wide current and future chemical exposures (2007);
- X-10 site iodine 131 releases (2008);
- X-10 site, Y-12 plant, and K-25 site PCB releases (2009); and
- K-25 site uranium and fluoride releases (2010);
- Other issues of community concern, such as contaminant releases from the Toxic Substances Control Act (TSCA) Incinerator (2005) and contaminated off-site groundwater (2006).

This public health assessment on the Y-12 mercury releases evaluates and analyzes the information, data, and findings of previous studies and investigations of releases of mercury from the Y-12 plant and assesses the health implications of past and current mercury exposures to residents living near the ORR.

The public health assessment is the primary public health process ATSDR uses to evaluate further these contaminants. The documents released to date are available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html and can also be ordered through the agency's toll-free number, 1-800-CDC-INFO (1-800-232-4636).

III.B. Evaluation of Past (1950–1990) Mercury Exposure Pathways

Over the years, three major efforts have been made to estimate Y-12 mercury releases to water and air. Two of them included investigations to account for past mercury inventories at the Y-12 plant. In 1977, Y-12 personnel prepared a classified report entitled the 1977 Mercury Inventory Report. In the early 1980s, after the public became aware that large quantities of mercury had been released from the Y-12 plant, DOE appointed a Mercury Task Force to investigate what was known about mercury use and releases. The Mercury Task Force studied the 1977 Mercury Inventory Report and released its own report in 1983 (UCCND 1983a, 1983b). The Task 2 report documents the third major effort to estimate Y-12 mercury releases. (See Section III.B.1 for a more detailed discussion of the report.) The Task 2 report did not revisit all of the previous inventory estimates, but it revised the previous estimates of mercury releases to the air and water.

The estimates of mercury inventories and releases to air and water in all three of these reports focused on the lithium enrichment production years (1953–1963).

The 1977 and 1983 mercury inventory estimates are presented in Table 5. Table 5 does not include the increased quantities of mercury released to the water and air that Task 2 estimated. The Task 2 team's estimates of the quantities of mercury lost to water and air were 40,000 pounds and 22,000 pounds greater, respectively, than the 1983 Mercury Task Force estimates (ChemRisk 1999a).

As shown in Table 5, a large amount of the mercury originally received at the Y-12 plant is unaccounted for. Table 5 distinguishes between what is lost and what is not accounted for. The term "lost" includes the quantities of mercury that were estimated to have gone into the air, soil, and water. The term "not accounted for" is arrived at by subtraction. It describes mercury quantities received at the plant that could not be accounted for in either the lost quantities (to air, water, and soil) or the remaining inventory of products and unused mercury. Personnel who wrote the 1983 Mercury Task Force Report estimated that over 700,000 pounds of mercury were lost to the environment and an additional 1,290,000 pounds of mercury were not accounted for (UCCND 1983a, 1983b).

In interviews with former workers, the 1983 Mercury Task Force identified possible explanations that might account for about half of the 1,290,000 pounds of mercury that was not accounted for.[5] It estimated that perhaps 500,000 pounds of the mercury "not accounted for" was never received, and that this discrepancy is a result of accounting errors. Mercury came into the plant in 76-pound flasks. But the mercury was not accounted for by weight; it was accounted for by the numbers of flasks (i.e., the amount of mercury coming into the plant was estimated by the number of flasks times 76 pounds). People who worked at the plant said that at times flasks that were leaking or not completely full would arrive at the plant. Thus, the 1983 Mercury Task Force Report suggested it was likely that the accounting practice for recording the incoming amount of mercury overestimated the true inventory. The 1983 Mercury Task Force also estimated that another 60,000 pounds of mercury was unaccounted for in the production building walls, floors, ceilings, and insulation (UCCND 1983a, 1983b). This rough estimate was based on a 1975 U.S.EPA study of mercury use in the chloralkali industry. The 1983 Mercury Task Force authors emphasized that these figures were speculative.

Including the Task 2 revisions, approximately 1,230,000 pounds of mercury that were vouchered into inventory during the lithium separation production years (1953–1963) are not accounted for. This is still larger by more than half than the amount of mercury that Task 2 estimated was lost to the environment (795,000 pounds; ChemRisk 1999a). Several theories might explain why the mercury inventories have not been accounted for, and the 1983 Mercury Task Force Report identifies some of them. Nevertheless, it's more likely that these discrepancies will never be confidently accounted for. More mercury might have been released to the environment than the Task 2 team estimated.

[5] The 1983 Mercury Task Force Report only presents two explanations that may account for 560,000 pounds. The report is silent on the other 85,000 pounds that it says it identified explanations for.

Table 5. 1977 and 1983 Mercury Material Balance Estimates by Y-12 Plant Staff

Source of Material Inventory and Losses	*1977 Mercury Inventory Report*	*1983 Mercury Task Force Report*
VOUCHERED to Y-12:	24,321,000	24,348,852
Returned unopened or rebottled and stored/sold	*	21,666,348
In lithium hydroxide tails, sold and stored	1,000	1,400
In Building 9201-5 scrap, sold	10,000	14,000
In Building 9201-5 sludge, removed and sold	111,000	174,000
As flasking overage given to GSA	12,000	17,212
In Building 9201-4 equipment, still in place	*	200,000
In sludges and sumps in Alpha-4 Building	100,000	250,000
In Building 9201-2 sewer pipe	**	800
ACCOUNTED FOR Total:	*	22,323,796
Known LOST and NOT ACCOUNTED FOR Total:	2,437,752	2,025,056
Known lost to air	30,000	51,300
Known lost to East Fork Poplar Creek	470,000	238,944
Known lost to New Hope Pond sediment, Chestnut Ridge	7,200	6,629
Known lost to New Hope Pond sediments now in place	**	8,475
Known lost to ground, Building 9201-5 spill accident	49,853	49,853
Known lost to ground, seven other spills	**	375,000
Known lost to ground, Building 81-10 operations	**	3,000
Known LOST Total:	557,053	733,201
NOT ACCOUNTED FOR Total:	1,880,699	1,291,855

Source: ChemRisk 1999a
* These data were classified for security reasons in 1977.
** Data not available in 1977 report.
Task 2 included the 1983 Mercury Task Force statement that the numbers are not known to the one pound level. However, the calculated values were retained "for accounting purposes."

III.B.1. The Oak Ridge Dose Reconstruction Project

In 1991, the State of Tennessee and DOE entered into the Oak Ridge Health Agreement. The agreement's purpose was to investigate health risks to off-site populations from past ORR-related releases of hazardous substances to the environment. TDOH administered The Oak Ridge Health Agreement for the State of Tennessee. As a part of the Oak Ridge Health Agreement, TDOH conducted the Oak Ridge Health Studies. The studies' purpose was to evaluate whether off-site populations were exposed to ORR-related chemical and radiological releases and to assess the risk posed by off-site exposures. The TDOH Commissioner appointed a 12-member panel—the Oak Ridge Health Agreement Steering Panel (ORHASP)—to direct and oversee the Oak Ridge Health Studies and to promote community interaction and cooperation.

McLaren/Hart-ChemRisk (referred to as ChemRisk) was hired to conduct Phase I of the Oak Ridge Health Studies—the feasibility study—which it did during 1992 and 1993. Using the feasibility study, ORHASP and TDOH recommended dose reconstruction for

- Radioactive iodine releases from the X-10 site (Task 1),
- Mercury releases from the Y-12 plant (Task 2),
- Releases of PCBs (Task 3), and
- Radionuclides released from the X-10 site to the Clinch River via White Oak Creek (Task 4).

ORHASP and TDOH also recommended

- Screening evaluations of Y-12 and K-25 uranium releases (Task 6), and
- A screening-level evaluation of additional materials of potential concern (Task 7).

Task 5 was an additional task comprising a systematic review of historical records to support the other six tasks. Phase II of the Oak Ridge Health Studies—the Oak Ridge Dose Reconstruction Project—began in late 1994 and was completed in July 1999.

The Task 2 report estimated and evaluated exposures to past releases (1950–1990) of mercury from the ORR. TDOH and ORHASP expended a great amount of work, resources, oversight, and peer review on the Oak Ridge mercury dose reconstruction (Task 2). Drawing on the comments from ATSDR's technical reviewers of the mercury dose reconstruction (see Section III.B.2, ATSDR decided that it would not attempt to reproduce the dose reconstruction work. It would use the results of the Task 2 mercury dose reconstruction to assess past exposures to mercury for its public health assessment.

In particular, Task 2 amassed and reviewed a large amount of data and a large number of documents. These data and documents described mercury inventories and releases, which formed the basis of the source terms used to estimate past environmental mercury concentrations. Thus further investigation of archived data would not substantially improve the Task 2 estimates of the mercury source terms. Secondly, the dispersion models used to estimate mercury concentrations in air and water are standard models—ATSDR would use the same or similar dispersion models. Therefore, without substantial new information about past releases of mercury, newly discovered historical environmental sampling data or meteorological data—none of which ATSDR presently has—ATSDR would not likely improve on the basic elements of the Task 2 mercury dose reconstruction.

III.B.2. ATSDR's Technical Review of the Task 2 Report

Although source terms and dispersion models are not easily subjected to external analysis, ATSDR can review many other assumptions go into dose estimation. In choosing to adopt the Task 2 results for its public health assessment, ATSDR recognizes that dose reconstruction is a technical investigation fraught with much uncertainty. Therefore, ATSDR wanted an additional round of expert review of the Task 2 report. Rather than attempting to reproduce the work or the results of the mercury dose reconstruction for its public health assessment, ATSDR believes that an independent expert review of the Task 2 report assumptions offers the best insight into the validity and usefulness of the Task 2 results for making public health decisions.

In 2001, ATSDR contracted with ERG to select five expert technical reviewers to determine whether the Task 2 report provides a foundation on which ATSDR can base its mercury public health assessment for the ORR and surrounding communities. The reviewers were asked to comment on the study design, methods, and completeness of the mercury dose reconstruction, as well as the conclusions of the report's authors. The reviewers read the entire dose reconstruction document on mercury releases, including appendices, and the appropriate sections of the steering panel document. ERG received the reviewer comments and compiled and summarized them for ATSDR in June 2001.

The five outside technical experts reviewed the following documents:

- Reports of the Oak Ridge Dose Reconstruction, Volumes 2 and 2A: The Report of Task 2 – July 1999.
- Mercury Releases from Lithium Enrichment at the Oak Ridge Y-12 Plant—a Reconstruction of Historical Releases and Off-Site Doses and Health Risks (submitted to the Tennessee Department of Health by ChemRisk) (ChemRisk 1999a).
- Releases of Contaminants from Oak Ridge Facilities and Risks to Public Health, report of the Oak Ridge Health Agreement Steering Panel (ORHASP 1999).

In July 2003, ATSDR released the compilation and summary of the reviewer comments to the public. The document is titled, "Comments by Technical Reviewers on the Oak Ridge Dose Reconstruction - Task 2 Report, Volume 2: Mercury Releases from Lithium Enrichment at the Oak Ridge Y-12 Plant - a Reconstruction of Historical Releases and Off-Site Doses and Health Risks, July 2003." The Task 2 report and the Comments by Technical Reviewers report were discussed in meetings of the Public Health Assessment Work Group (PHAWG) of the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) from July through December 2003. The PHAWG considered the merits and shortcomings of the two reports in supporting the conclusions and recommendations of this public health assessment.

III.C. Evaluation of Current (1990–2009) Mercury Exposure Pathways

III.C.1. Exposure Evaluation

What is meant by exposure?

An exposure pathway has five elements: (1) a source of contamination, (2) an environmental media, (3) a point of exposure, (4) a route of human exposure, and (5) a receptor population.

The source is the place where the chemical or radioactive material was released. The environmental media (such as, groundwater, soil, surface water, or air) transport the contaminants. The point of exposure is the place where persons come into contact with the contaminated media. The route of exposure (for example, ingestion, inhalation, or dermal contact) is the way the contaminant enters the body. The people actually exposed are the receptor population.

Exposure or contact drives ATSDR's public health assessments. Contaminants (chemicals or radioactive materials) released into the environment have the potential to cause harmful health effects. Nevertheless, a release does not always result in exposure. People can only be exposed to a contaminant if they come into contact with it. If no one comes into contact with a contaminant, no exposure occurs, and no health effects occur. Often the public does not have access to the source area of contamination or areas where contaminants move through the environment. This lack of access becomes important in determining whether people could come into contact with the contaminants.

The route of a contaminant's movement is the pathway. ATSDR identifies and evaluates exposure pathways by considering how people might come into contact with a contaminant. An exposure pathway could involve air,

surface water, groundwater, soil, dust, or even plants and animals. Exposure can occur by breathing, eating, drinking, or by skin contact with the chemical contaminant.

How does ATSDR determine which exposure situations to evaluate?

ATSDR scientists evaluate site-specific conditions to determine whether people are exposed to site-related contaminants. When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (soil, water, air, waste, 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. ATSDR selects contaminants for further evaluation by comparing environmental contaminant concentrations against health-based comparison values. ATSDR develops comparison values from available scientific literature on exposure and health effects. Comparison values are derived for each of the media and reflect an estimated contaminant concentration 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.

ATSDR uses comparison values to screen chemicals that require additional evaluation.

Comparison values are not thresholds for harmful health effects. ATSDR comparison values represent contaminant concentrations many times lower than levels at which no effects were observed in studies on experimental animals or in human epidemiologic studies. 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 toxicology of the contaminant, other epidemiology studies, and the weight of evidence. Figure 9 illustrates ATSDR's chemical screening process.

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 the agency at 1-800-CDC-INFO (1-800-232-4636).

Figure 9. ATSDR Chemical Screening Process

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	Decision Diagram	Illustration	Criteria
Pathway Evaluation	Chemicals detected in environmental media YES Are there completed and/or potential exposure pathways where chemicals have been detected? NO → Not a contaminant of concern	Chemicals Exposure Pathways	• Based on the results of environmental investigations • Can or are exposures occurring? • Identify potential or completed exposure pathways
Preliminary Screening	YES Are the chemical concentrations higher than medium-specific comparison values? NO → Not a contaminant of concern	Medium-Specific Comparison Values	• Based on maximum exposure conditions – maximum concentration detected – maximum exposure duration – maximum exposure frequency – maximum exposure bioavailability
Exposure Dose Comparison	YES Are estimated exposure doses higher than screening guidelines? NO → Not a contaminant of concern	Screening Guidelines	• Estimate doses based on site-specific exposure conditions • Use more realistic exposure assumptions – realistic concentrations – realistic exposure duration – realistic exposure frequency – realistic exposure bioavailability
Contaminants of Concern	YES Contaminants of concern		• Evaluate the public health implications of contaminants of concern in greater detail
Public Health Implications	YES Evaluate 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

If people are exposed, will they get sick?

Exposure does not always result in harmful health effects. The type and severity of health effects in a person as the result of contact with a contaminant depend on several factors:

- Exposure concentration (how much),
- Frequency (how often) and duration of exposure (how long),
- Route or pathway of exposure (breathing, eating, drinking, or skin contact), and
- Multiplicity of exposure (combination of contaminants).

Once exposure occurs, characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status of the exposed person influence how that person 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 contaminant in the environment.

III.C.2. Evaluating Exposures

ATSDR evaluated available, current data to determine whether mercury concentrations were above ATSDR's comparison values. ATSDR also reviewed relevant toxicologic and epidemiologic data about mercury toxicity. It's important to remember that exposure to a contaminant does not always result in harmful health effects. The type and severity of health effects expected to occur depends on the exposure concentration, the toxicity of the contaminant, the frequency and duration of exposure, and the multiplicity of exposures.

Comparing Environmental Data to Comparison Values

Concentrations are compared to comparison values to determine which contaminants need to be further evaluated. Comparison values are concentrations derived using conservative exposure assumptions and health-based doses. Comparison values reflect concentrations much lower than those found 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 do not warrant health concern**. While concentrations at or below the relevant comparison value can reasonably be considered safe, it does not automatically follow that any environmental concentration exceeding a comparison value would be expected to produce adverse health effects. The fact that comparison values are not thresholds of toxicity cannot be emphasized strongly enough. **If contaminant concentrations are above comparison values, ATSDR further analyzes exposure variables (for example, duration and frequency of exposure), the toxicology of the contaminant, other epidemiology studies, and the weight of evidence for health effects.** The likelihood that adverse health outcomes will actually occur depend on site-specific conditions and individual lifestyle that affect the route, magnitude, and duration of actual exposure, as well as current health condition (e.g., chronic health conditions) and genetic factors. An environmental concentration alone will not cause an adverse health outcome.

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

Overestimated values are considered conservative.

When evaluating chemical effects of mercury exposure, ATSDR scientists used comparison values specific to each environmental media. The comparison values used are shown in Table 6.

Table 6. Comparison Values for Mercury

Media	*Comparison Value*	*Source*
Air	0.0002 mg/m^3	Chronic EMEG for elemental mercury
Surface Water	2 μg/L	LTHA/MCLG for inorganic mercury
Soil/Sediment	20 mg/kg	Child RMEG for mercuric chloride
Fish	0.14 mg/kg	RSL for methylmercury

EMEG: ATSDR's environmental media evaluation guide
LTHA: U.S.EPA's lifetime health advisory
MCLG: U.S.EPA's maximum contaminant level goal
μg/L: microgram per liter (parts per billion or ppb)
mg/kg: milligram per kilogram (parts per million or ppm)
mg/m^3: milligram per cubic meter
RMEG: ATSDR's reference dose media evaluation guide
RSL: U.S.EPA's regional screening level

ATSDR's environmental media evaluation guide (EMEG) is a compilation of nonenforceable, health-based comparison value developed for screening environmental contamination for further evaluation. ATSDR's reference dose media evaluation guide (RMEG) is a lifetime exposure level at which adverse, noncarcinogenic health effects would not be expected to occur. U.S.EPA's regional screening level (RSL) is a health-based comparison value. Concentrations are above the RSL may warrant further investigation or site cleanup. The lifetime health advisory (LTHA) is the concentration of a chemical in drinking water not expected to cause any adverse noncarcinogenic health effects for a lifetime of exposure. U.S.EPA's maximum contaminant level goal (MCLG) is the risk-based level of a contaminant that may be present in drinking water under the Safe Drinking Water Act. The MCLG for mercury is the same as the enforceable maximum contaminant level (MCL).

III.C.3. Comparing Estimated Doses to Health Guidelines

Deriving exposure doses

Exposure doses are expressed in milligrams of mercury per kilogram of body weight per day (mg/kg/day). When estimating 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 a person'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 conservative exposure assumptions to estimate exposures.

An exposure dose is the amount of chemical a person is exposed to over a specified period of time.

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 in parts per million (ppm, which is also mg/kg)

IR = Intake Rate—varies with media[§]
EF = Exposure Frequency, or number of exposure events per year of exposure—varies with media[§]
ED = Exposure Duration, or the duration over which exposure occurs: adult = 70 years; child = 6 years
BW = Body Weight: adult = 70 kg; child = 28.1 kg (mean weight of an 8-year-old child; EPA 1997)
AT = Averaging Time, or the period over which cumulative exposures are averaged: adult = 70 years*365 days/year; child = 6 years*365 days/year

[§] The ingestion rate and exposure frequency factors are different for each media (e.g., air, soil, water). These assumptions are described during the media-specific health evaluations.

Using health guidelines to evaluate potential health hazards

Noncancer effects

ATSDR analyzes the weight of evidence of available toxicologic, medical, and epidemiologic data to determine whether exposures might be associated with harmful health effects. As part of this process, ATSDR examines relevant health effects data to determine whether estimated doses are likely to result in harmful health effects. As a first step in evaluating noncancer effects, ATSDR compares estimated exposure doses to conservative health guideline values, including ATSDR's minimal risk levels (MRLs) and U.S.EPA's reference doses (RfDs). MRLs and RfDs are based on noncancer health effects only. Proposed MRLs undergo a rigorous scientific review process:

- Health Effects/MRL workgroup,
- Reviews within ATSDR's Division of Toxicology;
- Expert panel of external peer reviews; and
- Agency-wide MRL workgroup reviews, with participation from other federal agencies, including U.S.EPA;

The MRLs are then submitted for public comment. MRLs are derived when data are sufficiently reliable to identify the target organs of effect or the most sensitive health effects for a specific duration for a given route of exposure.

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

The LOAEL is the lowest tested dose of a substance in a study that has been reported to cause harmful (adverse) health effects in people or animals.

Proposed RfDs also undergo rigorous internal and external peer reviews and are submitted for agency consensus, technical editing, and quality assurance.

MRLs and RfDs are estimates of the daily human exposure to a hazardous substance likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure. These substance-specific estimates, which are intended to serve as screening levels, are used to rule out contaminants at levels that are not expected to cause

adverse health effects. It is important to note that MRLs are not intended to define clean-up or action levels. MRLs are intended only to serve as a screening tool to help public health professionals decide where to look more closely.

MRLs and RfDs are derived for hazardous substances using the no-observed-adverse-effect level (NOAEL)/lowest-observed-adverse-effect level (LOAEL)/uncertainty factor approach. They are below levels that might cause adverse health effects in the people most sensitive to such effects. Most MRLs and RfDs contain a degree of uncertainty because of the lack of precise toxicologic information on the 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. Consistent with the public health principle of prevention, ATSDR uses a conservative (that is, protective) approach to address this uncertainty.

MRLs and RfDs are generally based on the most sensitive noncancer end point considered of relevance to humans. Exposure to levels above the MRL or RfD does not mean that adverse health effects will occur. Estimated doses less than these values are not considered of health concern. To maximize human health protection, MRLs and RfDs have built-in uncertainty or safety factors, making these values considerably lower than levels at which health effects have been observed. The result is that even if a dose is higher than the MRL or RfD, it does not necessarily follow that harmful health effects will occur.

Table 7 shows the MRLs and RfDs developed for the different forms of mercury. Also, see Figure 10 for levels of significant exposure to elemental mercury, Figure 11 for levels of significant exposure to inorganic mercury, and Figure 12 for levels of significant exposure to organic mercury. More detailed information is available in ATSDR's Toxicological Profile for Mercury (ATSDR 1999) and U.S.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 (EPA 1993, 1995, 2002c). ATSDR's toxicological profile for mercury is available on the Internet at http://www.atsdr.cdc.gov/toxprofiles/tp46.html or by contacting the National Technical Information Service (NTIS) at 1-800-553-6847. IRIS is available on the Internet at http://www.epa.gov/iris. For more information about IRIS, please call U.S.EPA's IRIS hotline at (202) 566-1676 or send an e-mail to hotline.iris@epa.gov. Additional information is provided in Appendix D. Toxicologic Implications of Mercury Exposure.

If health guideline values are exceeded, ATSDR examines the health effects 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 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 (known as the margin of exposure). 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.

When comparing estimated exposure doses to actual health effects levels in the scientific literature, ATSDR estimates doses based on more realistic, site-specific, exposure scenarios to use for comparison. In this level of the evaluation, an average concentration is used to calculate exposure doses to estimate a more probable exposure. This approach is taken because it is highly unlikely that anyone would contact the maximum concentration on a daily basis and for an extended period of time.

Cancer effects

Animal studies provide limited information about whether mercury causes cancer in humans (ATSDR 1999). U.S.EPA has determined that mercuric chloride and methylmercury are possible human carcinogens (EPA 2011a, 2011b). International Agency for Research on Cancer (IARC) has determined that methylmercury compounds are possibly carcinogenic to humans (Group 2B), and metallic mercury and inorganic mercury compounds are not classifiable as to their carcinogenicity to humans (Group 3) (IARC 1997). The National Academy of Sciences (NAS) concluded that studies on carcinogenic effects in humans are inconclusive (NRC 2000). Some studies observed an increase in incidence of renal tumors in male mice from chronic exposure to methylmercury, however, that effect was observed only at doses that were toxic to the kidney and is thought to be secondary to cell damage and repair. Exposure to methylmercury did not increase tumor rates in female mice or rats of either sex (NRC 2000). Therefore, the focus of methylmercury exposure in this health assessment will be on the most sensitive endpoint for methylmercury toxicity (i.e., noncancer neurodevelopmental health effects).

1 **Table 7. Health Guidelines for the Forms of Mercury**

	Elemental Mercury	*Inorganic Mercury*	*Organic Mercury*
Example	Metallic mercury	Mercuric sulfide	Methylmercury
Primary exposure pathway	Inhalation (air)	Ingestion (soil, sediment, surface water, plants)	Ingestion (fish)
Primary target organ	Central nervous system and kidneys	Kidneys	Developmental effects in offspring
Acute MRL	Not available	0.007 mg/kg/day	Not available
Dose and Endpoint	There are no NOAELs. The lowest serious LOAEL is 0.05 mg/m^3 in rats (hyperactive offspring, significantly impaired spatial learning).	NOAEL; No renal effects were observed in rats administered 0.93 mg/kg/day once daily for 14 days, excluding weekends.	The highest NOAEL is 24 mg/kg/day in mice. The lowest less serious LOAEL is 0.0012 mg/kg/day in human infants (delayed walking, abnormal motor scores).
Source	Fredriksson et al. 1992	NTP 1993	Yasutake et al. 1991; Cox et al. 1989
Intermediate MRL	Not available	0.002 mg/kg/day	Not available
Dose and Endpoint	The highest NOAEL is 3.0 mg/m^3 in rats. The lowest less serious LOAEL is 0.17 mg/m^3 in mice (serum antinucleolar antibodies).	NOAEL; No renal effects were observed in rats administered 0.23 mg/kg/day 5 days a week for 26 weeks.	The highest NOAEL is 0.84 mg/kg/day in rats. The lowest less serious LOAEL is 0.0012 mg/kg/day in human infants (delayed walking, abnormal motor scores).
Source	Kishi et al. 1978; Warfvinge et al. 1995	NTP 1993	Magos and Butler 1972; Cox et al. 1989
Chronic MRL/RfD	0.0002 mg/m^3 (MRL)	0.0003 mg/kg/day (RfD)	0.0003 mg/kg/day (MRL) 0.0001 mg/kg/day (RfD)
Dose and Endpoint	LOAEL; Increased frequency of hand tremors were observed in male workers exposed to doses of 0.026 mg/m^3 for about 15 years.	LOAELs; Autoimmune effects were observed in rats exposed to doses of 0.226, 0.317, and 0.633 mg/kg/day. U.S.EPA notes that the oral RfD was "arrived at from an intensive review and workshop discussions of the entire inorganic mercury data base."	MRL NOAEL; No adverse effects were observed in over 700 mother-infant pairs exposed to doses of 0.0013 mg/kg/day in fish for 66 months. RfD LOAEL; A 5% increase in neurodevelopmental effects were observed in the 7-year-old offspring of 900 mothers with a benchmark dose lower limit (BMDL05) range of 46 to 79 ppb methylmercury in maternal cord blood. This BMDL05 equates to doses of 0.000857-0.001472 mg/kg/day. NAS health effect level; A 5% increase in abnormal scores on Boston Naming Test was observed in offspring of mothers with a BMDL of 58 ppb methylmercury in maternal blood cord. The BMDL equates to a dose of 0.0011 mg/kg/day.
Source	Fawer et al. 1983	Druet et al. 1978; Bernaudin et al. 1981; Andres 1984	Davidson et al. 1998; Grandjean et al. 1997; NRC 2000

Figure 10. Levels of Significant Exposure to Elemental Mercury

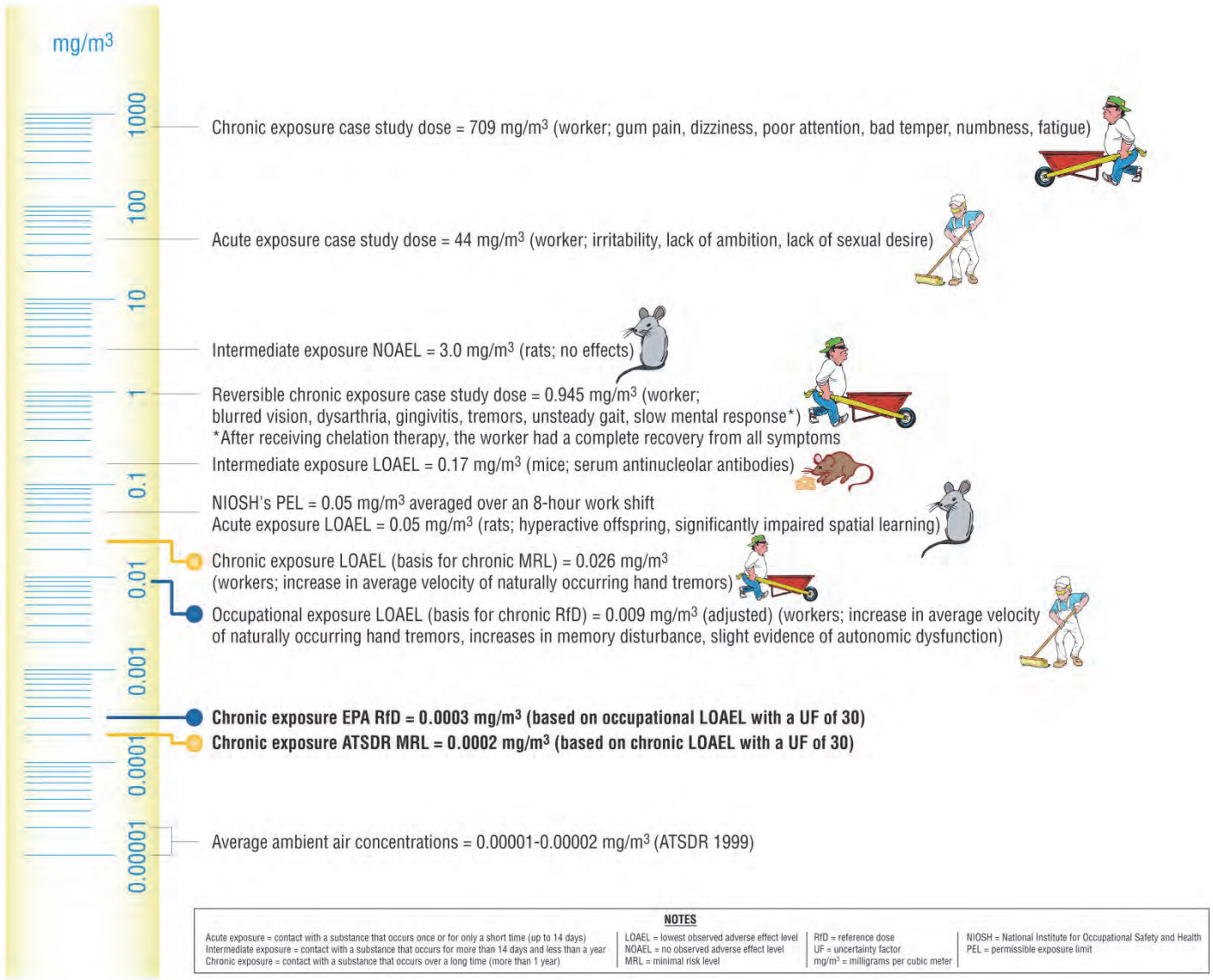


Figure 11. Levels of Significant Exposure to Inorganic Mercury

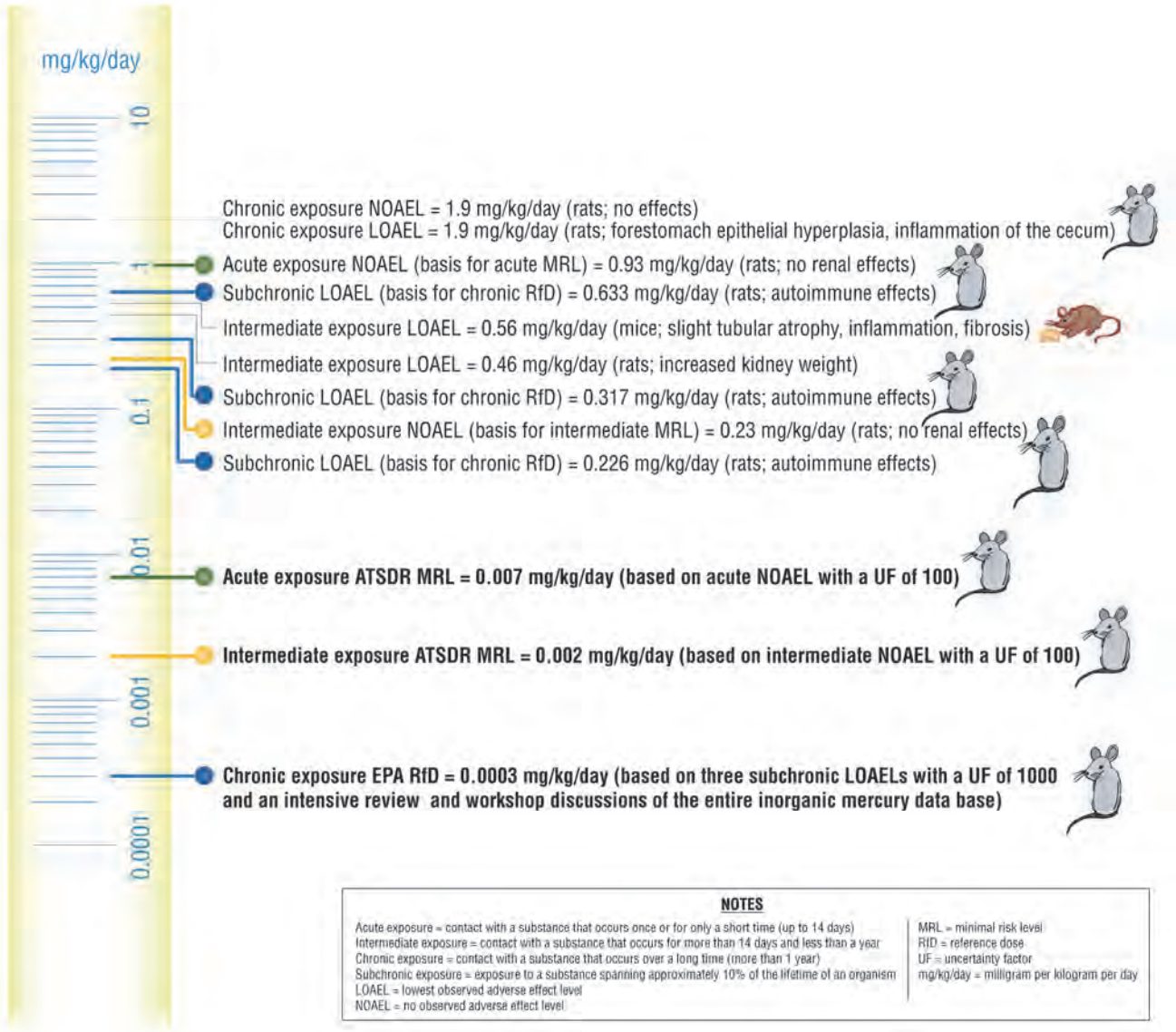
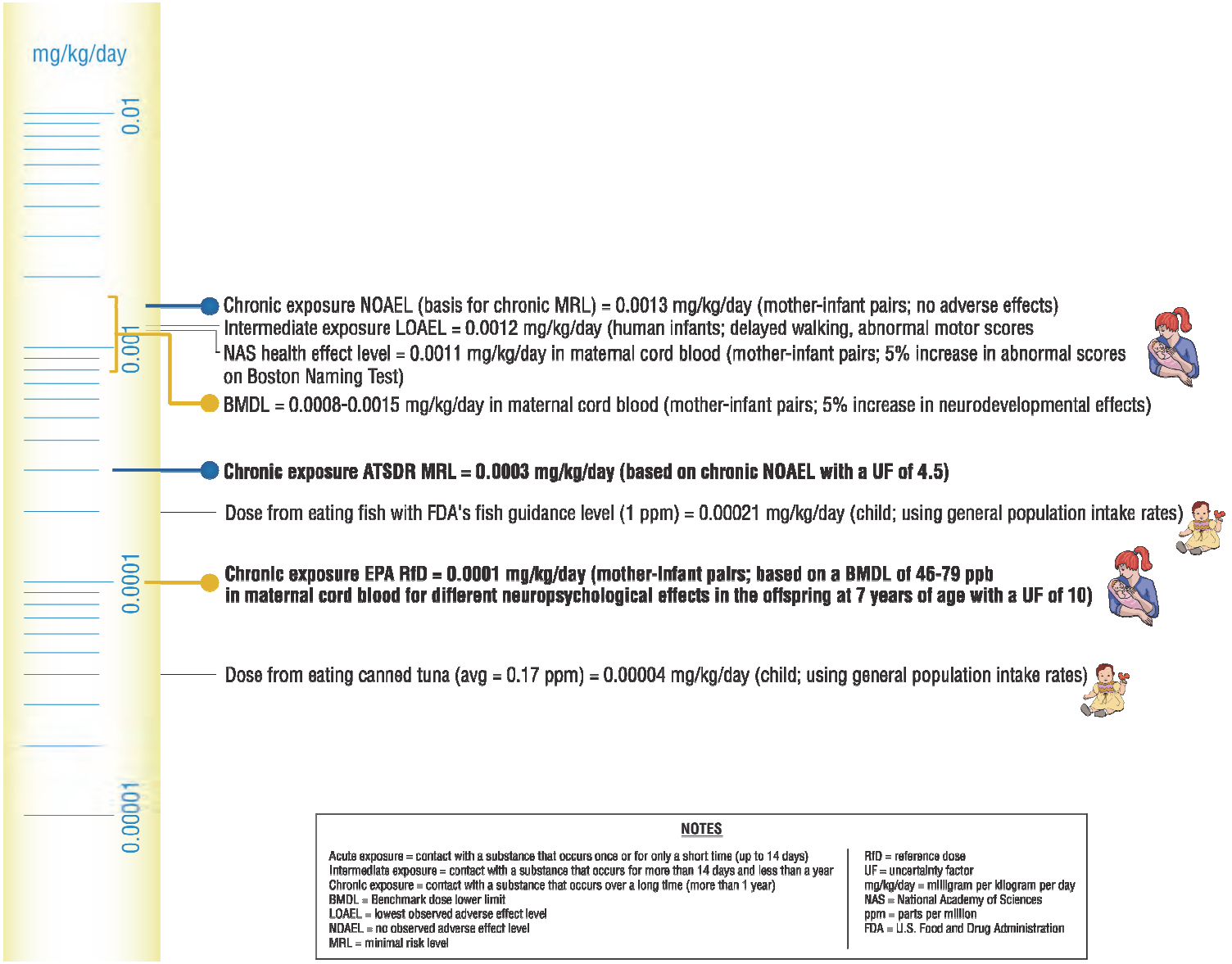


Figure 12. Levels of Significant Exposure to Organic Mercury



IV. Public Health Evaluation

IV.A. Past Exposure (1950–1990)

IV.A.1. Potentially Exposed Communities

The potentially exposed communities ATSDR used to evaluate exposures to past mercury releases from the Y-12 operations are the same as those selected in the Task 2 report (ChemRisk 1999a), namely Wolf Valley residents, Scarboro community residents, Robertsville school children, East Fork Poplar Creek farm families, Oak Ridge community residents (two populations), and several fish consumer populations who ate fish from Watts Bar Reservoir, Clinch River/Poplar Creek, and EFPC (see Table 8 and Figure 13).

Table 8. Task 2 Exposure Pathways for Which Mercury Doses were Estimated for Each Potentially Exposed Community

Exposure Pathway	Mercury Species	Wolf Valley Resident	Scarboro Community Resident	Robertsville School–General Student	Robertsville School–Student Recreator	EFPC Floodplain Farm Family	Oak Ridge Community Populations (2)	Clinch River/Poplar Creek Fish Consumer	Watts Bar Reservoir Fish Consumer
Air pathways									
Inhalation	Elemental	X[a]	X[b]	X[c]	X[c]	X[c]	X[c]		
Fruit/vegetable consumption	Inorganic	X[a]	X[b]			X[c]	X[c]		
Milk consumption	Inorganic	X[a]				X[c]			
Beef consumption	Inorganic	X[a]				X[c]			
Soil pathways									
Soil ingestion	Inorganic		X	X	X	X			
Skin contact with soil	Inorganic		X	X	X	X			
Vegetable consumption	Inorganic		X			X			
Milk consumption	Inorganic					X			
Beef consumption	Inorganic					X			
Sediment pathways									
Sediment ingestion	Inorganic		X		X	X			
Skin contact with sediment	Inorganic		X		X	X			
Surface water pathways									
Incidental ingestion of water	Inorganic		X		X	X			
Skin contact with water	Inorganic		X		X	X			
Milk consumption	Inorganic								
Beef consumption	Inorganic								
Fish consumption	Methylmercury		X			X		X	X

Source: ChemRisk 1999a

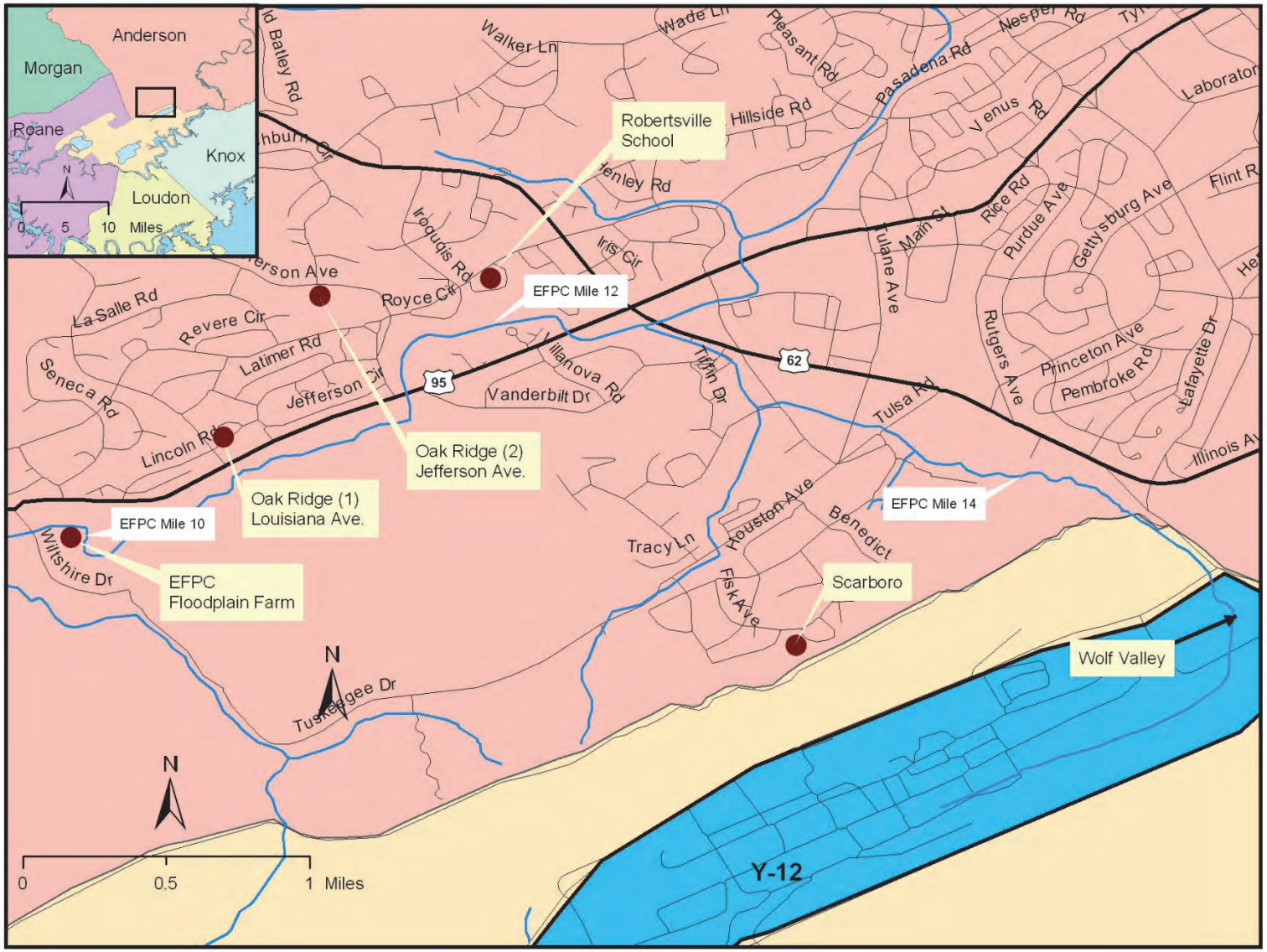
Xs indicate that the exposure pathway was evaluated for the potentially exposed community.

[a] Evaluated for direct airborne releases of mercury from the Y-12 plant.

[b] For 1953–1962, evaluated for both direct airborne releases of mercury from the Y-12 plant and volatilization of mercury from EFPC; for the remaining years, evaluated for volatilization of mercury from EFPC only.

[c] Evaluation for volatilization of mercury from EFPC only.

Figure 13. Task 2 Potentially Exposed Communities



IV.A.2. Past Air Exposure Pathway

Task 2 Estimated Y-12 Mercury Releases to Air

When lithium separation studies began at the Y-12 plant, mercury was known to pose a health hazard to people who inhaled mercury vapors. Y-12 personnel were concerned about indoor air mercury concentrations; they made efforts to reduce and maintain indoor air mercury concentrations below the acceptable worker standard at the time (0.1 mg/m^3). Engineering controls, such as the installation of large high-speed exhaust fans in the buildings, helped to reduce indoor air mercury concentrations, but possibly increased mercury vapor releases off site. Other modifications, such as resurfacing indoor building walls to reduce microscopic mercury adhesion and flooding building floors with water or sodium thiosulfate solutions to suppress the vaporization of spilled mercury, would have decreased the indoor air mercury concentrations, as well as the release of mercury to the outdoors.

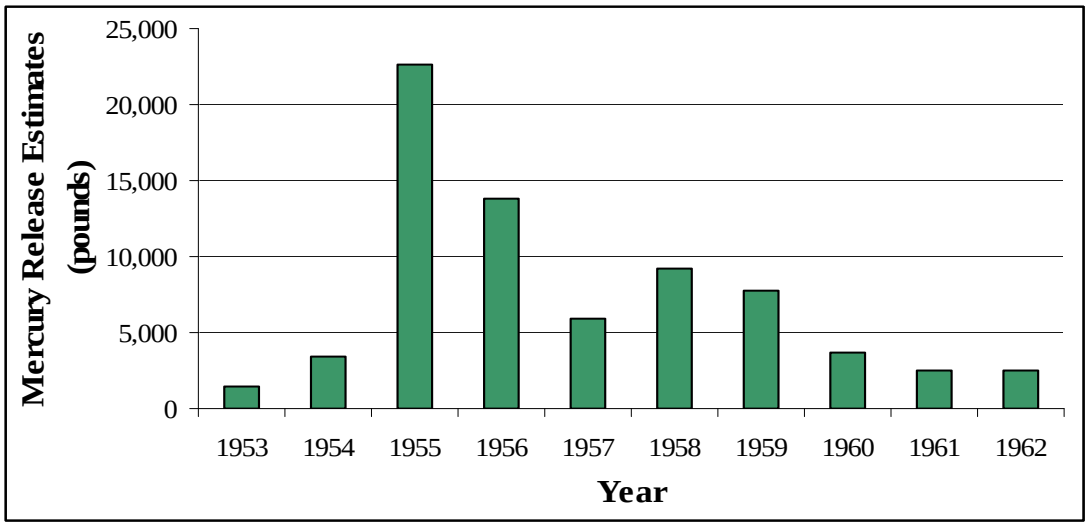
Airborne mercury contaminants at the Y-12 plant may have occurred as a result of primary operations and accidental releases. Information pertaining to air mercury releases is largely based on available statistics regarding process operations, accidents, on-site and off-site release monitoring data, and air dispersion modeling.

Three investigation teams (1977 Mercury Task Force, 1983 Mercury Task Force, and Task 2 team) independently estimated air mercury releases from the Y-12 plant. Specifically, Task 2 studied building engineering reports that included flow and ventilation diagrams, exhaust measurements, and information on the upgrade of ventilation systems. Task 2 also gathered hundreds of weekly-, monthly-, and quarterly-average indoor air measurements that were only made in some of the pilot and production buildings for a select period of time during lithium isotope separation operations. To compensate for missing data, air concentrations and flow rates were estimated, based on similar conditions in buildings where measurements had been made.

Task 2 identified 114 point sources that included 62 stacks, 43 fans, and 9 vents on 9 buildings. The buildings included three main production facilities, three steam plants, a mercury storage warehouse, a scrap metal furnace, and Building 81-10, which housed the mercury recovery furnace.[6] A separate source term was estimated for each point source for each year that the source was known to have been in operation (1953–1962). Air source terms are expressed in units of mass per unit time. Task 2 estimated that a total of 73,000 pounds of mercury had been released from Y-12 operations during the 11 years of lithium isotope separation activities (see Figure 14). This represents a 43 percent increase over the 1983 Mercury Task Force estimates. None of the three investigation teams estimated Y-12 air mercury releases for the years before or after the 1953–1962 operational time period.

[6] Building 81-10 was a facility at Y-12 designed to recover mercury from waste sludge materials through draining and evaporation. Air releases from the furnace occurred because of incomplete condensation of evaporated mercury. The furnace in Building 81-10 operated from March 1957 through July 1962, and physical separations continued through September 1982. More than 3 million pounds of mercury were recovered from waste materials in Building 81-10.

Figure 14. Task 2 Estimated Mercury Releases to Air from Y-12 Operations (1953–1962)



Source: ChemRisk 1999a

ATSDR scientists did not attempt to verify or reproduce the Task 2 air source terms—that work is beyond the scope of this public health assessment. Consequently, the quality of the Task 2 air mercury source terms was not evaluated. But confidence in those estimates is high: three separate teams have studied the applicable records over the years. As a result, each team has made contributions to our understanding of the activities at the Y-12 plant that resulted in air mercury releases. ATSDR accepts the Task 2 air mercury source terms with one reservation—Task 2 stated that it did not develop a source term for certain mercury spills to soil "because any mercury runoff to EFPC within the plant boundary and before the [water] sampling location would have been included in the mercury concentrations measured [in water] at the site boundary." All the mercury spills to soil, however, did not go into EFPC.

Some mercury spills to the ground were routed to the storm sewer system, which fed into EFPC. In 1957, after the mercury recovery furnace was constructed in Building 81-10, some mercury spills were removed and taken to the furnace. But no estimates are available of how long mercury from any spill was on the ground and how long that mercury emitted vapors before it was contained or removed. The percent recovery of mercury after some of the spills was low. The 1983 Mercury Task Force estimated that 85,000 pounds of mercury were "not recovered" after a major spill occurred outside between production buildings in 1956; and, 3,000 pounds of mercury were lost to the ground (as of 1971) at Building 81-10. In another example, shelves containing mercury flasks collapsed under the load inside a building and resulted in spilled mercury. It is not known whether indoor air measurements or window exhaust estimates reflected the effects from these types of incidents.

With no data to describe air releases from outdoor mercury spills, estimating air mercury releases from historic on-site mercury spills is not possible. In addition, Task 2 did not estimate air mercury releases from mercury spill to soils. The description of mercury spills suggests that they may have been a source of substantial air mercury releases, but spill information is not sufficient to estimate air concentrations and subsequent health effects.

Finally, Task 2 and the 1983 Mercury Task Force reported air mercury releases that were not used to develop the Task 2 source terms for Y-12 plant releases. For example, the K-25 powerhouse, near S-50, emitted 319 pounds of mercury annually from 1953 to 1961 and half that amount in 1962 (ChemRisk 1999a). The total air mercury releases for these years is approximately 4 percent of the total amount of the estimated air mercury releases from the Y-12 plant. Yet in individual years, the mercury released from the K-25 powerhouse was as much as 20 percent of the amount released from the Y-12 plant in 1953. The Task 2 team did not evaluate the impact of the K-25 air mercury releases to the Task 2 potentially exposed communities, presumably because the releases did not come from the Y-12 plant and the effect on the potentially exposed communities was thought to be insignificant.

Mercury Concentrations in Air

Significant releases of elemental mercury to air from the Y-12 plant occurred from1953 to 1963, the years of production-scale lithium separation activities. The peak Y-12 mercury releases to air occurred in 1955. Task 2 concluded that the volatilization of mercury from EFPC could have significantly contributed to air mercury concentrations near the EFPC floodplain. The evidence for this conclusion is the presence of elevated mercury concentrations in tree-core samples collected in 1993, from red cedars growing in the EFPC floodplain (near the location where East Tulsa Road crosses EFPC).

The primary exposure pathway to mercury in air is the direct inhalation of airborne elemental (or metallic) mercury. Other forms of mercury are not considered an inhalation hazard.

Moreover, mercury evasion from water is partly a function of the concentration of mercury in the water. The air above EFPC would have been an important source of mercury, primarily from1953 to 1963, when the Y-12 lithium separation program was active and Y-12 mercury releases to water were greatest. Peak Y-12 mercury releases to water occurred in 1957. Although releases of mercury to EFPC water did not cease when the lithium separation program ended, they decreased considerably. This was due to 1959 process changes and due to additional abatement efforts in later years. Total mercury concentrations decreased from a high of 14.5 milligrams per liter (mg/L) in effluent in 1958 to below 1 mg/L after 1962, and below 0.1 mg/L after 1974,[7] according to weekly measurements in EFPC at the Y-12 plant (ChemRisk 1999a).

But off-site mercury air exposures from the Y-12 plant have another important source. ATSDR has ample anecdotal information presented in public meetings that in the past Y-12 workers intentionally brought metallic mercury home with them (e.g., to show their children). Or they unintentionally brought mercury home on their work boots and clothing. In either case, it is very possibly mercury was lost or dispersed in homes and therefore posed an indoor air hazard. ATSDR has no quantitative data to evaluate the magnitude of this hazard in the communities surrounding the ORR. Still, elemental mercury has a high vapor pressure. And that air exposures to elemental mercury vapor indoors can be a greater hazard than outdoor air mercury exposures is well known today. Elemental mercury in a home is easily lost into carpeting, flooring, furniture, drapes, and other household materials. The body of literature identifying this hazard has grown in recent years. The possibility for adverse effects from breathing mercury vapor, particularly among children, can be significant. ATSDR believes this exposure pathway may have continued well beyond the years when the lithium isotope separation process ended in 1963.

[7] Data through 1982, though some values are missing.

Three Task 2 Models

The earliest off-site ambient air mercury concentrations were measured in 1986. Therefore, no air data are available from the years that air and water mercury releases from the Y-12 plant were highest. To compensate for the lack of data, Task 2 modeled the average annual air mercury concentrations for six potentially exposed communities in or near Oak Ridge (Table 9). Task 2 used three different models to estimate annual air mercury concentrations for each off-site community, depending on its location. (See Appendix E. Task 2 Pathway Discussions for a more detailed discussion of the three Task 2 air mercury models.)

Table 9. Three Task 2 Air Models and Potentially Exposed Communities

Potentially Exposed Communities	*U.S.EPA Dispersion Model*	*χ/Q Model*	*EFPC Volatilization Model*
Wolf Valley	X		
Scarboro Community		X	X
Robertsville School			X
EFPC Floodplain			X
Oak Ridge 1			X
Oak Ridge 2			X

Among the three models that Task 2 used, the U.S.EPA ISCST3 Dispersion Model and the χ/Q Model depend on the estimated air mercury releases during Y-12 operations. The third model, EFPC Volatilization, depends on the water mercury releases during Y-12 operations. One limitation of all three air models is that they produce average annual air mercury concentrations that cannot be used to evaluate acute exposures. Therefore, whether spills or other activities at the Y-12 plant resulted in mercury air plumes that caused short-term adverse health effects is unknown. The 1983 Mercury Task Force report listed these significant mercury spills:

- In1956, an estimated 180,000–400,000 pounds of mercury spilled
- In 1966, a spill totaled 105,000 pounds of mercury
- An undetermined number of spills occurred from 1951–1955 that exceeded 100,000 pounds of mercury (UCCND 1983a, 1983b).

These spills were not necessarily outdoors, and the mercury was not necessarily disposed of in the environment. Some of the mercury was recovered for reuse. But information is insufficient to determine whether any of these events—or others—could have led to air mercury concentrations off site that resulted in short-term adverse health effects. Task 2 estimated the average annual air mercury concentrations to evaluate chronic inhalation exposures.

U.S. EPA Dispersion Model

Among the three Task 2 models, the U.S.EPA Dispersion Model used to predict air concentrations in Wolf Valley is the only one about which ATSDR has no concerns. The Task 2 estimated air mercury concentrations in Wolf Valley ranged from 0.0000008 to 0.000014 milligrams per cubic meter (mg/m^3) for the 1953 through 1962 time period (ChemRisk 1999a). The peak value (0.000014 mg/m^3) was in 1955. Task 2 estimated that the uncertainty associated

with the modeled air concentrations in Wolf Valley was ± 44 percent of the true concentration values.

ATSDR compared the highest estimated mercury concentration in Wolf Valley (0.000014 mg/m^3) to the ATSDR chronic inhalation MRL for elemental mercury vapor (0.0002 mg/m^3). The highest annual concentration is more than 14 times lower than the ATSDR MRL. Even with the Task 2 uncertainty added, the upper-bound average concentration is 10 times lower than the ATSDR MRL. ATSDR concludes, then, that the mercury concentrations in the air in Wolf Valley were not expected to have posed a chronic public health hazard for the period of study. ATSDR cannot evaluate or draw a conclusion about acute, short-term exposures. Task 2 conducted an analysis of mercury doses to Wolf Valley residents and reached the same conclusion.

Chi over Q (χ/Q) Model

Task 2 used the "chi over Q" (χ/Q) Model and the EFPC Volatilization Model to estimate air mercury concentrations in the Scarboro community. The χ/Q Model is based on two physical quantities: the measured air uranium concentrations in Scarboro (χ) and uranium release rates from the Y-12 plant to the air (Q). The basis of this model is the assumption that air mercury releases from Y-12 will follow a physical pattern similar to air uranium releases from Y-12. But no evidence supports that assumption. ATSDR does not accept that the χ/Q model reliably predicted past air mercury concentrations in the Scarboro community.

EFPC Volatilization Model

Due to the volatilization of mercury from EFPC, Task 2 used the EFPC Volatilization Model to estimate air mercury concentrations for the following potentially exposed communities: Scarboro community, EFPC floodplain farm family, Robertsville School children, and two populations in Oak Ridge ("Oak Ridge 1" on Louisiana Avenue and "Oak Ridge 2" on Jefferson Avenue).

The Task 2 report suggests it used the EFPC Volatilization Model because of the absence of an adequate air dispersion model that could predict historic air mercury concentrations beyond Scarboro. Task 2 gave as an additional reason the presence of significant mercury levels in tree-core samples.

Task 2 had planned to use tree-ring mercury concentrations to estimate air mercury concentrations in the EFPC floodplain, but the tree core data collected in 1993 suggested that the mercury did not stay put in individual rings. Therefore, Task 2 could not reliably assign the measured mercury concentrations in specific tree rings to specific years. As a result, Task 2 abandoned its effort to estimate annual historic air mercury concentrations from tree core data.

The EFPC Volatilization Model estimated air mercury concentrations from the amount of mercury released from the Y-12 plant to the creek, the distance the mercury traveled in the water, and the fraction of the mercury mass in the water that volatilized into the air. The pivotal feature of the EFPC Volatilization Model is the volatilization fraction, which is the fraction of metallic mercury mass in EFPC that volatilized from the water. Task 2 assumed a log triangular distribution of values, with a minimum value a "best estimate," and a maximum value equal to 1, 5, and 30 percent, respectively, of the total mercury mass released annually to the creek. Task 2 apparently selected these values from data collected in the 1990s. ATSDR suggests that conditions in EFPC were too different in the 1990s compared with the 1950s to warrant unqualified application of those values. Task 2 did not explain how it derived the volatilization fractions it used, and ATSDR believes this key variable needs to be justified. Finally, Task 2 adopted a log triangular distribution of the volatilization fractions, also without explanation or justification. ATSDR is not aware of any evidence that supports the assumption that volatilization fractions are distributed in this way. ATSDR concludes that the EFPC Volatilization Model is only qualitatively supported by tree-core data, not quantitatively supported, and that the model does not provide reliable predictions of air mercury concentrations off site from the Y-12 plant.

Information Regarding the Tree Core Ring Samples

1. Although the tree core data cannot establish annual air mercury concentrations, they indicate that air mercury concentrations were elevated during the 1950s and 1960s, compared with later decades in areas beyond Scarboro. However, the tree core data cannot indicate from where the mercury came.

2. Task 2 indicated that mercury concentrations in the tree core ring corresponded to 1938. This concentration was higher than in subsequent years in a tree on the west end of the Y-12 property. It is not known whether this mercury may have been absorbed in later years and migrated toward the center of the tree, or whether it was absorbed prior to the Manhattan Project.

3. Unfortunately, the EFPC tree core samples were all collected from red cedars in the same vicinity of the EFPC floodplain, which is on the eastern-most end of EFPC, near Illinois Avenue and East Tulsa Road. This area could have been impacted by air releases from the Y-12 plant, or sources other than the ORR. A more representative sampling of trees along the EFPC floodplain might have provided quantitative support that mercury volatilization from EFPC declined with distance from Y-12, and that volatilization was responsible for increased air mercury concentrations. Alternatively, the samples may have indicated that additional mercury sources were affecting the communities around the ORR.

Task 2 Results

Using a 30 percent volatilization fraction, Task 2 estimated that mercury air concentrations in the EFPC floodplain and in Scarboro exceeded the inhalation MRL (0.0002 mg/m^3) during the years 1953 through 1961, and from 1957 through 1958, respectively. Using a 5 percent volatilization fraction, Task 2 air concentrations in the EFPC floodplain exceeded the MRL for the years 1957 and 1958, and did not exceed the MRL at all in Scarboro (ChemRisk 1999a). Using the assumption that 1 percent of the mercury mass in EFPC volatilized from the water, none of the estimated air mercury concentrations for any potentially exposed community exceeded the MRL for any year. These results reflect the relative magnitude of mercury released from the Y-12 plant to water in different years, the distance of the potentially exposed communities from the creek, and the assumed mercury volatilization fractions. That said, the few environmental data available do not support the key model assumptions that volatilization of mercury was proportional to distance from the Y-12 plant and formed a log triangular distribution from 1 to 30 percent with a "best estimate" value of 5 percent.

Past Air Exposure Pathway Summary

- None of the Task 2 models are adequate for evaluating possible past, short-term (acute) air exposures to mercury vapor.
- ATSDR believes the U.S.EPA ISCST3 Dispersion Model is an appropriate model for estimating annual air mercury concentrations in Wolf Valley.
- ATSDR's chronic inhalation mercury MRL is the basis for evaluating the Task 2 estimated average annual air mercury concentrations in Wolf Valley.
- ATSDR does not believe the χ/Q Model or the EFPC Volatilization Model is adequate for quantitatively estimating annual air mercury concentrations for any potentially exposed community.
- Elemental mercury taken into the home could have been spilled, resulting in unsafe indoor air mercury concentrations.

Mercury Emissions from Selected Electricity Generating Facilities

ERG, an independent contractor for ATSDR, evaluated whether electric generating facilities in close proximity to the Y-12 plant would lead to air concentrations of health concern. ERG concluded the following:

EPA's "Mercury Study Report to Congress" suggests that emissions from coal-fired power plants have extremely limited incremental effects on ground-level air quality. The modeling analyses EPA conducted on a hypothetical coal-fired power plant found essentially no ground-level impacts at locations 2.5 kilometers (km), 10 km, and 25 km downwind.

Consistent with these general findings, ERG's screening modeling analysis showed that past mercury emissions from the Tennessee Valley Authority's Kingston Fossil Plant almost certainly did not have substantial air quality impacts (i.e., concentrations approaching the reference concentration) near the Y 12 plant, even when considering a series of health-protective assumptions.

A copy of ERG's memo to ATSDR is included in Appendix F. Evaluation of Mercury Emissions from Selected Electricity Generating Facilities.

Past Air Exposure Pathway Conclusions

The following conclusions refer to the past potential for mercury in air from the Y-12 plant to cause harm. The conclusions are not a measure of the past occurrence of adverse health effects. Health outcome and exposure data are unavailable that allow for an evaluation of the actual occurrence of adverse health effects during the 1950s and 1960s from exposure to mercury in air.

ATSDR concludes

- Elemental mercury carried from the Y-12 plant by workers into their homes could potentially have harmed their families—especially young children—in the past (1950–1963).
- Air and water mercury releases from the Y-12 plant after 1963 are not expected to have harmed people living off site near the ORR.
- ATSDR concludes that breathing past (1950–1963) air mercury releases from the Y-12 plant is not expected to have harmed people living off site in the Wolf Valley area.

ATSDR cannot conclude

- Whether off-site populations breathing elemental mercury releases in the past (1950–1963) from the Y-12 plant could have been harmed, except for the Wolf Valley area.
- Whether people living near the EFPC floodplain breathing mercury vapors from Y-12 releases to the water from 1950 through 1963 could have been harmed.

IV.A.3. Past Surface Water Exposure Pathway

Y-12 Mercury Releases to Water

Unlike exposure to mercury in air, the health hazards posed by exposure to mercury in water were generally unknown before 1970. Therefore, during the years of lithium isotope separation operations, Y-12 managers were not concerned that releases of mercury to water would affect human health or the environment. From an economic standpoint, Y-12 administrators were more concerned about mercury losses—mercury was a valuable commodity at the time.

Mercury contamination of water sources at the Y-12 plant may have occurred as a result of primary operations, waste disposal activities, or accidental releases.

Y-12 Mercury Releases to EFPC

Y-12 mercury releases to EFPC were highest during the years when the lithium separation program was active. Research and development for the lithium separation processes began in 1950, and full-scale production began in 1953. Water mercury releases peaked during 1957 and 1958, but some mercury continued to enter the creek after the lithium separation operations shut down in June 1963 (WJ Wilcox, Jr., personal communication, March 17, 2005). Subsequent sources of mercury to EFPC included on-site cleaning operations and seepage from mercury deposits inside building walls, ducts and equipment, and under floors. Today, the Y-12 National Security Complex continues to release very small amounts of mercury into EFPC.

Y-12 Mercury Releases to the Storm Sewer System

The primary path by which mercury entered EFPC was via the storm sewer system that ran through the Y-12 property. The main production buildings disposed of their liquid wastes into collection tanks, and mercury was routinely removed from them. Overflow from the collection tanks entered the storm sewer system that led into EFPC.

In the production waste streams, mercury was in the form of dissolved inorganic mercuric ions. During the Colex process, liquid wastes were in the form of dilute nitric acid solutions. Nitric acid was used to remove impurities from water and mercury used in the lithium separation process. But washing the mercury with nitric acid dissolved a substantial amount, which then entered the storm sewer and EFPC. When the nitric acid wash procedure was modified in June 1958, the mercury released off site through the storm sewer significantly reduced.

Indoor and outdoor mercury spills were also fed into the storm sewer. Mercury spills would have included mercuric ions in liquid solutions and liquid elemental or metallic mercury. Spills occurred in the production buildings, between the production buildings, in the loading area, around the Building 81-10 recovery operations, and during stripping operations (cleaning, tearing down, or salvaging equipment).

Y-12 Mercury Releases to New Hope Pond

In 1963, New Hope Pond was created in EFPC, downstream of the Y-12 buildings on the Y-12 property. The pond was intended to serve as a mixing location to stabilize the fluctuation of pH in the water that flowed from the Y-12 operations. Before constructing the pond, the water pH value that led into EFPC ranged between 3 and 12. The pond served to bring the pH into acceptable limits (6–9) to protect fish and other aquatic life, as stipulated by the State of

Tennessee. After the pond was constructed, it became a settling location for mercury, which reduced the amount of mercury traveling off site. New Hope Pond was dredged in 1973, and closed, cleaned, and filled in 1989 (ChemRisk 1999a; SAIC 2007).

Estimated Mercury Releases to Water

The 1983 Mercury Task Force and Task 2 scientists used measured concentrations of mercury in water samples on the Y-12 property. They also used measurements of the storm sewer/EFPC water flow rate to estimate mercury releases to EFPC (see Table 10).

Table 10. Estimated Y-12 Mercury Releases to Water

Terms	*Mercury concentration*	*multiply*	*Stream flow rate*	*equals*	*Mercury released*
Equation:	mercury mass / volume	x	volume / time	=	mercury mass / time
Example: (1957)	2.22 mg/L (1.85 E-5 pounds/gal)	x	11.0 MGD[1] (4.02 E-9 gal/year)	=	72,211 pounds/year
Sources of data:	measurements from water samples or estimated percentage of inventories		water flow measurements or assumed default values		(These quantities are the source terms for modeling water mercury concentrations.)

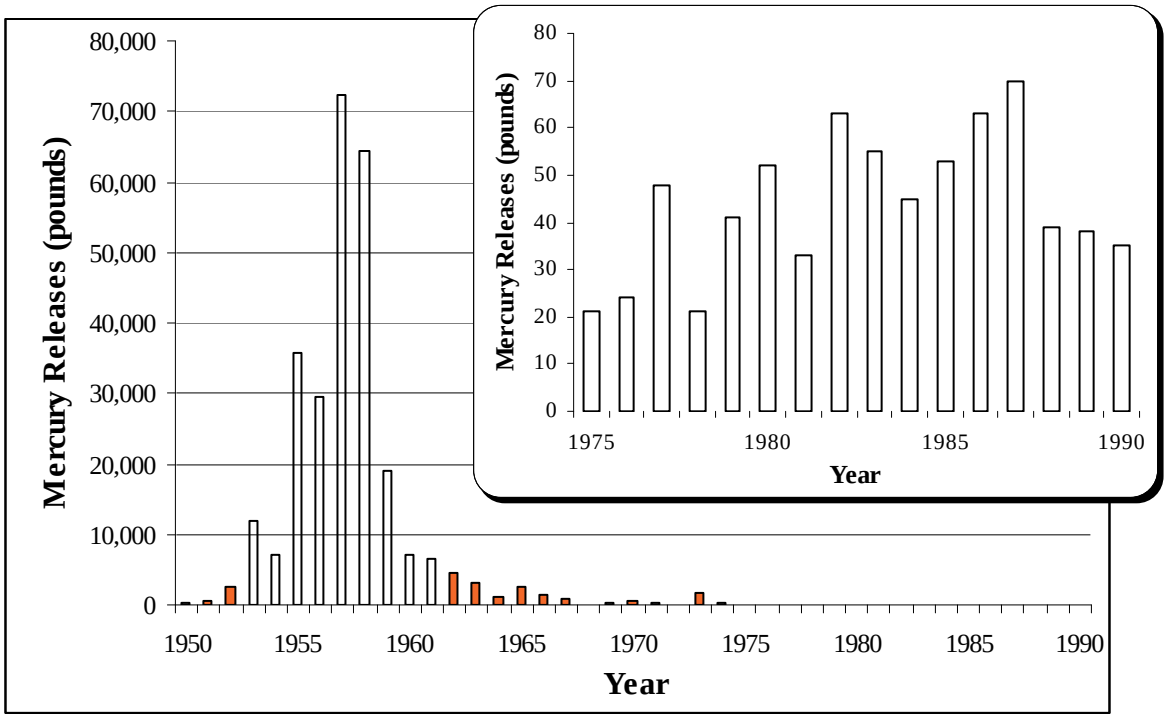
[1] MGD: millions of gallons per day

Given that some stream flow data, mercury concentration data, or both are absent before 1956 (and both are completely absent before 1953), Task 2 estimated values for those quantities. The period of 1950–1955 is important—not only because both lithium separation pilot operations and full-scale production were occurring, but because formal mercury recovery operations had not yet begun. The operations were new, many changes were made. Spills happened, and the on-site storm sewer became the means for liquid waste disposal.

For the flow rate estimates during this early period, Task 2 used an average of flow rates measured in later years (1955–1957). All missing flow rate values were assumed to be 11 million gallons per day (MGD). For missing mercury concentration data, Task 2 calculated values from concentration measurements taken in 1953 and 1954. For those years, mercury concentrations in samples were between 2.9 percent and 7.3 percent of mercury inventories. Task 2 estimated that mercury losses during 1950–1952 were between 3 percent and 8 percent of the mercury inventories for those years.

Task 2 estimated that mercury releases to EFPC exceeded 10,000 pounds in 1953, and again in years 1955–1959. During the peak years of mercury releases to EFPC, more than 72,000 pounds and 64,000 pounds of mercury were released in 1957 and 1958, respectively. Annual releases dropped below 1,000 pounds in 1967 (except for a small increase in 1973, probably as a result of dredging New Hope Pond). They decreased below 100 pounds in 1975. Mercury releases to EFPC for the years 1988–1990 were below 40 pounds per year (see Figure 15).

Figure 15. Task 2 Estimated Mercury Releases to EFPC



To estimate mercury releases in the early 1950s, Task 2 used data from a relatively small number of water samples and water flow measurements. The Task 2 report did not state how many sample data were used, or how well the samples distributed over time. ATSDR does not know the quality of the data, nor how well the "percentage of inventory" model predicted water mercury releases for the years 1950–1952. In all likelihood, these limitations will never be resolved.

Water Sampling at the Y-12 Plant

During the second quarter of 1953, Y-12 employees began collecting water samples to measure mercury concentrations. The earliest available stream flow data are from 1954; but until September 1955, the data are sporadic. Fortunately, composite water sample data are available for the peak years, 1957 and 1958. The highest composite weekly water mercury concentration was 14.5 mg/L, from a sample collected during the second week of May in 1958. Water samples were collected in the storm sewer on site, downstream of the Y-12 buildings, and later from the outlet of New Hope Pond to EFPC. Data were reported in hundreds of weekly, monthly, and quarterly internal technical and environmental reports over the years.

Water Collection Method before 1956

Between 1953 and 1955, water samples were taken from the surface of the storm sewer stream. Surface water samples would likely not have captured all of the elemental mercury releases, nor would it have captured mercury attached to particulate matter—it would have sunk in the water and followed the course at the bottom of the streambed. Sufficient anecdotal evidence is available in both the 1983 Mercury Task Force report and the Task 2 report that elemental mercury releases, which occurred prior to 1955, were not accounted for in the early water measurements. In 1955, a "dipper type" sampler was installed in the storm sewer. But whether

the device would have adequately measured elemental mercury releases is not certain (ChemRisk 1999a).

Acidification of Water Samples

During the early testing period, samples were not acidified at the time of collection. This would have minimized volatilization of mercury vapor from the sample containers. An acidic pH favors dissolved ionic mercury, and a basic pH favors undissolved, elemental mercury. Once mercury is in the elemental form, it may evaporate, or it may volatilize from water at ambient temperatures. Due to the nitric acid in the liquid wastes, the risk of mercury loss from the samples would probably have been minimal. Not all of the liquid waste streams were acidic, however.

In 1974, U.S.EPA recommended acidifying water samples collected for mercury analysis to minimize loss of mercury from the samples due to volatilization. Y-12 staff began acidifying water samples in the laboratory in 1977. In 1982, water samples were acidified in the field. Samples collected before 1977 were not acidified. Reported pH measurements of composite weekly water samples collected from June 1955 through 1959 were between 7.1 and 11.1 (i.e., they were all in the basic range). The basic pH favors the formation of dissolved elemental mercury, which may escape from the water. ATSDR does not know whether the water samples were capped or sealed prior to analysis, nor whether the absence of acidification of water samples collected prior to 1977 significantly affected the reported mercury concentrations.

Uncertainty in the Analytical Methods

Until June 1957, Y-12 analytical chemists determined the mercury content of EFPC water using a colorimetric technique. This method provided a detection limit of 0.1 mg/L with a relative limit of error for a single analysis of ± 50 percent. In July 1957, the colorimetric method was replaced by the mercurometer method, which provided a detection limit of 0.01 mg/L, with a relative limit of error for a single analysis of ± 40 percent. In August 1967, an atomic absorption method was adopted that provided a detection limit of 0.001 mg/L with a relative limit of error for a single analysis of ± 20 percent (UCCND 1983a, 1983b). Note that the uncertainties in the measurements of water mercury concentrations through mid-1967 were relatively large.

Composite Water Sampling Data

The mercury water data of greatest interest were from samples collected weekly until the end of the lithium separation operations in June 1963. Weekly water sample data from September 1955 through November 1960 are available, with only four data points missing during this period. The data represent averages of mercury concentrations from composite water samples collected over the duration of a week. The data from composite water sampling are useful; they allow for a review of mercury concentrations within the period of acute exposures (2 weeks). Nevertheless, the data cannot indicate the maximum water mercury concentration that may have occurred following a single large release over the course of a few hours or a day.

Missing Water Sampling Data

Gaps appear in the weekly water sampling data before September 1955 and after November 1960. Only the gaps in the earlier period, however, appear important. Data from total mercury release estimates, as well as monthly and quarterly reports, consistently indicate that mercury releases to EFPC after 1958 did not result in mercury concentrations at levels that would have

posed a public health concern. Whether high acute mercury exposures occurred between 1953 and 1955 is not known, given that the weekly water sampling data and supporting information are incomplete.

The production scale lithium isotope separation work began using the Elex process in August 1953 and the Colex process in January 1955. (The Orex process never progressed beyond pilot development.) These were new technologies at the time, and production start-up was marred by difficult problems such as the loss of mercury. Estimated mercury spills before 1957 ranged from 200,000–500,000 pounds (UCCND 1983a, 1983b). Some of the spilled mercury was recovered, though the 1983 Mercury Task Force report does not estimate how much went into the water. From the earliest production days Y-12 managers considered mercury losses from the Colex process "serious," and considerable effort went into addressing them.

Fate and Transport of Mercury Releases in Water

Except for a period from 1974 through mid-1977, the analytical data are measurements of total mercury in the water. From January 1974 to June 1977, water samples were filtered and analyzed for soluble mercury only. ATSDR has a qualitative—not quantitative—knowledge of the species of mercury in the water: through multiple physical and chemical processes in the creek, as described below, the mercury released from the Y-12 plant to EFPC may change form. These uncertainties are accounted for, to the extent possible, in the subsequent discussion on the bioavailability of mercury.

We could not assess acute mercury exposure because the data were not representative of an acute exposure scenario (0–14 days). The monthly water sample data collection that began in April 1954 and the quarterly water sample data collection that began in June 1953 were combined averages of the weekly data. The longer the duration over which periodic data are averaged, the lower the peak values. For example, the average annual water mercury concentrations were lower than some of the quarterly concentrations for the same period, and the average quarterly concentrations were lower than some of the monthly concentrations.

The longer-period average mercury water concentration values are appropriate to evaluate average long-term exposures, but not to estimate short-term (acute) exposures. Because not enough appropriate data are available, ATSDR scientists cannot determine whether short-term mercury releases to EFPC from 1953–1955 could have resulted in harmful, acute exposures.

The mercury released into the storm-sewer drainage ditch at the Y-12 plant was primarily divalent mercuric nitrate and elemental mercury. Mercuric nitrate is very soluble in water, but neutralization of the acid in the creek water would have formed mercuric oxide, or in the presence of sulfide ion, mercuric sulfide. Mercury also adheres to, and forms compounds with, other inorganic and organic species, including particulate matter and plant material. The basic pH of the composite weekly water samples at Y-12 during the 1950s would have favored the formation of the oxide and sulfide salts, some of which would have precipitated out of solution and would have been carried along in the stream. Some of them would have settled in the streambed or floodplain soil and diminished the concentration of mercury in the water. But the 1983 Mercury Task Force noted that suspended mercuric salts could have "resolubilized" during "acid-dominated periods" when the water released to EFPC was acidic (UCCND 1983a, 1983b). Basic pH (and warm temperatures) also would have favored volatilization of dissolved elemental mercury to the air.

The level of hazard depends on the species and the quantity of mercury in the water.

In 1995, Saouter et al. reported that water samples collected from the outlet of Reality Lake (which fed EFPC on Y-12 property) contained approximately 83

percent mercury associated with particulate matter and 17 percent dissolved mercury (Saouter et al. 1995). Methylmercury was less than 0.1 percent of the total mercury concentration of 0.00175 mg/L.

Southworth et al. (2004) published data from sixteen streams and rivers throughout the Southeast United States (including EFPC) showing that the percent of methylmercury in water decreases with increases in the total mercury concentration (unfiltered water samples). Given that total mercury concentrations during the 1950s were thousands of times greater in EFPC water than in the 1990s, these data suggest the methylmercury concentrations in water during the 1950s did not exceed the methylmercury quantities measured in later decades. The portion of dissolved and suspended inorganic mercury that remained in the water downstream of the Y-12 plant in the 1950s and 1960s, however, remains highly uncertain.

The Oral Bioavailability of Mercury in EFPC

Not all of the mercury a person swallows is absorbed into the blood. Some of it passes through the gastrointestinal tract and is eliminated in the feces. Adverse health effects associated with the ingestion of mercury depend on how much mercury gets into the blood, not how much mercury is swallowed. Mercury can also cause harm to the inside lining of the stomach and intestines, but not at levels reported in EFPC. The fraction of the mercury swallowed that passes through the lining of the stomach and intestines and enters the bloodstream is referred to as the amount that is bioavailable. This fraction is biologically available to cause harm to the tissues and organs inside the body through its transport in the circulatory system.

The oral bioavailability of a substance is the fraction of the total amount of the substance swallowed that is absorbed.

Different forms of mercury have different bioavailabilities. Studies in humans regarding the oral ingestion of methylmercury bound to fish muscle protein have shown that absorption is almost complete (95 percent) (ATSDR 1999). In contrast, elemental mercury absorbs poorly into the blood, even when it is ingested in large quantities. The highest oral bioavailability factor reported in the scientific literature for inorganic mercury is 38 percent for mercuric chloride administered in water to week-old suckling laboratory mice (ATSDR 1999).

Newborn mice exhibited higher mercury absorption than adult mice. Similarly, the stomach lining of nursing human infants is not fully developed. It allows more substances, such as milk proteins, from the mother into the blood. In this way, mothers transfer nutritional and immune proteins to their children. Yet immature stomach linings also make infants more vulnerable to heavy metal poisoning than are older children and adults.

In adult mice, the bioavailability of mercuric chloride has been reported to be 20–25 percent. In human studies, mercuric nitrate was reported to be 15 percent bioavailable (ATSDR 1999). In other studies, the mercury concentration in kidneys of mercuric sulfide-dosed mice was approximately 20-fold to 50-fold lower than in mercuric chloride-dosed mice, even when significantly higher doses of mercury were administered to the mercuric sulfide-dosed mice, and at more frequent intervals (Paustenbach et al. 1997; Sin et al. 1983, 1990). After identical exposures, the kidney deposition of mercury was approximately 30–60 times lower in mice exposed to mercuric sulfide, as compared with mice exposed to mercuric chloride. Although these studies do not measure the bioavailability of mercuric sulfide, they do show that mercuric sulfide is absorbed from the gastrointestinal tract to a measurable extent, though likely to a lesser extent than mercuric chloride (Schoof and Nielsen 1997). A quantitative determination of the relative bioavailabilities of mercuric sulfide versus mercuric chloride has not been derived

in the available studies, nor has the relative bioavailability of mercuric sulfide in humans been examined (ATSDR 1999). Nevertheless, because of mercury's high water solubility, scientists generally believe that mercuric chloride is among the most bioavailable of inorganic mercury species. Thus an upper bound bioavailability factor for the oral ingestion of inorganic mercury in non-nursing children and adults appears to be approximately 25 percent.

In this evaluation, ATSDR compared exposure doses with the ATSDR oral inorganic mercury MRLs, which are based on measured exposure doses to mercuric chloride. The inorganic mercury in EFPC water, however, is expected to be primarily mercuric nitrate. ATSDR therefore calculated doses using the relative bioavailability of mercuric nitrate to the bioavailability of mercuric chloride (Paustenbach et al. 1997). The oral bioavailability of mercuric nitrate in humans has been reported as 15 percent. In the dose calculations for exposures to mercuric nitrate, ATSDR used a bioavailability factor of 0.6. Relative to mercuric chloride, the bioavailability of mercuric nitrate is 60 percent (i.e., $0.15 \div 0.25 = 0.6$). See Appendix G. Past Exposure Pathway Parameters for ATSDR's assumptions and formulas used to estimate exposure doses.

Past Surface Water Exposure Pathway Conclusions

ATSDR based the following conclusions on a comparison of the calculated exposure doses with the ATSDR oral organic and inorganic mercury MRLs. A person whose dose exceeds an MRL may not experience adverse health effects. No health data are available that would allow ATSDR to evaluate the actual occurrence of adverse health effects during the 1950s and 1960s from exposure to water in EFPC. With these points in mind, ATSDR concludes

Note that many uncertainties are associated with the estimated exposure doses, and note that people vary widely in their response to hazardous substances. The conclusions refer to the past potential for mercury in EFPC to cause harm. The conclusions are not a measure of the past occurrence of adverse health effects.

- Children who swallowed water from EFPC with inorganic mercury for a short period of time (acute exposure, less than 2 weeks) during some weeks in 1956, 1957, and 1958 could potentially have experienced renal effects. Adults, who swallowed water from EFPC for a short time during some weeks in 1958, could also potentially have experienced renal effects.
- Swallowing water from EFPC with inorganic mercury for a short time before 1953, or after the summer of 1958, is not expected to have harmed people's health.
- Intermittently (intermediate exposure, greater than two weeks and less than a year) swallowing water from EFPC with inorganic mercury is not expected to have harmed people's health during any year.
- Swallowing water from EFPC with inorganic mercury over a long period of time (chronic exposure, more than a year) in the past is not expected to have harmed people's health.
- Swallowing water from EFPC with methylmercury is not expected to have harmed people's health.

ATSDR concludes, from the Task 2 water model that long-term exposures to mercury in EFPC water were not a public health hazard. ATSDR's separate evaluation agrees with the Task 2 results.

ATSDR cannot conclude whether

- Swallowing water from EFPC with inorganic mercury for a short time during 1953, 1954, and 1955 could have harmed people's health.

ATSDR also examined the average annual and quarterly mercury concentrations (inorganic and organic) in water at the Y-12 plant. These data may represent the highest mercury concentrations in EFPC, with the possible exception of areas where mercury deposits in the EFPC floodplain may have served as secondary sources. None of the data from water samples at Y-12 exceeded ATSDR's assessment of intermediate-term exposures (15–364 days) (i.e., calculated doses were below ATSDR's intermediate MRL). These data sets indicate that none of the mercury concentrations in EFPC were an oral hazard to children playing in the creek.

IV.A.4. Past Soil and Sediment Exposure Pathways

Y-12 Mercury Releases to the EFPC Floodplain

Y-12 mercury releases to water during the 1950s and 1960s resulted in significant mercury deposits in off-site soils within the EFPC floodplain. Before 1983, people collected EFPC floodplain soil to supplement private gardens. The city of Oak Ridge personnel collected EFPC floodplain soil to backfill 10 miles of sewer line installation. These activities resulted in distribution of mercury-contaminated soils from the EFPC floodplain to other areas of Oak Ridge.

Mercury contamination of soil and sediments along the EFPC floodplain near the Y-12 plant occurred primarily as a result of mercury releases to surface water.

Sediment consists of dirt, silt, and sand that accumulate at the bottom and along the banks of rivers, streams, and other surface water bodies. Sediment accumulates in areas where the stream depth, breadth, or direction changes. Some stretches of EFPC have very little bottom sediment; the stream scours the bedrock and moves the lighter weight particulate matter downstream. Thus collection of sediment samples from all locations along EFPC is difficult. Fewer sediment samples were collected from EFPC compared with soil samples collected from the EFPC floodplain.[8] But compared with floodplain soil, people have less opportunity for exposure to EFPC sediment. Mercury concentrations detected in sediment (as reflected in the sampling data) are generally comparable to, or less than, those detected in soil. This discussion therefore primarily focuses on mercury levels detected in soil, with less emphasis on the limited sediment data.

During the early 1980s, the Oak Ridge Associated Universities (ORAU) and the TVA conducted the earliest comprehensive surveys of mercury in EFPC floodplain soils and sediment. ORAU collected more than 3,000 surface soil samples between 1983 and 1985 from the EFPC floodplain, the Oak Ridge sewer line beltway, and private lawns and gardens in and around Oak Ridge. TVA collected approximately 100 core samples in 10-inch increments from 27 transects across the EFPC floodplain during 1984 (SAIC 1993). The DOE EFPC Floodplain and Sewer Line Beltway Remedial Investigation (RI) is the most recent large-scale sampling effort. This investigation is discussed in greater detail in the following section.

Transects are imaginary lines that cross the floodplain. They're a method of plotting where soil samples are collected.

The EFPC Floodplain and Sewer Line Beltway RI

In October 1990, DOE began soil and sediment sampling of the lower EFPC floodplain. DOE reviewed earlier ORAU and TVA data. These data indicated where the mercury contamination was most concentrated along the floodplain. The RI is the most comprehensive soil and sediment

[8] There were 50 sediment samples in both the CERCLA RI Phases Ia and Ib combined.

investigation of mercury in the EFFC floodplain and the sewer line beltway area of Oak Ridge (SAIC 1993, 1994). The RI characterizes mercury distribution in the EFPC floodplain and is the primary source of data used to evaluate potential past mercury exposures for people living near Lower EFPC.

The two-phase investigation comprised Phase Ia, which included more than 100 soil samples and was designed to identify contaminants of potential concern;[9] and Phase Ib, which was designed to establish the nature and extent of contamination.[10] Phase Ib included more than 2,600 soil samples collected from 159 transects across the EFPC floodplain.

RI Sampling Methodology

Transects were separated at approximately 100-meter (330-foot) intervals beginning from the confluence of EFPC with Poplar Creek and culminating at the mouth of Lake Reality on the Y-12 property.[11] Samples were collected at the edge of the water and every 20 meters (65 feet) along each transect, up to (or beyond) the elevation of the 100-year floodplain and on both sides of the creek (see Figure 16). The spacing of the samples (i.e., sampling density) collected was initially determined from a statistical analysis of the costs of sampling and remediation and the variation of mercury concentrations in surface soil as measured in the earlier ORAU study.

Most of the RI soil samples were core samples collected in depths of 1 or 2 feet (for Phase Ia samples) or 16 inches (for Phase Ib samples). To minimize Phase Ib costs, collection of core samples below the first 16-inch cores was planned for every other transect. In some cases, physical obstacles prevented deeper sampling. Each core sample was turned into a composite (i.e., the soil was blended into a uniform mixture) for analysis. The average mercury concentration for that sample interval was reported.

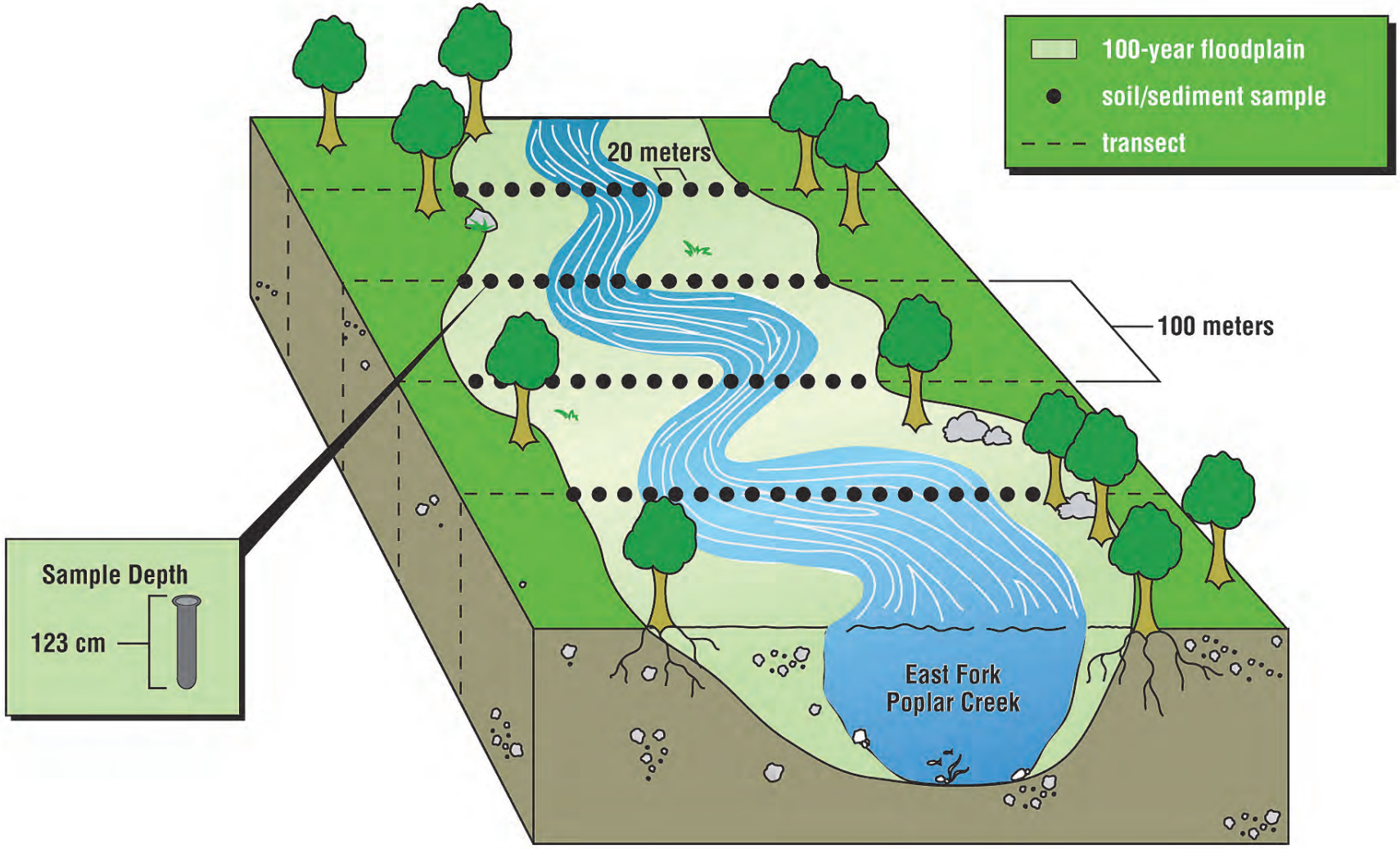
Vertical Integration Study

The vertical integration study (VIS) was included in the RI report and examined the vertical stratification of mercury in one-inch increments down to 16 inches below ground surface.

The purpose of the study was to examine the stratification of mercury in the soil and the effect which compositing the cores had on the analytical results. Five core samples were collected from four locations in the floodplain with one duplicate sample at the Bruner site.

[9] In addition to mercury, many other analytes were tested in the samples.
[10] Surface water, groundwater, air, and biota samples were also collected for the RI.
[11] The total distance was approximately 23 kilometers or 14.2 miles.

Figure 16. EFPC RI Sampling Strategy



Sampling Results

The data collected for the RI provided a comprehensive view of ORR mercury distribution in off-site soils. The RI data are consistent with those collected in the earlier ORAU and TVA studies. The RI sampling data demonstrated that mercury was present in some soils along the entire length of EFPC. Mercury contamination did not typically extend out very far from the creek banks and rarely to the elevation of the 100-year floodplain. The greatest deposition of mercury in the EFPC floodplain was found in two regions: 1) behind the NOAA building at 456 South Illinois Avenue and 2) along a stretch (approximately 2,000 feet) of the creek—south of the Oak Ridge Turnpike—from about 750 feet west of Louisiana Avenue to about 1,000 feet west of Jefferson Avenue. In DOE reports, the former area is referred to as the NOAA site and the latter area is referred to as the Bruner site.[12] These two locations contained the highest measured and the most broadly distributed[13] mercury concentrations in the EFPC floodplain soils (see Table 11). The highest soil mercury concentrations detected during the RI were 2,110 ppm from a 1-foot core composite sample collected from the Bruner site and 1,590 ppm from a 16-inch core composite sample from the NOAA site (SAIC 1993).

Table 11. Maximum Mercury Concentrations Detected in EFPC Floodplain Soil

Location	*Sample type*	*Concentration (ppm)*	*Data Set*
Bruner site	1-foot core	2,110	RI
	10-inch core	1,300	TVA
	16-inch core[1]	3,420	VIS
NOAA site	16-inch core	1,590	RI
	Surface soil	2,400	ORAU (April 1985)
	10-inch core	1,800	TVA
	16-inch core[1]	2,870	VIS

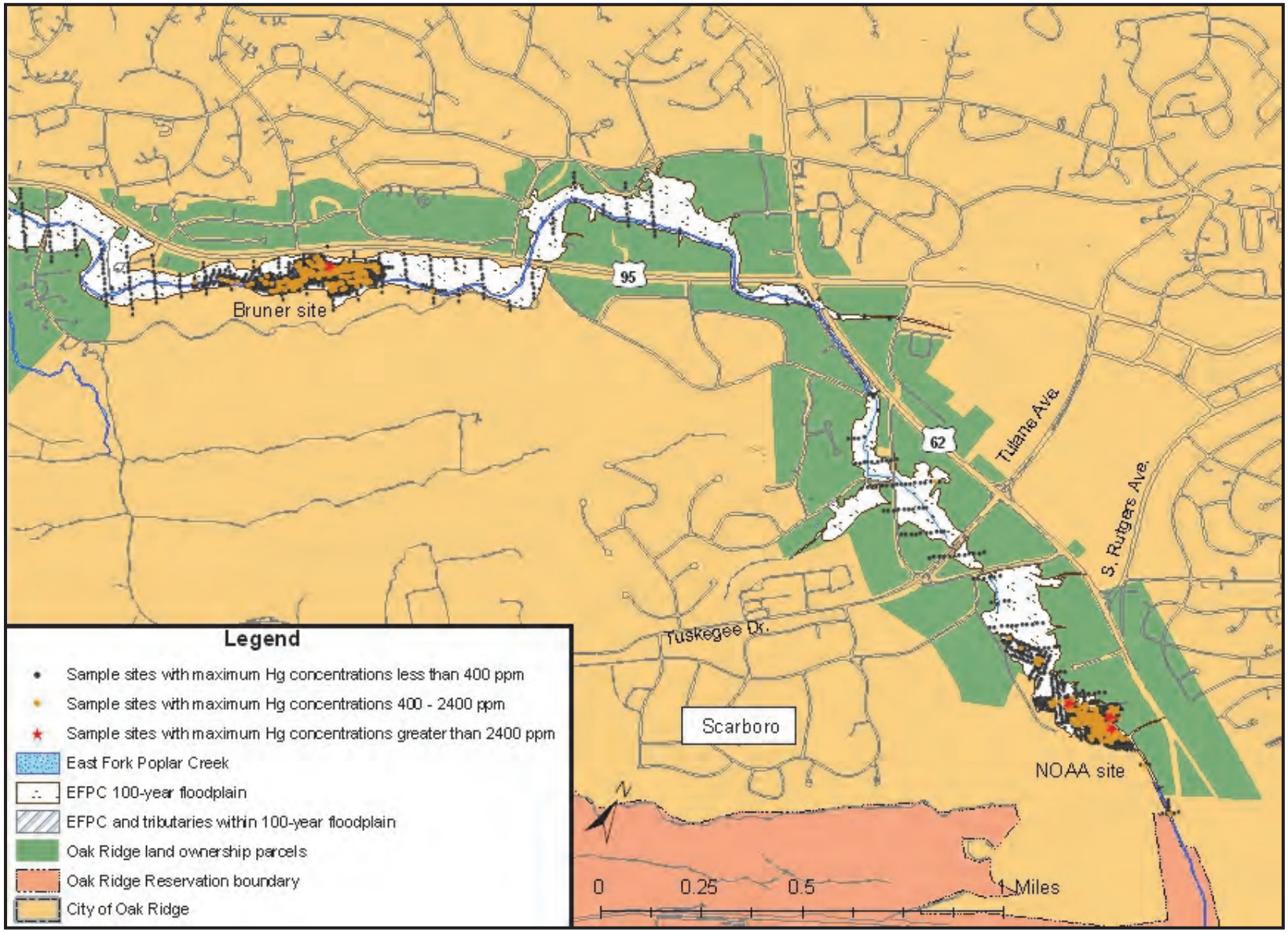
Sources: ChemRisk 1999a; SAIC 1993
ppm: parts per million (this is the same as mg/kg)
RI: EFPC Floodplain and Sewer Line Beltway Remedial Investigation
TVA: Tennessee Valley Authority
ORAU: Oak Ridge Associated Universities
VIS: vertical integration study
[1] These peak concentrations were found 10–11 inches and 9–10 inches below ground surface, respectively (ChemRisk 1999a).

In 1995, DOE, U.S.EPA, and TDEC established a 400-ppm remediation (clean-up) goal for mercury in the EFPC floodplain. Most of the core mercury samples (more than 98 percent) collected during the RI were below 400 ppm (DOE 2001; SAIC 2004). In fact, almost all of the soil and sediment samples collected during the RI were below this concentration. Exceptions were several samples each at the NOAA site and the Bruner site, one sample near the creek in the Grand Cove area of Oak Ridge, two samples near South Illinois Avenue northwest of Tuskegee Drive, and three samples on DOE property—one on the Y-12 property and two core

[12] The Bruner site is also referred to as the Bruner's Center site or the Bruner and Sturm properties. At the time of the RI, the Bruner site included properties in the EFPC floodplain southeast of the Oak Ridge Turnpike. The name Bruner referred to the owners of a shopping area on the northwest side of the Turnpike. The virtual extension of Louisiana Avenue across the Turnpike.
[13] Detected at the greatest distance from EFPC and greatest vertical depths

samples at the same location on the K-25 property. Figure 17 shows the extent of mercury contamination in the EFPC floodplain prior to remediation.

Figure 17. Extent of Mercury Contamination in the EFPC Floodplain (prior to completion of remediation in 1997)



Remedial Activities

Remedial activities were first initiated in 1984, when DOE removed mercury-contaminated soils from private residences (upon request) and from the Oak Ridge sewer line beltway.

The CERCLA Lower East Fork Poplar Creek Remedial Action prompted removal of mercury-contaminated soil occurred at the NOAA and Bruner sites. The NOAA site was remediated in 1996, and the Bruner site in 1997. Remedial activities consisted of removing about 34,000 cubic yards of mercury-contaminated soils from the NOAA and Bruner sites, transporting the contaminated soil to the Y-12 Industrial Landfill V, and subsequently backfilling the excavated areas with clean fill and topsoil (SAIC 2002a). Soils at the Grand Cove location and soil northwest of Tuskegee Drive (maximum core mercury concentration = 443 ppm) were not removed. Nearby sample concentrations were below 400 ppm and contamination in that area was not expected to pose a public health risk.

Evaluation of Soil Mercury Data

Exposures to contaminants in soil typically occur in the top 3 inches. Still, children sometimes dig deeper in the soil than 3 inches when playing, and adults may dig deeper when gardening or during construction work, such as building a foundation for a bridge or some other structure. In addition, soil below the ground surface was at one time close to or at the surface. Thus the possibility remains that people were exposed in the past to mercury currently below the EFPC floodplain surface. People may in the future come in contact with excavated subsurface soils or sediments, or sediments that rise to the surface through natural processes. ATSDR scientists assume that beginning in the early 1950s, people generally had access to soils with the highest mercury concentrations; that is, until soil removal activities occurred in the 1980s and 1990s.

Human exposure pathways to mercury in both soil and sediment include incidental ingestion and dermal absorption (contaminants passing through skin). Digging in the soil or playing in or near EFPC connects people with the contamination. Incidental ingestion may occur because people transfer soil from their hands to their mouths. Note here that dose estimates of mercury exposure are based on a series of assumptions that account for how much mercury is in the soil, how much soil or sediment people ingest, how much adheres to the skin, and ultimately, how much mercury is absorbed into the bloodstream. See Appendix G. Past Exposure Pathway Parameters for ATSDR's assumptions and formulas used to estimate exposure doses.

In evaluating the soil and sediment data, ATSDR can eliminate from further consideration those places along EFPC where mercury concentrations were detected below its comparison values; these levels have not been shown to cause adverse health effects. Using the exposure dose assumptions outlined in Appendix G. Past Exposure Pathway Parameters, mercury concentrations at or below 2,400 ppm will result in doses at or below ATSDR's oral mercury MRLs (see Table 7). Using ATSDR's dose assumptions, this site-specific comparison value (2,400 ppm) applies to both dermal absorption and oral ingestion pathways, both inorganic and organic mercury species in the soil and sediment, and to acute, intermediate, and chronic exposures.

Among the reported soil and sediment data, three vertical integration study (VIS) core samples collected at the NOAA and Bruner sites contained mercury concentrations above 2,400 ppm. Among the three core samples, mercury exceeding 2,400 ppm was detected in six 1-inch layers (layers were analyzed separately within each core sample). The maximum mercury concentration

reported was 3,420 ppm. None of the other soil or sediment data in the ORAU, TVA, or RI data sets contained mercury concentrations above 2,400 ppm (ChemRisk 1999a).

The TVA and RI data sets include soil mercury concentrations in composite core samples, not in undisturbed soil layers. The VIS data indicate the mercury concentrations varied considerably by vertical depth, even for core samples collected near each other. The highest mercury concentrations in each of the five VIS samples (in 1-inch layers) ranged from 1 to 4.3 times greater than the average concentration in each of the 16-inch core composite samples collected from the same areas. But this is a small sample set, and it contains highly variable patterns of mercury distribution in the soil (mercury concentrated in a fairly narrow band in one sample and mercury highly dispersed throughout the core in another). The VIS data, then, are not especially useful for predicting when the mercury was deposited in the floodplain or what mercury concentrations people were actually exposed to in the past.

ATSDR scientists considered that the mixing of soil within each core sample (using composite samples) likely diluted the mercury that was concentrated in narrow bands within the cores. During the RI, an average concentration for each core composite sample was produced rather than a minimum and maximum range across core layers. The range would have more accurately reflected any large differences in concentration that may have occurred across varying core depths. ATSDR accounted for this dilution effect of composite samples by applying an adjusted core sample value that provides an estimate of the maximum mercury concentration possibly detected within each core sample (see Appendix E. Task 2 Pathway Discussions for more details).

Among the adjusted RI data, 27 samples (among 2,808 data points[14]) exceeded 2,400 ppm. The range of mercury concentrations among the adjusted RI data that exceeded 2,400 ppm was from 2,491 to 8,440 ppm. Except for one sample, all were collected from the NOAA and Bruner sites. The exception was one subsurface core sample (16–32 inches below ground surface) collected east of the Horizon Center property, upstream from Bear Creek on the northwest side of the Oak Ridge Turnpike (Highway 95), and on the south side of EFPC at a sharp bend in the creek. The adjusted mercury concentration for this sampling location is 3,010 ppm. This sample location is on DOE property and is not currently zoned for residential development.

At the upper end of the adjusted RI data (8,400 ppm) the estimated child exposure doses exceed ATSDR's inorganic mercury oral MRLs (acute = 0.007 mg/kg/day; intermediate = 0.002 mg/kg/day). Exposure doses did not exceed the mercury MRLs in adults. Nor does the maximum adjusted concentration (8,400 ppm) result in exposure doses to children or adults exceeding ATSDR's methylmercury MRL (0.0003 mg/kg/day).

Although childhood exposures to inorganic mercury exceed their respective MRLs at the highest adjusted mercury concentration (8,400 ppm), the estimated dose is approximately 10 times lower than the NOAEL of 0.23 mg/kg/day used to derive the intermediate oral inorganic mercury MRL (the smaller of the two inorganic mercury oral MRLs) (ATSDR 1999). Using health-protective exposure assumptions and the highest adjusted mercury concentration, health effects have not been observed in human or animal studies at the estimated doses. However, the uncertainties in the assumed exposure dose parameters and limitations with the studies used to derive the MRLs

[14] This adjusted RI data group did not include RI sediment or sewer line beltway data, or data from the TVA or ORAU data sets. ATSDR examined all of those data and confirmed that none would have exceeded 2,400 ppm if they were similarly adjusted.

do not assure us that exposures—particularly for very young children—are safe. While the likelihood of young children playing in the floodplain soils diminishes with decreasing age, the risk of harm from equivalent exposures increases with decreasing age and body size. In short, the uncertainties in both the exposure parameters and the comparison values suggest that the mercury in the floodplain soil could have posed an oral and dermal hazard to young children.

Past Soil and Sediment Exposure Pathway Conclusions

ATSDR concludes

- Children who played at the NOAA site and Bruner site before the soil removal activities in 1996 and 1997 could have accidentally eaten inorganic mercury in EFPC floodplain soils. For children, eating this soil could have caused harmful renal effects. Adults are not expected to have been harmed.
- Accidental ingestion of methylmercury in EFPC floodplain soils in the past is not expected to have caused harmful health effects for anyone contacting the floodplain soil.

Past Soil and Sediment Exposure Pathway Recommendations

DOE should maintain long-term oversight of the mercury-contaminated soil at the spot in the EFPC floodplain east of the Horizon Center. DOE should also consider remediation of the spot or deed restrictions if the property is transferred to another party.

IV.A.5. Mercury in Fish

Mercury in fish and shellfish is predominantly methylmercury, with small amounts of inorganic mercury. When elemental or inorganic mercury enters freshwater environments, some of it is transformed into methylmercury, which accumulates in fish and seafood. It is the methylmercury form in fish that is harmful to the developing fetus and young children. Tests for mercury in fish, however, often measure all forms of mercury. We refer to these tests as total mercury concentration or just mercury concentration. Identification of just the methylmercury or inorganic mercury concentrations in fish requires specific tests.

Sampling Data

Fish downstream from the Y-12 plant were first collected and analyzed for total mercury[15] in 1970. ATSDR reviewed mercury concentrations in fish samples collected from 1970 through 1990. This data was also used by the Task 2 investigators to develop the fish mercury model. Table 12 provides a summary of the fish data. Bolded numbers represent the maximum fish mercury concentrations in each stream sampled: EFPC, Poplar Creek, Clinch River, and Watts Bar Reservoir. The numbers of fish contributing to each dataset are not available from the Task 2 report; each data set specifies a different location, a different collection period, or a different fish species (ChemRisk 1999a).

[15] Methylmercury comprises nearly 100% of the mercury in fish tissue (ChemRisk 1999a).

Table 12. Mercury[1] Concentrations in Fish Collected Downstream of the Y-12 Plant

Location	*Year*	*No. of Data Sets*	*Concentration (ppm)*	
			Average[2]	*Maximum*
EFPC	1970	3	0.55	1.3
EFPC	1982	4	1.4	3.6
EFPC	1983	6	0.28	0.74
EFPC	1984	18	0.73	1.4
Poplar Creek	1976	6	0.5	1.4
Poplar Creek	1977	36	0.3	2.1
Poplar Creek	1982	24	0.35	1.3
Poplar Creek	1984	3	0.2	0.42
Poplar Creek	1990	3	0.49	0.88
Clinch River	1976	23	0.29	2.1
Clinch River	1977	24	0.23	1.5
Clinch River	1979	7	0.11	1.1
Clinch River	1984	7	0.24	1.2
Clinch River	1990	2	0.27	0.77
Watts Bar Reservoir	1984	6	0.14	0.45
Watts Bar Reservoir	1987	1	< 0.10	< 0.10
Watts Bar Reservoir	1990	2	0.08	0.25

Source: ChemRisk 1999a (Refer to Appendix J Table J-3 in the Task 2 report for information regarding fish species sampled and specific sample location.)
EFPC: East Fork Poplar Creek
ppm: parts per million
All concentrations are reported as fresh (i.e., wet) weight.
Bolded numbers represent the highest average and maximum fish concentrations in each stream sampled.
[1] Methylmercury comprises nearly 100% of the mercury in fish tissue (ChemRisk 1999a).
[2] The average represents the average of the mean reported for each data set and is not weighted to reflect the difference in sample size across the different studies.

ATSDR used the fish data from Table 12 to evaluate past exposures to methylmercury[16] in fish. ATSDR scientists considered both chronic and acute exposures to mercury in fish. For chronic exposures (eating fish from the local streams over an extended period of time, more than a year), we used the highest yearly average mercury concentrations reported in fish tissue samples collected from each of the sampling location. For acute exposures (eating fish for short periods of time with high mercury concentrations, fewer than 2 weeks), we used the maximum fish concentrations reported.

Although the datasets are limited, the mercury concentrations detected in fish samples fall within a relatively narrow range (range of mean values: <0.10–1.4 ppm). This suggests mercury levels do not vary widely across the different sampling locations. But we have no way of knowing how mercury concentrations in fish caught prior to 1970 compare with these data.

[16] ATSDR assumed that the mercury measured in fish is 100% methylmercury.

Results and Discussion: Chronic Exposures from Eating Fish

Estimating mercury intake from eating fish is uncertain. The intake varies depending on the type, frequency, and quantity of fish eaten. Fish mercury concentrations generally decrease with distance downstream from the Y-12 plant, while the fish consumption rates increase with distance from the Y-12 plant. The highest mercury concentrations were in EFPC. However, the anglers who ate fish from Poplar Creek, Clinch River, and Watts Bar Reservoir have the higher estimated mercury doses than anglers who ate fish from EFPC; they eat more fish than anglers in EFPC because EFPC is not a productive fishing location. See Appendix G. Past Exposure Pathway Parameters for ATSDR's assumptions and formulas used to estimate exposure doses.

To evaluate the long-term (chronic exposure, more than a year) methylmercury exposure to the average individual eating fish caught downstream from the Y-12 plant, ATSDR used the average mercury concentrations from EFPC, Poplar Creek, Clinch River, or Watts Bar Reservoir (see bold concentrations in Table 12) and the average fish consumption rates reported in the Task 2 report (see Table G-2 and Table G-3). For EFPC, Clinch River, and Watts Bar Reservoir, the estimated doses of the fish-eating populations are about an order of magnitude lower than both the ATSDR chronic organic mercury MRL of 3.0×10^{-4} mg/kg/day and the U.S.EPA RfD of 1.0×10^{-4} mg/kg/day (see Table 13, Table 7, and Figure 12). The estimated doses for Poplar Creek were above the U.S.EPA RfD, but below the ATSDR MRL (see Table 13, Table 7, and Figure 12).

To evaluate people eating the estimated maximum amount of fish from EFPC, we used the average yearly mercury concentrations and the maximum fish consumption rates reported in the Task 2 report to estimate methylmercury doses. The estimated exposure doses were below both the U.S.EPA RfD and the ATSDR MRL (see Table 13, Table 7, and Figure 12).

For recreational anglers (adults and child) eating Poplar Creek, Clinch River, or Watts Bar Reservoir fish, we also used the average yearly mercury concentrations and the maximum fish consumption rates reported in the Task 2 report to estimate methylmercury doses. All of the estimated doses were above the U.S.EPA RfD (see Table 13, Table 7, and Figure 12). Some were also above the ATSDR MRL.

Table 13. Methylmercury Exposure Doses from Fish Collected Downstream of the Y-12 Plant

Location	*Year*	*Average Concentration (ppm)*	*Exposure Doses Using Average Concentrations and Average Consumption Rates[1] (mg/kg/day)*		*Exposure Doses Using Average Concentrations and Maximum Consumption Rates[1] (mg/kg/day)*	
			Adults	*Children*	*Adults*	*Children*
EFPC	1970	0.55	9.4×10^{-6}	1.2×10^{-5}	3.1×10^{-6}	3.9×10^{-5}
EFPC	1982	1.4	2.4×10^{-5}	3.0×10^{-5}	8.0×10^{-6}	1.0×10^{-4}
EFPC	1983	0.28	4.8×10^{-6}	6.0×10^{-6}	1.6×10^{-6}	2.0×10^{-5}
EFPC	1984	0.73	1.3×10^{-5}	1.6×10^{-5}	4.2×10^{-6}	5.2×10^{-5}
Poplar Creek	1976	0.5	1.3×10^{-4}	1.6×10^{-4}	4.6×10^{-4}	5.9×10^{-4}
Poplar Creek	1977	0.3	7.7×10^{-5}	9.6×10^{-5}	2.8×10^{-4}	3.5×10^{-4}
Poplar Creek	1982	0.35	9.0×10^{-5}	1.1×10^{-4}	3.3×10^{-4}	4.1×10^{-4}
Poplar Creek	1984	0.2	5.1×10^{-5}	6.4×10^{-5}	1.9×10^{-4}	2.3×10^{-4}
Poplar Creek	1990	0.49	1.3×10^{-4}	1.6×10^{-4}	4.6×10^{-4}	5.8×10^{-4}
Clinch River	1976	0.29	7.5×10^{-5}	9.3×10^{-5}	2.7×10^{-4}	3.4×10^{-4}
Clinch River	1977	0.23	5.9×10^{-5}	7.4×10^{-5}	2.1×10^{-4}	2.7×10^{-4}
Clinch River	1979	0.11	2.8×10^{-5}	3.5×10^{-5}	1.0×10^{-4}	1.3×10^{-4}
Clinch River	1984	0.24	6.2×10^{-5}	7.7×10^{-5}	2.2×10^{-4}	2.8×10^{-4}
Clinch River	1990	0.27	6.9×10^{-5}	8.6×10^{-5}	2.5×10^{-4}	3.2×10^{-4}
Watts Bar Reservoir	1984	0.14	6.0×10^{-5}	7.5×10^{-5}	2.2×10^{-4}	2.7×10^{-4}
Watts Bar Reservoir	1987	< 0.10	4.3×10^{-5}	5.3×10^{-5}	1.6×10^{-4}	2.0×10^{-4}
Watts Bar Reservoir	1990	0.08	3.4×10^{-5}	4.3×10^{-5}	1.3×10^{-4}	1.6×10^{-4}

[1] See Table G-2 in Appendix G for average and maximum consumption rates.
Bold text indicates that the exposure dose is higher than the U.S.EPA RfD of 1.0×10^{-4} mg/kg/day.

The ATSDR chronic MRL of 3×10^{-4} mg/kg/day for ingestion of organic mercury is based on the Seychelles Child Development Study, in which people who were exposed to 1.3×10^{-3} mg/kg/day of methylmercury from eating fish did not experience any adverse health effects (Davidson et al. 1998) (See Table 7 and Figure 12.) Over 700 mother-infant pairs have been followed and tested from birth through 107 months of age (Myers et al. 2009). The Seychellois regularly consume a large quantity and variety of ocean fish, with 12 fish meals per week representing a typical methylmercury exposure. Developing fetuses were exposed to methylmercury *in utero* through maternal fish ingestion before and during pregnancy. Neonates continued to be exposed to maternal mercury during breastfeeding (some mercury is secreted in breast milk), and methylmercury exposure from the regular diet continued after the gradual post-weaning shift to a fish diet (Davidson et al. 1998). After 66-months test results revealed no evidence of adverse effects in offspring attributable to a mother's chronic ingestion of low levels of mercury (median total mercury concentration in 350 fish sampled from 25 species consumed by the Seychellois was <1 ppm [range, 0.004–0.75 ppm]) of methylmercury in fish (Davidson et al. 1998). After 107 months test results revealed a number of associations between postnatal exposure and test outcomes, but the results varied. Although the authors concluded that the

findings were consistent with the earlier 66-month testing, they suggested that postnatal exposure should be further studied (Myers et al. 2009). More information about the harmful effects of methylmercury is available in ATSDR's Toxicological Profile for Mercury (ATSDR 1999).

The U.S.EPA RfD of 1.0×10^{-4} mg/kg/day for methylmercury is based on a long-term study of children born to women who lived on the Faroe Islands (See Table 7 and Figure 12.) This population relies heavily on seafood and whales as a protein source. The investigators used various neurological tests that monitor child development. They concluded that at birth, cord blood mercury levels in the mother were associated with lower performance on standardized neurobehavioral tests at age 7 years involving attention, verbal memory, confrontational naming, and to a lesser extent visual/spatial abilities and fine-motor functions (Grandjean et al. 1997). Follow-up studies at age 14 years showed similar findings (Debes et al. 2006). Using a mathematical model, U.S.EPA concluded that the benchmark dose lower limit (BMDL05) range from 46 to 79 ppb methylmercury concentration in maternal cord blood. This range of methylmercury concentration in maternal cord blood is associated with a 5 percent increase in the incidence of neurodevelopmental effects. This methylmercury concentration in maternal cord blood equated to a range of 8×10^{-4} mg/kg/day to 1.5×10^{-3} mg/kg/day as a dietary intake. The doses were divided by an uncertainty factor of 10 to arrive at the RfD of 1.0×10^{-4} mg/kg/day.

The U.S.EPA's approach is consistent with the National Academy of Sciences (NAS) recommendation of using the BMDL of 58 ppb methylmercury in maternal cord blood from the Faroe Islands Study to develop the methylmercury RfD (NRC 2000) (See Table 7 and Figure 12.) The National Academy of Sciences concluded that the Boston Naming Test was the most sensitive and reliable at detecting neurodevelopmental effects in the Faroe Island children (NRC 2000). The NAS concluded that the estimated BMDL of 58 ppb of methylmercury in maternal cord blood is the dose that resulted in a 5 percent increase in the incidence of abnormal scores on the Boston Naming Test (a picture-naming, vocabulary test) (NRC 2000). The cord blood concentration of 58 ppb methylmercury corresponds to 12 ppm methylmercury concentration in maternal hair (NRC 2000). The associated dietary intake was calculated to be 1.1×10^{-3} mg/kg/day (NRC 2000).

None of the estimated exposure doses from fish collected downstream of the Y-12 plant were higher than the NOAEL (1.3×10^{-3} mg/kg/day) from the Seychelles study (Davidson et al. 1998) (Table 13, Table 7, and Figure 12). Nor were they higher than the LOAELs (8×10^{-4} mg/kg/day to 1.5×10^{-3} mg/kg/day) from the Faroe Island study (Grandjean et al. 1997). However, some of the doses were in the same order of magnitude as the LOAELs from the Faroe Island study.

East Fork Poplar Creek

In Table 13, the estimated methylmercury doses are below the U.S. EPA RfD and ATSDR MRL and are not at levels associated with harmful effects in children or fetuses of women who consumed an average or maximum rate of EFPC fish in 1970 and the 1980s. These estimated doses for EFPC are based on an occasional meal of EFPC fish (approximately 4 meals a year for a child and 9 meals a year for an adult). Low consumption rates are used because EFPC is not a productive fishing area.

Poplar Creek

Developing fetuses were at an increased risk of subtle neurodevelopmental effects if, before and during pregnancy, women ate approximately 12 meals per month of Poplar Creek fish caught in

the 1970s, 1980s, and 1990. In Table 13, a woman's estimated methylmercury dose from eating Poplar Creek fish at the maximum consumption rate approached 1.1×10^{-3} mg/kg/day. This was identified by the NAS in the Faroe Islands study as a dose that results in a 5 percent increase in the incidence of abnormal scores on the Boston Naming Test (a picture-naming, vocabulary test) (NRC 2000). The NAS effect level is consistent with the range of 8.5×10^{-4} mg/kg/day to 1.5×10^{-3} mg/kg/day identified as the benchmark dose lower limit (BMDL05) by the U.S. EPA. Based on the Faroe Islands study, this BMDL05 is the lowest dose that is expected to be associated with a 5 percent increase in the incidence of neurodevelopmental effects (NRC 2000). Possible harmful effects identified from studies of children exposed *in utero* involve attention, verbal memory, confrontational naming, and to a lesser extent visual/spatial abilities and fine-motor functions (Debes et al. 2006; Grandjean et al. 1997; NAS 2000). In addition, even if children were not exposed *in utero*, some children who frequently eat the same fish as their mother ate are also at risk of harmful effects. This conclusion is somewhat uncertain, primarily because a person's mercury response is itself somewhat uncertain. Contributing to that uncertainty is how the body handles mercury, and the sex, genetics, health, and nutritional status of the person who eats the fish, or how mercury is handled in the body.

Similarly, children who ate 6 meals a month (the maximum consumption rate) of Poplar Creek fish also have estimated doses approaching the NAS dose effect level and the EPA BMDL05. Whether children are as sensitive to the neurotoxic effects of mercury as the fetus is uncertain. To be protective, U.S. EPA's and FDA's national fish advisory includes a warning for children as well as women who are pregnant, who plan to become pregnant, and nursing mothers (see Appendix H).

Women who consumed an average rate of approximately 3 meals a month of Poplar Creek fish in the 1970s, 1980s, and 1990 are at a small increased risk of harming a developing fetus if they are pregnant or a baby if the mother is nursing. Also, children who ate less than 2 meals a month (average consumption rate) of Poplar Creek fish have a small increased risk of neurodevelopmental effects. Most of the estimated doses in Table 13 for these women and children are below the U.S.EPA RfD and ATSDR MRL and the few doses that are slightly above the RfD are not approaching the NAS dose effect level or the EPA BMDL05.

Clinch River

Women who consumed a maximum rate of approximately 12 meals a month of Clinch River fish in the 1970s, 1980s, and 1990 have a small increased risk of harming a developing fetus if they were pregnant or a baby if the mother was nursing the baby. Children who consumed an average rate of approximately 6 meals a month of Clinch River fish also have a small increased risk of neurodevelopmental effects. The estimated doses in Table 13 for these women and children are only slightly above the RfD and MRL; however, these estimated doses are not approaching the NAS dose effect level or the EPA BMDL05.

The estimated does in Table 13 for women and children who consumed 2-3 meals of Clinch River fish a month are not at risk of harmful effects from mercury in fish. The estimated dose in Table 13 for women and children are below the U.S. EPA RfD and ATSDR MRL.

Watts Bar Reservoir

Women who consumed a maximum rate of approximately 20 meals a month of Watts Bar Reservoir fish in the 1980s and 1990 had a small increased risk of harming a developing fetus if

they were pregnant or their baby if the mother was nursing the baby. Children who consumed an average rate of approximately 10 meals a month of Watts Bar Reservoir had a lower risk of neurodevelopmental effects. The estimated doses in Table 13 for these women and children are only slightly above the RfD; however, these estimated doses are not approaching the NAS dose effect level or the EPA BMDL05.

The estimated does in Table 13 for women and children who consumed 3-5 meals of Watts Bar Reservoir fish a month are not at risk of harmful effects from mercury in fish. The estimated dose in Table 13 for these women and children were below the U.S. EPA RfD and the ATSDR MRL.

National Fish Advisory

In March 2004, the U.S.EPA and the Food and Drug Administration (FDA) released a joint national fish advisory. It emphasized that fish and shellfish were an important part of a healthy diet. The advisory pointed out that fish and shellfish contained high-quality protein and other essential nutrients, were low in saturated fat, and provided omega-3 fatty acids (a heart healthy chemical). A well-balanced diet that included a variety of fish and shellfish could contribute to heart health and to children's proper growth and development. The advisory concluded that people, including women and young children, should include fish or shellfish in their diets (EPA 2004; FDA 2004).

The joint FDA/U.S.EPA advisory acknowledged that nearly all fish and shellfish contain traces of mercury. For most people, the risk of mercury-related health effects from eating fish and shellfish was not a concern. Yet some fish and shellfish may contain levels of mercury considered unhealthy. The risks from mercury in fish and shellfish depend on the mercury levels in the fish and shellfish and the amount eaten. The FDA and the U.S.EPA advised women who might become pregnant, women already pregnant, nursing mothers, and young children to avoid some types of fish and to eat fish and shellfish known to have lower mercury levels (EPA 2004; FDA 2004). The National Fish Advisory is included in Appendix H.

Results and Discussion: Acute Exposures from Eating Fish

To evaluate acute exposure, the maximum mercury concentration reported from the Task 2 fish data set was used (see Table 12). It was assumed that a person would eat one fish meal consisting of 170 grams (about 6 ounces) of fish.

The scientific literature includes one study in which the LOAEL for acute methylmercury exposure was estimated to be 0.001 mg/kg/day. This was a study of Iraqi children born to mothers who had consumed grain tainted with methylmercury used as a fungicide (Cox et al. 1989). The adverse affect was delayed onset of walking in young children. However, a closer examination of the study revealed numerous shortcomings and confounding factors (Crump et al. 1995). Further, the same results were not observed in the Seychelles study used to derive the ATSDR chronic methylmercury MRL (Davidson et al. 1998) nor in the Faroes study (Grandjean et al. 1997) used to derive the U.S.EPA RfD for methylmercury. Neither the Seychelles study nor other human studies examined acute methylmercury exposures.

In animal studies, neurotoxic signs, including muscle spasms, gait disturbances, flailing, and hindlimb crossing were observed in rats after acute-duration gavage dosing with methylmercury concentrations at doses as low as 4 mg/kg/day for 8 days (Inouye and Murakami 1975). The authors stated the effects may not be observed until several days after dosing has stopped. It is

not clear whether 4 mg/kg/day represents an acute toxicological threshold for humans. Evidence from the scientific literature, however, suggests that no adverse effects in rats occur at dose levels of 2 mg/kg/day (Inouye and Murakami 1975; Hughes and Annau 1976). At the highest mercury concentration reported in the Task 2 datasets (fish from EFPC, mercury concentration = 3.6 ppm), a child eating 2 six-ounce meals of fish per day would have a dose of 0.044 mg/kg/day, which is two orders of magnitude below these acute doses. Except for neurodevelopmental effects observed following methylmercury exposures *in utero* and to nursing babies via breast milk, the animal studies suggest exposures to older children and adults from consuming fish from EFPC or farther downstream will not result in acute adverse health effects.

The scientific evidence is clear that fetuses and breast feeding babies are much more sensitive to mercury than are older children and adults. Four-month old rats were reported to exhibit significant reduction in behavior performance tests after exposure *in utero* to methylmercury at doses as low as 0.008 mg/kg/day during gestational days 6–9. Doses of 0.004 mg/kg/day did not result in performance reduction (Bornhausen et al. 1980). A pregnant woman would not exceed the LOAEL dose of 0.008 mg/kg/day by eating only one 6-ounce fish meal (170 grams) with a mercury concentration of 2.8 ppm (6.9×10^{-3} mg/kg/day). And would not exceed the NOAEL dose (0.004 mg/kg/day) by eating one meal with a mercury concentration of 1.4 ppm (3.4×10^{-3} mg/kg/day). Only eating fish from EFPC in 1982 would result in an acute exposure dose higher than the LOAEL.

Conclusions for Fish

ATSDR's conclusions refer to the potential to cause harm for methylmercury exposures (in the past) from eating fish downstream from the Y-12 plant. Given the available information, an evaluation of reported adverse health effects that could be attributed to methylmercury exposure from consuming fish during the 1950s and 1960s is not possible. It is also important to emphasize that ATSDR's conclusions should only be interpreted as a *potential* for health effects to have occurred due to methylmercury exposures in the past.

1. ATSDR cannot conclude whether eating fish from EFPC, Poplar Creek, Clinch River, or Watts Bar Reservoir during the 1950s and 1960s could have harmed people's health (from both chronic and acute exposures). Although mercury concentrations in water, surface sediments, and surface soils were higher during the 1950s and 1960s than they were in later decades, we do not have adequate data characterizing the methylmercury concentrations in fish in those waters during the 1950s and 1960s. Earlier attempts to model the average annual mercury concentrations in fish or exposure doses from eating fish (beginning in 1950) included assumptions not easily verifiable and may not be appropriate for making public health decisions.
2. ATSDR cannot conclude whether eating fish from EFPC and Watts Bar Reservoir during the 1970s could have harmed people's health (from both chronic and acute exposures). A small number of fish samples were collected from EFPC in 1970 (after 1970, samples were not collected again until 1982). But they are not representative of the entire decade of the 1970s. No fish samples were collected from Watts Bar Reservoir in the 1970s. Therefore, the hazard posed by fish consumed from either EFPC or Watts Bar Reservoir during the 1970s cannot be evaluated.

3. ATSDR concludes that periodically eating fish from EFPC (up to nine meals per year) in the 1980s is not expected to have harmed people's health, including children who ate fish, nursing infants whose mothers ate fish, and children born to women who ate fish during pregnancy. Ingestion rates of fish from EFPC are low because it is not a productive fishing area, and the estimated methylmercury exposure doses are below both the U.S.EPA RfD and the ATSDR MRL for methylmercury.

4. ATSDR concludes that eating approximately 12 fish meals per month from Poplar Creek in the 1970s, 1980s, and 1990 may have increased the risk of subtle neurodevelopmental effects in children who ate fish and children born to women who ate fish during pregnancy. The estimated methylmercury exposure doses approach the dose of 1.1×10^{-3} mg/kg/day identified by the National Academy of Sciences in the Faroe Islands study as a dose that results in a 5 percent increase in the incidence of abnormal scores on the Boston Naming Test (a picture-naming, vocabulary test) (NRC 2000). The NAS effect level is consistent with the range of 8.5×10^{-4} mg/kg/day to 1.5×10^{-3} mg/kg/day identified as the BMDL05 by the U.S. EPA in the Faroe Islands study. Similarly, children who ate up to 6 meals a month of Poplar Creek fish also have estimated methylmercury doses approaching the NAS dose effect level and the EPA BMDL05.

   Women who consumed an average rate of approximately 3 meals a month of Poplar Creek fish in the 1970s, 1980s, and 1990 are at a small increased risk of harming a developing fetus or their nursing child. Also, children who consumed less than 2 meals a month (average consumption rate) of Poplar Creek fish were at a small increased risk of neurodevelopmental effects. Most of the estimated methylmercury doses for these women and children are below the EPA RfD and the few doses that are slightly above the RfD are not approaching the NAS dose effect level or the EPA BMDL05.

5. ATSDR concludes that women eating 12 fish meals per month (3 fish meals a week) from the Clinch River in the 1970s, 1980s, and 1990 had a small increased risk of subtle neurodevelopmental effects in children born to women who ate fish while pregnant. Children who ate approximately 6 fish meals a month from the Clinch River also had a small increased risk of subtle neurodevelopmental effects. The estimated methylmercury exposure doses are only slightly above the U.S. EPA RfD and ATSDR MRL and are not approaching the NAS dose effect level or the U.S. EPA BMDL05 identified in the Faroe Islands study. Pregnant women who ate up to three Clinch River fish meals per month would not have resulted in increased risk of harmful health effects to developing fetuses.

6. ATSDR concludes that pregnant or nursing women who ate 20 fish meals per month (five fish meals a week) from the Watts Bar Reservoir in the 1980s and in 1990 have a small increased risk of subtle neurodevelopmental effects in the fetus or nursing child. Children who ate approximately 10 fish meals a month from the Watts Bar Reservoir also had a small increased risk of subtle neurodevelopmental effects. The estimated exposure methylmercury doses are only slightly above the U.S. EPA RfD and not approaching the NAS dose effect level or the U.S. EPA BMDL05 identified in the Faroe Islands study. Eating fewer than six meals per month is not expected to have caused harmful health effects to a developing fetus.

IV.A.6. Mercury in Local Produce

Sampling Data

ORAU evaluated mercury accumulation in vegetation between 1983 and 1987; SAIC evaluated mercury accumulation in vegetation as part of the EFPC RI in 1992 (ChemRisk 1999a). ORAU collected approximately 150 vegetation samples and analyzed them for mercury. The samples were collected from a variety of locations throughout the city of Oak Ridge and EFPC floodplain with a wide range of reported soil mercury concentrations. SAIC collected 55 vegetation samples from the EFPC floodplain. ORAU also collected 32 samples from plants grown in a laboratory greenhouse. Table 14 lists the specific types of edible samples collected and analyzed for mercury.

Data from higher plants indicate that virtually no mercury is taken up from the soil into the shoots of plants such as peas, although mercury concentrations in the roots may be significantly elevated and reflect the mercury concentrations of the surrounding soil (Lindqvist 1991). ATSDR assumed that the total mercury measured in fruits and vegetables is inorganic mercury. Mercury speciation studies of plants grown in soil with inorganic mercury contamination indicate that the mercury taken into plants is taken up as inorganic mercury (i.e., mercuric ions) (ChemRisk 1999a).

Table 14. Types of Local Produce Tested for Mercury

Fruits and Other Vegetables	*Leafy Vegetables*	*Root Crops*
Banana Pepper	Broccoli	Beets
Bell Pepper	Cabbage	Carrots
Blackberry	Chard	Onions
Corn	Collard greens	Potatoes
Cucumber	Green beans-Pod	Radishes
Eggplant	Kale	Turnips
Grapes	Lettuce	
Green Beans	Radish leaves	
Okra	Spinach leaves	
Pea Pods	Turnip leaf	
Squash	Watercress	
Strawberry		
Tomato		
Watermelon		
Zucchini		

A flowering meadow perennial called sneezeweed had the highest total mercury concentration in vegetation across both studies (maximum = 239.4 ppm).[17]

[17] Mercury concentrations in vegetation are reported in ppm on a dry weight basis. The sneezeweed (genus, *Helenium*) samples were greenhouse samples grown in soil with soil mercury concentrations of 1,140 ppm.

Mercury concentrations in most of the edible produce sampled from Oak Ridge-area gardens were below 1 ppm. None of the ORAU vegetable samples collected in the city of Oak Ridge and EFPC floodplain exceeded 1 ppm, and only four of SAIC edible produce samples collected from the EFPC floodplain Bruner site exceeded 1 ppm (ChemRisk 1999a). The highest mercury concentration in edible produce samples from the Bruner site was 3.2 ppm in a kale leaf sample. On average, leafy vegetables and root vegetables had similar mercury concentrations, and both had higher mercury concentrations than fruits. The average mercury concentration was 1.6 ppm in leafy vegetables, 1.4 ppm in root vegetables, and 0.025 ppm in fruits (see Table 15).

Table 15. Mercury Concentrations in Locally Grown Produce

Edible Produce	*No. of Samples*	*Average Hg Concentration (ppm)*
Leafy vegetables	32	1.6
Fruits	72	0.025
Root vegetables	16	1.4
Total	120	0.64

Source: ChemRisk 1999a
ppm: parts per million
Hg: mercury

Results and Discussion for Local Produce

The data show that vegetables or fruits grown in private gardens with mercury-contaminated floodplain soils may contain inorganic mercury. That said, whether edible vegetation is consumed in large enough quantities or at a sufficient frequency to pose harm to people's health is unlikely. Based on an EPA estimated intake rate for people living in the south, adults and children were assumed to eat 2.27 grams of homegrown vegetables per kilogram of body weight per day (EPA 1997) (See Appendix G. Past Exposure Pathway Parameters for additional exposure assumptions.). The estimated mercury exposure doses for children and adults are well below the acute oral MRL (0.007 mg/kg/day) and the intermediate oral MRL (0.002 mg/kg/day). Using the average mercury concentration of 1.6 ppm in leafy vegetables, the estimated intermediate oral doses for children and adults are 0.0001 mg/kg/day and 0.00009 mg/kg/day, respectively. For acute exposure, the highest concentration of 3.2 ppm mercury in edible produce was used to estimate the acute oral doses of 0.001 mg/kg/day for children and 0.0007 mg/kg/day for adults. This analysis suggests that the mercury in the fruits and vegetables grown in the city of Oak Ridge and the EFPC floodplain are not expected to have harmed people's health, even when consumed regularly in moderate to high quantities.

Conclusions for Local Produce

ATSDR concludes

- Consuming local produce grown in mercury-contaminated gardens in the city of Oak Ridge and the EFPC floodplain is not expected to have harmed people's health.

IV.B. Current Exposure (1990–2009)

Because the Task 2 dose reconstruction evaluated past exposures through 1990, exposures since 1990 are evaluated as "current exposures" in this public health assessment.

To evaluate current exposures, ATSDR gathered and assessed available data from four main areas of interest: East Fork Poplar Creek, the city of Oak Ridge, the Scarboro neighborhood within the city of Oak Ridge, and the Lower Watts Bar Reservoir (including the Clinch River and Watts Bar Reservoir). The media evaluated include air, surface water, soil, sediment, and biota (including fish and vegetables) (see Table 16).

Table 16. Current Exposure Pathways Evaluated

Exposure Pathway	Mercury Species	East Fork Poplar Creek	Oak Ridge	Scarboro	Lower Watts Bar Reservoir
Air pathway	Elemental	X			X
Surface water pathway	Inorganic	X	X	X	X
Soil pathway	Inorganic	X	X	X	X
Sediment pathway	Inorganic	X	X	X	X
Biota pathways					
Fish consumption	Organic	X			X
Vegetable consumption	Inorganic	X	X		

IV.B.1. Current Air Exposure Pathway (elemental mercury)

Current EFPC Air

In 1993 and 1996, ATSDR evaluated ambient elemental air data from the EFPC RI (ATSDR 1993b, 1996a). These data were collected before the floodplain soil was remediated. Short-term (minutes to hours) and long-term (days to weeks) ambient air samples were collected from three floodplain locations (NOAA, Lysimeter, and Minit Chek) with known mercury soil contamination up to 3,000 mg/kg. Ambient mercury concentrations ranged from 0.0000059 to 0.0000109 mg/m^3 using short-term monitoring and from 0.0000031 to 0.0000124 mg/m^3 using long-term monitoring (DOE 1992b; SAIC 1994). All of the concentrations are one to two orders of magnitude below the chronic EMEG of 0.0002 mg/m^3 for mercury concentrations in air.

Before, during, and after Phase I remediation of the Lower EFPC floodplain soil, continuous mercury air monitoring was conducted at the NOAA site, located approximately 200 meters northeast of the excavation area (Barnett et al. 1997). Monitoring was conducted from March 10 to October 14, 1996 (Phase I excavation occurred from July 8 to September 14, 1996; SAIC 2002a). All of the concentrations were below the comparison value of 0.0002 mg/m^3 for mercury concentrations in air (the maximum concentration detected was 0.000061 mg/m^3; Barnett et al. 1997). As expected airborne mercury after the excavation was at least three times lower than the concentrations before and during remediation (Barnett et al. 1997).

During Phase II remediation of the Lower EFPC floodplain soil, over 10,000 ambient air samples were collected near the Bruner site (SAIC 2002a; OREIS 2009). Monitoring was conducted from March 12 to October 21, 1997. All of the mercury ambient air concentrations were at least 2.5

times lower than the comparison value of 0.0002 mg/m^3 for mercury concentrations in air (the maximum concentration detected was 0.00008 mg/m^3; OREIS 2009).

Ambient air sampling was conducted near the areas with the highest levels of mercury contamination. Sampling was also conducted during the summer months when increased sunlight and temperature cause more mercury vapor to release from the soil (Barnett 1997). All of the air samples were less than the comparison value for mercury in air. As stated earlier, health-based comparison values reflect concentrations much lower than those that have been observed to cause adverse health effects and are protective of public health in essentially all exposure situations. As a result, we do not consider concentrations detected at or below ATSDR's inhalation comparison values to warrant health concern. Therefore, no further evaluation is required. The air monitoring data indicate that the mercury levels in the ambient air at EFPC are not at levels of public health concern.

Current LWBR Air

No ambient air samples have been analyzed for mercury concentrations at the LWBR. But the occurrence of harmful health effects from exposure to mercury vapor from contaminated soil is not a concern for the LWBR. The mercury contamination accumulated in the sediments of the river channel (where little, if any, exposure occurs), buried under as much as 80 centimeters of cleaner sediment (ORNL and Jacobs Engineering Group 1995). The near-shore sediment concentrations in the LWBR (less than 1 mg/kg; ORNL and Jacobs Engineering Group 1995) are much lower than those found in the EFPC floodplain. Thus mercury levels in the ambient air near LWBR (if any) are not expected to be at levels of public health concern.

IV.B.2. Current Surface Water Exposure Pathway (inorganic mercury)

Current EFPC Surface Water

In a 1993 health consultation concerning Y-12 plant releases into EFPC, ATSDR evaluated exposures to mercury contamination in surface water using data from a summary of the EFPC Phase Ia RI (ATSDR 1993b). Within the creek in 1991 and 1992, surface water was sampled from five stations (the mouth of Lake Reality, confluence of EFPC with Poplar Creek, two intermediate stations, and an area of known high contaminant concentrations in the floodplain soil). Mercury was only detected in one sample. The mercury concentration was 0.72 ppb (SAIC 1993); a level below U.S.EPA's MCLG of 2 ppb in drinking water. Therefore, no further evaluation is required. ATSDR concluded that the levels of mercury in the surface water do not present a public health concern.

As stated earlier, comparison values reflect concentrations that are much lower than those that have been observed to cause adverse health effects and are protective of public health in essentially all exposure situations. As a result, concentrations detected at or below ATSDR's comparison values are not considered to be a health concern.

The OREIS Environmental Database contains almost 650 surface water samples from EFPC (OREIS 2009). The majority of the surface water samples were collected during Phase II remediation of the Lower EFPC floodplain soil (Phase II excavation occurred from March 3 to October 24, 1997; SAIC 2002a). Water samples were collected in 1991–1994, 1996, 1997, and 1999–2009 from 25 different locations in the creek. Of the 647 samples collected from the EFPC surface water, mercury was detected in only 126 samples (about 1 out of 5 samples). As shown in Table 17, in 1992, only one mercury concentration (about 0.1 percent) was detected slightly above U.S.EPA's MCLG of 2 ppb for drinking water. None of the 643 water samples collected

since 1992 have exceeded the MCLG. This indicates that the vast majority of the concentrations were detected at levels not warranting health concern.

Table 17. Mercury Concentrations in EFPC Surface Water

Year	*Minimum (ppb)*	*Maximum (ppb)*	*Average (ppb)*	*Detection Frequency*
1991	0	0.54	0.092	3/14
1992	2.8	2.8	2.8	1/1
1993	ND	ND	ND	0/2
1994	0	0.25	0.016	6/39
1996	0.10	0.52	0.30	5/5
1997	0	0.77	0.022	30/505
1999	0.22	0.71	0.467	2/2
2000	0.03	0.5	0.19	8/8
2001	0.029	0.96	0.25	11/11
2002	0.025	0.35	0.13	8/8
2003	0.02	0.21	0.093	8/8
2004	0.024	0.45	0.16	8/8
2005	0.028	0.45	0.15	8/8
2006	0.016	0.28	0.12	8/8
2007	0.022	0.28	0.095	8/8
2008	0.017	0.46	0.13	8/8
2009	0.19	0.28	0.15	4/4
Overall	0	2.8	0.047	126/647

Source: OREIS 2009
ND: not detected

Note: remember that exceeding a comparison value does not automatically mean that the environmental concentrations are expected to produce harmful health effects. Comparison values are not thresholds of toxicity. They simply indicate to ATSDR that further evaluation is warranted. Keep in mind, too, that the comparison value ATSDR is using to screen surface water samples is a drinking water guideline based on a lifetime exposure that assumes ingesting 1 liter (children) or 2 liters (adults) of water per day. Adults and children are unlikely to participate in recreational activities in EFPC surface water, especially since signs are posted to warn the public to avoid contact with the water because of the bacterial contamination.

To evaluate the *potential* for exposure, ATSDR calculated exposure doses using the maximum concentration detected in the EFPC surface water (2.8 ppb; OREIS 2009) and the formula described in Section III.C.3 Comparing Estimated Doses to Health Guidelines. Both adults and children were assumed to ingest 0.15 liters of water/day during a 3-hour swimming event (EPA 1997) for 4 days/year (minimum value for a farm family member described in ChemRisk 1999a). ATDSR assumed that adults weighed 70 kg and were exposed for 30 years, and children

weighed 28.1 kg and were exposed for 6 years. Using these assumptions in the exposure dose formula, both the estimated adult dose (6.6×10^{-5} mg/kg/day) and child dose (1.6×10^{-4} mg/kg/day) were below the U.S.EPA RfD of 3.0×10^{-4} mg/kg/day for chronic exposure to inorganic mercury. The RfD is an estimate of the daily human exposure to a hazardous substance likely to be without appreciable risk of adverse noncancer health effects. It has built-in uncertainty or 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 of health concern. ATSDR does not expect that exposure to EFPC surface water would cause adverse health effects.

ATSDR also evaluated an additional exposure scenario, assuming that the posted bacterial advisory is ignored. If this happens, children may begin to play in the creek more frequently. Children were assumed to ingest 0.15 liters/day during a 3-hour swimming event (EPA 1997) for 18 days/year (four times per month for 3 months plus six times over the remainder of the year). As noted earlier, ATDSR assumed that children weighed 28.1 kg and were exposed for 6 years. This scenario produced an estimated exposure dose (1.1×10^{-4} mg/kg/day) below the RfD (3.0×10^{-4} mg/kg/day) using the average concentration (0.42 ppb).[18] Even if children ignore the bacterial advisory, slightly more frequent exposures to mercury in the surface water are also not expected to cause harmful health effects.

Current Oak Ridge Surface Water

The OREIS Environmental Database contains 53 surface water samples from the city of Oak Ridge (OREIS 2009). Samples were collected in 1990, 1991, 1993, 1995–2001, and 2003–2005 from 15 different locations within the city of Oak Ridge. Of the 53 samples collected, mercury was only detected in 10 samples (19 percent). In 1993, only one sample containing mercury was above U.S.EPA's MCLG of 2 ppb for drinking water (see Table 18). None of the water samples collected since 1993 have exceeded the MCLG. In fact, mercury was only detected in one sample since 1993. This indicates that the vast majority of the concentrations were detected at levels not warranting a health hazard.

[18] By using an average concentration, ATSDR can estimate a more probable exposure. In this case, using the average concentration is even more appropriate given that the maximum detection seems to be an outlier. The second highest concentration was 0.96 ppb and all but one sample were detected below the conservative comparison value of 2 ppb (OREIS 2009).

Table 18. Inorganic Mercury Concentrations in Oak Ridge Surface Water

Year	*Minimum (ppb)*	*Maximum (ppb)*	*Average (ppb)*	*Detection Frequency*
1990	0.2	0.2	0.2	1/1
1991	ND	0.3	0.15	1/2
1993	0.2	4.7	1.08	7/7
1995	ND	ND	ND	0/2
1996	ND	ND	ND	0/11
1997	ND	0.1	0.014	1/7
1998	ND	ND	ND	0/2
1999	ND	ND	ND	0/4
2000	ND	ND	ND	0/6
2001	ND	ND	ND	0/2
2003	ND	ND	ND	0/6
2004	ND	ND	ND	0/2
2005	ND	ND	ND	0/1
Overall	ND	4.7	0.15	10/53

Source: OREIS 2009
ND: not detected

To evaluate the exposure further, ATSDR calculated exposure doses using the maximum concentration detected in Oak Ridge surface water (4.7 ppb; OREIS 2009) and the formula described in Section III.C.3 Comparing Estimated Doses to Health Guidelines. Both adults and children were assumed to ingest 0.15 liters of water/day during a 3-hour swimming event (EPA 1997) for 4 days/year (minimum value for a farm family member described in ChemRisk 1999a). As noted earlier, ATDSR assumed that adults weighed 70 kg and were exposed for 30 years, and children weighed 28.1 kg and were exposed for 6 years. Using these assumptions in the exposure dose formula, both the estimated adult dose (1.1×10^{-4} mg/kg/day) and child dose (2.7×10^{-4} mg/kg/day) were below the RfD of 3.0×10^{-4} mg/kg/day for chronic exposure to inorganic mercury. ATSDR does not expect that exposure to surface water in the city of Oak Ridge would cause harmful health effects.

Remember that the RfD is an estimate of daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects. It has built-in uncertainty 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 a health hazard.

Current Scarboro Surface Water

In May 1998, the Environmental Sciences Institute at FAMU collected seven surface water samples from drainage ditches in the Scarboro community. Mercury was not detected in any of the samples (the quantitation limit was 0.1 ppb; FAMU 1998; OREIS 2009). In September 2001, U.S.EPA collected two surface water samples from the Scarboro community to validate the 1998 FAMU results. Mercury was not detected in either sample (the detection limit was 0.029 ppb;

EPA 2003). Therefore, no further evaluation is required—mercury has not been detected in any surface water samples collected from the Scarboro community. The data indicate that exposure to the surface water in Scarboro is not at levels that could cause adverse health effects.

As mentioned earlier in the hydrogeology section, the southward sloping orientation of the bed planes beneath Pine Ridge prevents groundwater from flowing north toward Scarboro. Furthermore, Scarboro is located outside of the EFPC floodplain. As Figure 7 shows, the elevation of Scarboro is greater than 50 feet higher than EFPC. Therefore, contamination from EFPC could not have reached Scarboro.

Current LWBR (Clinch River/Watts Bar Reservoir) Surface Water

In a 1996 health consultation on LWBR, ATSDR evaluated exposures to mercury contamination in surface water in the reservoir. ATSDR determined that the levels of mercury in the surface water do not present a public health concern, and the reservoir is safe for swimming, skiing, boating, and other recreational purposes (ATSDR 1996b).

To arrive at this conclusion, ATSDR used surface water data from the LWBR RI/FS (ORNL and Jacobs Engineering Group 1995), which references data from Phase I of the Clinch River RI (Cook et al. 1992) and the ORR Environmental Monitoring Program (Energy Systems 1993). Mercury was not detected in any of the surface water samples analyzed (detection limits ranged from 0.05 to 0.2 ppb; ORNL and Jacobs Engineering Group 1995). Because mercury was not detected in the surface water and the detection limits were below the comparison value of 2 ppb for surface water, no public health concerns arise from exposure to mercury in LWBR surface water.

The OREIS Environmental Database contains 311 surface water samples from LWBR (OREIS 2009). Samples were collected in 1990 and from 1993 to 2009 from 19 different locations in the reservoir. Mercury was only detected 5 percent of the time (OREIS 2009). As shown in Table 19, when mercury was detected, the concentrations were less than the comparison value of 2 ppb for mercury in surface water. No further evaluation is required, and the data indicate that exposure to mercury in the surface water in LWBR is not causing harmful health effects.

Table 19. Mercury Concentrations in LWBR Surface Water

Year	*Minimum (ppb)*	*Maximum (ppb)*	*Average (ppb)*	*Detection Frequency*
1990	ND	ND	ND	0/4
1993	ND	ND	ND	0/14
1994	ND	1.3	0.024	10/90
1995	ND	0.056	0.0056	1/10
1996	ND	ND	ND	0/11
1997	ND	ND	ND	0/15
1998	ND	ND	ND	0/14
1999	ND	ND	ND	0/16
2000	ND	ND	ND	0/26
2001	ND	ND	ND	0/13
2002	ND	ND	ND	0/28
2003	ND	0.2	0.033	3/12
2004	ND	ND	ND	0/17
2005	ND	ND	ND	0/12
2006	ND	ND	ND	0/12
2007	ND	ND	ND	0/10
2008	ND	ND	ND	0/4
2009	ND	ND	ND	0/3
Overall	ND	1.3	0.0084	14/311

Source: OREIS 2009
ND: not detected

Municipal Water Systems

Drinking water from the municipal water supply systems is safe. The City of Oak Ridge, including Scarboro, is supplied with treated water from the Clinch River (Melton Reservoir) upstream of the ORR. Rockwood and Spring City draw surface water from the Piney River and King Creek tributary embayments of the LWBR. The Kingston municipal water system intake is in the Tennessee River upstream from where the Clinch River joins with the Tennessee River to form LWBR (see Figure 1). Harriman receives their public water supply from the Emory River, which flows into the LWBR. In addition, these municipal water systems are required to meet specific drinking water quality standards set by U.S.EPA. Under the authorization of the Safe Drinking Water Act, U.S.EPA has set national health-based standards to protect drinking water and its sources. TDEC enforces these requirements and ensures that the drinking water is safe for public consumption. Residents who use municipal drinking water should have no health concerns about that water.

Information about Tennessee's Safe Drinking Water Program can be found at http://www.state.tn.us/environment/dws/DWprogram.shtml.

Seeps and Springs

In 2006, ATSDR conducted a public health assessment that evaluated potential exposures to contaminated off-site groundwater from the ORR (ATSDR 2006). In this assessment, ATSDR evaluated data from seeps and springs from various sampling locations around the main ORR facilities: near the East Tennessee Technology Park (formerly the K-25 site), near the Oak Ridge National Laboratory (formerly the X-10 site), and near the Y-12 National Security Complex (formerly the Y-12 plant). Elevated levels of mercury were not found in any of the seep or spring water samples. For the complete evaluation of seeps and springs, please refer to ATSDR's *Public Health Assessment: Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation* (ATSDR 2006) (available on the Internet at http://www.atsdr.cdc.gov/HAC/oakridge/phact/groundwater/index.html).

IV.B.3. Current Groundwater Exposure Pathway

In the 2006 public health assessment, ATSDR concluded that no human exposures to contaminated groundwater outside the ORR boundary have occurred in the past, are currently occurring, or are likely to occur in the future (ATSDR 2006). Therefore, ATSDR does not expect any health effects from exposure to contaminated off-site groundwater. For a complete evaluation of groundwater, please refer to ATSDR's *Public Health Assessment: Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation* (ATSDR 2006) (available on the Internet at http://www.atsdr.cdc.gov/HAC/oakridge/phact/groundwater/index.html).

IV.B.4. Current Soil Exposure Pathway (inorganic mercury)

Current EFPC Soil

EFPC Floodplain Soil (prior to remediation in 1997)

In a 1993 health consultation concerning Y-12 plant releases into EFPC, ATSDR evaluated soil data from the EFPC Phase Ia RI (ATSDR 1993b). ATSDR concluded that in some locations along EFPC, mercury levels in the floodplain soil could pose a threat to people—especially children—who ingest, inhale, or have dermal contact with contaminated soil while playing or fishing along the creek's floodplain (ATSDR 1993b).

See section IV.A.4. Past Soil and Sediment Exposure Pathways for a more extensive public health analysis of potential exposure to the EFPC floodplain soil prior to remediation of soil containing greater than 400 ppm of mercury in 1996 and 1997. ATSDR concluded that children who played at the NOAA site and Bruner site before the soil removal activities could have accidentally eaten inorganic mercury in EFPC floodplain soils, which could have caused harmful renal effects. Adults are not expected to have been harmed from exposure to inorganic mercury in soil. Accidental ingestion of methylmercury in EFPC floodplain soils in the past is not expected to have caused harmful health effects for anyone contacting the floodplain soil.

ATSDR's Evaluation of DOE's Proposed Mercury Cleanup Level for EFPC Floodplain Soil

In response to public comments on the *1995 Proposed Plan for East Fork Poplar Creek*, DOE, U.S. EPA, and TDEC selected a remedial action to remove soils containing greater than 400 ppm

of mercury from the EFPC floodplain (DOE 1995b). This 400 ppm mercury clean-up level is higher than the original remediation goal of 50 ppm. Some community members and organizations were concerned about this higher clean-up level and asked ATSDR to evaluate whether the proposed clean-up level of 400 ppm in EFPC floodplain soil was protective of public health.

To help evaluate the proposed EFPC mercury clean-up level for soil, ATSDR sponsored a *Science Panel Meeting on the Bioavailability of Mercury in Soil*. The science panel convened to identify methods and strategies for the development of data-supported, site-specific estimates of the bioavailability of inorganic mercury and other metals from soils. Private consultants and academicians internationally known for their metal bioavailability research were invited to the meeting, which was held in August 1995. In addition to these members, the panel included experts from ATSDR, CDC, U.S.EPA, and the National Institute for Environmental Health Sciences. The science panel published four articles on bioavailability of inorganic mercury in soil in *Risk Analysis* 17 (5), 527-569 (1996).

ATSDR analyzed the clean-up level using a worst-case scenario and a likely mercury exposure scenario of young children in a residential setting (ATSDR 1996a). The worst-case exposure scenario assumed a 16-kg child ingested 100 mg of soil every day. The likely exposure scenario assumed that a 16-kg child ingested 100 mg/day, 5 days/week for 36 weeks/year. For both exposure scenarios, estimated oral exposure doses of mercury were orders of magnitude lower than the NOAEL and LOAEL for inorganic mercury. ATSDR also considered inhalation of mercury vapor from the floodplain soil and determined that the level of mercury vapor in air above floodplain soil with 400 ppm of mercury or less would be too low to be a health hazard (ATSDR 1996a). ATSDR concluded that the clean-up level of 400 ppm of mercury in EFPC floodplain soil is protective of public health and poses no health threat to children or adults (ATSDR 1996a).

The excavation of floodplain soils with greater than 400 ppm of mercury was conducted in two phases. From July 8 to September 14, 1996 (Phase I), 4,250 m^3 of mercury-contaminated soils were removed from the floodplain near the NOAA Atmospheric Diffusion Laboratory off Illinois Avenue. From March 3 to October 24, 1997 (Phase II), an additional 29,970 loose m^3 of mercury-contaminated soils were removed from the floodplain near the NOAA site and across the Oak Ridge Turnpike from the Bruner's Shopping Center on the Wayne Clark Property (SAIC 1993, 2002a). Confirmatory samples[19] were taken during both phases of the excavation to ensure that the remediated areas contained less mercury than the clean-up standard (SAIC 1998). Postremediation monitoring (mercury input, stream stability, and fish sampling) is conducted to ensure the effectiveness of the excavation (SAIC 2002a). Following cleanup and removal in 1996 and 1997, mercury in EFPC is not a public health hazard.

Current Oak Ridge Soil

The OREIS Environmental Database contains over 200 soil samples from the city of Oak Ridge (OREIS 2009). Samples were collected in 1991, 1992, 1995, 1999, and 2000 from 176 different locations within the city. As shown in Table 20, mercury was detected in 157 samples (70 percent). Of the 224 samples collected from soil in the city of Oak Ridge, 34 samples (15 percent) were detected above the comparison value of 20 ppm (OREIS 2009).

[19] Data from Phase Ia and Ib of the EFPC RI, including the confirmatory samples, appear to be included in OREIS.

Table 20. Mercury Concentrations in Oak Ridge Soil

Year	*Minimum (ppm)*	*Maximum (ppm)*	*Average (ppm)*	*Detection Frequency*
1991	2.3	126	14.13	45/45
1992	ND	158	22.18	45/52
1995	ND	48.6	6.38	45/85
1999	ND	49.5	2.62	21/41
2000	0.13	0.13	0.13	1/1
Overall	ND	158	10.89	157/224

Source: OREIS 2009
ppm: parts per million

Because the comparison value was exceeded, ATSDR continued to evaluate exposures to Oak Ridge soil. As the next step in the screening process, ATSDR calculated exposure doses using the maximum concentration detected in the soil (158 ppm; OREIS 2009) and the formula described in Section III.C.3. Comparing Estimated Doses to Health Guidelines. To calculate exposure doses, an adult was assumed to ingest 100 mg of soil/day for 16 days/year (2 times a month for 8 months; likely scenario described in ChemRisk 1999a). A child was assumed to ingest 200 mg/day for 180 days/year (20 times a month for 6 months). As noted earlier, ATDSR assumed that adults weighed 70 kg and were exposed for 30 years, and children weighed 28.1 kg and were exposed for 6 years.

As stated earlier, comparison values reflect concentrations much lower than those that have been observed to cause adverse health effects and are protective of public health in essentially all exposure situations. As a result, concentrations detected at or below ATSDR's comparison values are not considered a health concern.

Using these assumptions in the exposure dose formula, the estimated adult dose (9.9×10^{-6} mg/kg/day) was below U.S.EPA's RfD of 3.0×10^{-4} mg/kg/day for chronic exposure to inorganic mercury. Estimated doses less than the RfD are not considered a health hazard. But the child dose (5.5×10^{-4} mg/kg/day) was slightly higher than the RfD. Still, when compared with actual health effects levels studied in the toxicological and epidemiological literature (autoimmune effects were observed in Brown Norway rats exposed to doses of 0.226, 0.317, and 0.633 mg/kg/day [Andres 1984; Bernaudin et al. 1981; Druet et al. 1978]), the child dose is three orders of magnitude lower. Therefore, ATSDR does not expect that exposure to mercury in Oak Ridge soil to cause adverse health effects.

Current Scarboro Soil

In May 1998, the Environmental Sciences Institute at FAMU collected 40 surface soil samples from the Scarboro community. Mercury concentrations ranged from 0.021 to 0.30 ppm, with a median value of 0.11 ppm (FAMU 1998; OREIS 2009). In September 2001, U.S.EPA collected six surface soil samples from the Scarboro community to validate the 1998 FAMU results. Mercury concentrations ranged from 0.0432 to 0.0904 ppm, with an average concentration of 0.07 ppm (EPA 2003). All of these concentrations are below the comparison value of 20 ppm for mercury in soil. Therefore, no further evaluation is required. The sampling data indicate that the mercury levels in the surface soil in Scarboro are not at levels of public health hazard.

Current LWBR Soil

The OREIS Environmental Database does not contain any soil samples collected from the LWBR (OREIS 2009). Even though no data are available, the occurrence of harmful health effects from exposure to mercury in soil along the LWBR shoreline is not a concern. Mercury from ORR operations has not contaminated the soil near LWBR. Mercury from the ORR was released into EFPC from the Y-12 plant and traveled to the LWBR through Poplar Creek and the Clinch River. The mercury accumulated in the sediments of the LWBR river channel (where little, if any, exposure would occur) and is buried under as much as 80 centimeters of cleaner sediment (ORNL and Jacobs Engineering Group 1995). The near-shore sediment concentrations in the LWBR were less than 1 ppm—much lower than the comparison value of 20 ppm for mercury in soil (ORNL and Jacobs Engineering Group 1995). The mercury levels in the soil near the LWBR are not a public health hazard.

IV.B.5. Current Sediment Exposure Pathway (inorganic mercury)

Current EFPC Sediment

In a 1993 health consultation concerning Y-12 plant releases into EFPC, ATSDR evaluated sediment data from the EFPC Phase Ia RI (ATSDR 1993b). From Autumn 1990 to Spring 1991, nine samples were collected from seven sites within EFPC to define source contributions (SAIC 1993). Phase 1b of the EFPC RI was conducted from August 1991 to February 1992 to determine the extent and distribution of contaminants within the floodplain (SAIC 1993). Transects were established across the floodplain at 100-meter intervals. Stream sediment samples were taken at odd-numbered transects, and every three sequential sediment samples were composited for analysis. Investigators collected 27 sediment samples, each one representing 600 meters of the creek (SAIC 1993). Sediment samples from both phases ranged from 10 to 2,240 ppm, which exceeded the comparison value of 20 ppm for mercury in sediment. But the maximum value (2,240 ppm) appears to be an outlier; it was reportedly taken from an area with obvious creek sediment contamination (SAIC 1993). The second highest concentration from this dataset appears to be 95.6 ppm,[20] which also exceeds the comparison value (SAIC 1993). The mean concentration, based on a total of 35 samples (excluding the 2,240 ppm outlier) is 14.9 ppm (SAIC 1993). The data from the EFPC RI does not appear to be in the OREIS Environmental Database. Because ATSDR does not have access to the raw data from this investigation, the EFPC RI data cannot be combined with the data available in OREIS.

Remember, an environmental concentration that exceeds a comparison value doesn't automatically mean harmful health effects. Comparison values are not thresholds of toxicity. They simply indicate to ATSDR that further evaluation is warranted.

The OREIS Environmental Database contains 58 sediment samples from EFPC (OREIS 2009). Samples were collected in 1990–1992, 1994, and 1996 from 38 different locations in the creek. As shown in Table 21, mercury concentrations exceeded the comparison value of 20 ppm for sediment. Of the 58 samples collected from the EFPC sediment, 20 samples (34 percent) were detected above the comparison value (OREIS 2009).

[20] ATSDR does not have access to the raw data. ATSDR makes an assumption about the 2,240 ppm detection being an outlier based on the data presented in tables within the EFPC RI (SAIC 1993). Specifically, Table 3.19, the results for the Phase 1a and 1b sediment sampling, does not contain this value.

Table 21. Mercury Concentrations in EFPC Sediment

Year	*Minimum (ppm)*	*Maximum (ppm)*	*Average (ppm)*	*Detection Frequency*
1990	15.4	42	28.7	2/2
1991	ND	101	17.58	13/26
1992	0.94	120	24.13	19/19
1994	0.03	0.061	0.045	2/2
1996	2.24	78.89	40.00	9/9
Overall	ND	120	21.59	45/58

Source: OREIS 2009
ppm: parts per million

Because the comparison value was exceeded in both datasets, ATSDR continued to evaluate exposures to EFPC sediments. Adults and children are unlikely to participate in recreational activities in the EFPC sediments, especially since signs are posted to warn the public to avoid contact with the creek's surface water because of the bacterial contamination. In 1992, some of the advisory signs along the creek were replaced and additional signs were posted (TDEC 1992).

However, to evaluate the *potential* for exposure, ATSDR calculated exposure doses using the maximum concentration detected in the sediments (2,240 ppm; SAIC 1993) and the formula described in Section III.C.3. Comparing Estimated Doses to Health Guidelines. To calculate exposure doses, an adult was assumed to ingest 50 mg of sediment/day for 4 days/year (minimum value for a farm family member described in ChemRisk 1999a). A child was assumed to ingest 100 mg/day for 4 days/year (minimum value for a farm family member described in ChemRisk 1999a). ATDSR assumed that adults weighed 70 kg and were exposed for 30 years, and children weighed 28.1 kg and were exposed for 6 years.

Using these assumptions in the exposure dose formula, both the estimated adult dose (1.8×10^{-5} mg/kg/day) and child dose (8.7×10^{-5} mg/kg/day) were below U.S.EPA's RfD of 3.0×10^{-4} mg/kg/day for chronic exposure to inorganic mercury. Remember that the RfD 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. Estimated doses below these values are not considered of health concern. Furthermore, ATSDR used the maximum concentration (2,240 ppm) (most likely an outlier) to calculate these exposure doses. The levels that people are actually being exposed to are expected to be much lower. Exposures to EFPC sediments are not expected to cause harmful health effects.

ATSDR also evaluated an additional exposure scenario: assume the posted bacterial advisory for no contact with the water is ignored. If this happens, children may begin to play in the creek more frequently. Children were assumed to ingest 100 mg/day for 18 days/year (four times per month for 3 months plus six times over the remainder of the year). As noted earlier, ATDSR assumed that children weighed 28.1 kg and were exposed for 6 years. Using the maximum concentration (2,240 ppm; SAIC 1993), this scenario produced an estimated exposure dose (3.9×10^{-4} mg/kg/day) slightly above the RfD (3.0×10^{-4} mg/kg/day). As stated earlier, however, ATSDR believes that the maximum concentration from the EFPC RI is an outlier. If this data point is removed and the dose is recalculated using the second highest concentration (120 ppm

from the OREIS database), the resulting exposure dose (2.1×10^{-5} mg/kg/day) is lower than the RfD for chronic exposure to inorganic mercury. Thus, even if the bacterial advisory for water is ignored, more frequent exposures to mercury in the sediments are not expected to cause harmful health effects for children.

Current Oak Ridge Sediment

The OREIS Environmental Database contains 36 sediment samples from the city of Oak Ridge (OREIS 2009). Samples were collected in 1990, 1991, 1993, 1995, and 1997–2001 from 15 different locations within the city. As shown in Table 22, mercury was detected in 30 samples (83 percent). Of the 36 samples collected from sediment in the city of Oak Ridge, 6 samples (17 percent) were detected above the comparison value of 20 ppm (OREIS 2009).

Table 22. Mercury Concentrations in Oak Ridge Sediment

Year	*Minimum (ppm)*	*Maximum (ppm)*	*Average (ppm)*	*Detection Frequency*
1990	34.4	34.4	34.4	1/1
1991	20.4	35.7	30.57	3/3
1993	0.096	6.6	1.64	7/7
1995	ND	31.8	6.19	7/11
1997	ND	0.93	0.47	1/2
1998	0.29	0.37	0.33	2/2
1999	0.12	0.25	0.18	6/6
2000	ND	0.35	0.18	1/2
2001	0.12	0.17	0.15	2/2
Overall	ND	35.7	5.80	30/36

Source: OREIS 2009
ppm: parts per million

Comparison value exceedences caused ATSDR to continue its evaluation of exposures to Oak Ridge sediment. As the next step in the screening process, ATSDR calculated exposure doses using the maximum concentration detected in the sediment (35.7 ppm; OREIS 2009) and the formula described in Section III.C.3. Comparing Estimated Doses to Health Guidelines. To calculate exposure doses, an adult was assumed to ingest 50 mg of sediment/day for 24 days/year (4 times per month for 4 months plus two times a month for 4 months). A child was assumed to ingest 100 mg/day for 32 days/year (6 times a month for 4 months plus 2 times per month for 4 months). ATDSR assumed that adults weighed 70 kg and were exposed for 30 years, and children weighed 28.1 kg and were exposed for 6 years.

Using these assumptions in the exposure dose formula, both the estimated adult dose (1.7×10^{-6} mg/kg/day) and child dose (1.1×10^{-5} mg/kg/day) were below U.S.EPA's RfD of 3.0×10^{-4} mg/kg/day for chronic exposure to inorganic mercury. Estimated doses below the RfD are not considered to be a health hazard. ATSDR does not expect that exposure to mercury in the sediment in the City of Oak Ridge would cause adverse health effects.

Current Scarboro Sediment

In May 1998, the Environmental Sciences Institute at FAMU collected nine sediment samples from drainage ditches in the Scarboro community. Mercury concentrations ranged from 0.018 to 0.12 ppm, with an average of 0.05 ppm (FAMU 1998; OREIS 2009). In September 2001, U.S.EPA collected two sediment samples from the Scarboro community to validate the 1998 FAMU results. Mercury was detected at concentrations of 0.0271 and 0.0393 ppm (EPA 2003). All of these concentrations are at least two orders of magnitude below the comparison value of 20 ppm for mercury in sediment. No further evaluation is required—the sampling data indicate that the mercury levels in Scarboro sediment are not at levels of public health concern.

Current LWBR Sediment

Mercury from the ORR was released into EFPC from the Y-12 plant and traveled to the LWBR through Poplar Creek and the Clinch River. The mercury accumulated in the deep sediments of the LWBR river channel, buried under as much as 80 centimeters of cleaner sediment and several meters of water (ORNL and Jacobs Engineering Group 1995). Exposure to sediments in the deep channel, therefore, is not expected. On the other hand, exposure to sediment in shallow, near-shore areas is more likely. ATSDR thus evaluated these exposure scenarios separately, except when the depths of the sediment sampling were unspecified.

Shallow, near-shore sediment

For several months every winter, sediments in shallow areas along the LWBR are above the water line. In a 1996 LWBR health consultation, ATSDR evaluated exposures to mercury contamination in surface sediments in the reservoir using maximum concentrations and worst-case scenarios (ATSDR 1996b). ATSDR assumed children could be exposed to mercury in the shallow sediments while swimming or fishing in the reservoir or if surface sediments were dredged and used for surface soil at residential properties. ATSDR determined that the levels of mercury in the surface sediments did not present a public health concern.

ATSDR used near-shore sediment data from the LWBR RI/FS (ORNL and Jacobs Engineering Group 1995), which references data from TVA's Recreation Area Sampling Study (TVA 1991). In May and June1990, the TVA sampled near-shore sediments from recreational areas along the LWBR. Five sediment samples were collected from each recreational area, which were then combined to make one composite sample for analysis (TVA 1991). Mercury was only detected in three of the 12 composite samples in concentrations of 0.15 ppm[21] (the detection limit was 0.1 ppm; TVA 1991). These concentrations are two orders of magnitude below the comparison value of 20 ppm for mercury in sediment. Therefore, no further evaluation is required—the sampling data indicated that the mercury levels in the shallow sediments in LWBR were not at levels of public health concern.

Deep channel sediments

As stated earlier, people are not directly exposed to the highest concentrations of mercury in the subsurface sediments; these deposits are found in deep channels where contaminants are covered by 40 to 80 centimeters of sediment and several meters of water (ORNL and Jacobs Engineering Group 1995). In a 1996 health consultation, ATSDR evaluated potential exposure a child might

[21] These data appear to be included in the OREIS database.

receive if the subsurface sediments were removed from the deep reservoir channels and used as surface soil in residential properties (ATSDR 1996b). ATSDR determined that the levels of mercury in the deep channel sediments do not present a public health concern.

ATSDR used deep-water sediment data from the LWBR RI/FS (ORNL and Jacobs Engineering Group 1995), which references mercury data from a 1986 study in which two core samples from the LWBR were analyzed (TVA 1986) and a 1992 study in which four core samples from the LWBR were analyzed (Cook et al. 1992). Mercury was detected in concentrations ranging from 1 to 3 ppm (ORNL and Jacobs Engineering Group 1995). These concentrations are six to 20 times lower than the 20-ppm comparison value for mercury in sediment. No further evaluation is required—the sampling data indicate that the mercury levels in the deep channel sediments in LWBR are not at levels of public health concern.

Unspecified sediment depths

The OREIS Environmental Database contains 140 sediment samples from the LWBR (OREIS 2009). In 1990, from 1993 to 2002, and in 2004, samples were collected from 43 different reservoir locations. The depths of the sediment samples are not clear. As shown in Table 23, in 1990 and 2002, *maximum* mercury concentrations exceeded the comparison value of 20 ppm for sediment. Yet the *average* mercury concentrations were below the comparison value. Of the 140 samples collected from the LWBR sediment, only six samples (about 4 percent) were detected above the comparison value (OREIS 2009). This indicates that the vast majority of the concentrations were detected at levels that do not warrant health concern.

Table 23. Mercury Concentrations in LWBR Sediment

Year	*Minimum (ppm)*	*Maximum (ppm)*	*Average (ppm)*	*Detection Frequency*
1990	0.061	160	11.76	39/39
1993	1.4	6.4	2.35	16/16
1994	0.05	12.3	1.77	42/42
1995	ND	1.21	0.60	4/5
1996	0.11	6.2	1.48	6/6
1997	0.52	0.52	0.52	1/1
1998	0.57	0.59	0.58	2/2
1999	0.24	4.5	1.42	6/6
2000	0.09	2.79	1.57	6/6
2001	0.17	1.05	0.55	5/5
2002	0.08	42.2	6.15	8/8
2004	ND	11.4	3.6	3/4
Overall	ND	160	4.78	138/140

Source: OREIS 2009
ppm: parts per million

Nevertheless, because the comparison value was exceeded, ATSDR further evaluated exposures to LWBR sediments. As the next step in the screening process, ATSDR calculated exposure doses using the maximum concentration detected in the unspecified sediments (160 ppm; OREIS 2009) and the formula described in Section III.C.3. Comparing Estimated Doses to Health Guidelines. For exposure purposes, ATSDR assumed that all the unspecified depth samples were shallow, near-shore sediments—that is, that they were accessible.

LWBR is a high-use recreational area. Not only do people live in the vicinity of the reservoir, but people from outside the area visit the many parks and recreational facilities (TVA 1987, 1990). People, particularly children, who fish, play, hike, or swim along the reservoir may be exposed to mercury through ingestion of sediment from inadvertent hand-to-mouth activities. Young children have the greatest risk of exposure to mercury. Given that children play in the dirt and engage in frequent hand-to-mouth activity and often mouth objects, they are likely to have the most frequent and longest duration exposure to LWBR near-shore sediments.

To calculate exposure doses. ATSDR assumed an adult ingested 50 mg of sediment/day for 24 days/year (four times per month for 4 months plus two times a month for 4 months). We assumed a child ingested 100 mg/day for 32 days/year (six times a month for 4 months plus two times per month for 4 months). ATDSR assumed that adults weighed 70 kg and were exposed for 30 years, and children weighed 28.1 kg and were exposed for 6 years.

Using these assumptions in the exposure dose formula (see Section III.C.3. Comparing Estimated Doses to Health Guidelines), both the estimated adult dose (7.5×10^{-6} mg/kg/day) and child dose (5.0×10^{-5} mg/kg/day) were well below U.S.EPA's RfD of 3.0×10^{-4} mg/kg/day for chronic exposure to inorganic mercury. Remember that estimated doses less than the RfD are not considered of health concern. Furthermore, ATSDR used the maximum concentration (160 ppm) to calculate these exposure doses, but the vast majority of the samples (96 percent) were detected below the conservative comparison value of 20 ppm. Exposures to LWBR sediments are not expected to cause harmful health effects.

Still, to prevent unnecessary exposures to workers and the public, ATSDR cautions that the sediments should not be disturbed, removed, or disposed of without careful review by the interagency working group (DOE, TDEC, U.S.EPA, TVA, and the U.S. Army Corps of Engineers). Established in 1991, the interagency working group coordinates and reviews permitting and other use activities that could result in the disturbance, resuspension, removal, disposal—or a combination thereof—of contaminated sediments in the Watts Bar Reservoir (DOE 1995c; SAIC 2004).

IV.B.6. Current Biota Exposure Pathway

Current EFPC Biota

EFPC Fish (methylmercury)

In a 1993 health consultation concerning Y-12 plant releases into EFPC, ATSDR evaluated a summary of the November, 1990, and May, 1991, fish data from EFPC compiled by the DOE Biological Monitoring and Abatement Program (ATSDR 1993b). Concentrations of mercury in fish fillets ranged from 0.08 to 1.31 ppm[22] (ORNL 1992). This exceeded the comparison value of

[22] These data appear to be included in the OREIS database.

0.14 ppm for fish samples. ATSDR concluded that the levels of mercury found in fish from EFPC were at levels of public health concern (ATSDR 1993b).

The OREIS Environmental Database contains 430 samples from redbreast sunfish, rock bass, largemouth bass, and crayfish collected from seven locations in EFPC (OREIS 2009). Redbreast sunfish were collected in 1991 and 1995 through 2001 and 2004–2008; rock bass were collected in 2004, 2006, 2008, and 2009; largemouth bass were collected in 1995; and crayfish were collected in 1991. As shown in Table 24, mercury was detected in all 430 fish and crayfish samples above the comparison value of 0.14 ppm (OREIS 2009). Remember this does not automatically mean that an environmental concentration exceeding a comparison value is expected to produce harmful health effects. Comparison values are not thresholds of toxicity. They simply indicate a need for further evaluation.

Table 24. Mercury Concentrations in Fish from EFPC

Species	*Portion*	*Minimum (ppm)*	*Maximum (ppm)*	*Average (ppm)*	*Detection Frequency*
Largemouth Bass (Hg)	Muscle	0.51	0.61	0.56	2/2
Redbreast Sunfish (Hg)	Fillet/Muscle	0.37	1.8	0.87	167/167
Redbreast Sunfish (Hg)	Whole body	0.59	2.5	1.4	8/8
Redbreast Sunfish (Hg)	Unknown	0.35	1.6	0.86	120/120
Redbreast Sunfish (MeHg)	Muscle	0.50	1.5	0.92	24/24
Redbreast Sunfish (MeHg)	Unknown	0.19	1.6	0.63	36/36
Rock Bass (Hg)	Muscle	0.64	1.58	1.0	67/67
Crayfish (Hg)	Whole body	0.51	6.6	3.3	6/6
Overall		0.19	6.6	—	430/430

Source: OREIS 2009
ppm: parts per million

Some of the fish samples were analyzed specifically for methylmercury and other samples were analyzed for total mercury (OREIS 2009). In fish tissue, mercury is present predominantly as methylmercury (about 85 percent; Jones and Slotten 1996). Methylmercury is the organic form of mercury and is much more harmful via the oral route than the elemental and inorganic forms (ATSDR 1999). Thus ATSDR took a conservative approach and assumed that all the total mercury detected in the fish was methylmercury.

Because the comparison value was exceeded, ATSDR continued to evaluate mercury exposures from eating EFPC fish. That anyone is actually eating fish from EFPC is unlikely. EFPC is not a productive fishing location, and a fish consumption advisory is in place. Nevertheless, ATSDR evaluated a *potential* exposure scenario and assumed people would ignore the advisory.

To evaluate this potential exposure scenario, ATSDR calculated exposure doses using the average concentration detected in the EFPC fish fillet and muscle samples[23] and the formula described in Section III.C.3. Comparing Estimated Doses to Health Guidelines. ATSDR assumed

[23] It is standard protocol to analyze fillets/edible portions when evaluating human health concerns.

that both adults and children ate one 8-ounce fish meal each month (12 meals/year = 7.5 grams/day). As noted earlier, ATDSR assumed that adults weighed 70 kg and were exposed for 30 years, and children weighed 28.1 kg and were exposed for 6 years.

Using these assumptions in the exposure dose formula, some of the estimated doses from eating EFPC fish once a month were above both the ATSDR MRL for methylmercury (3.0×10^{-4} mg/kg/day) and the U.S.EPA RfD for methylmercury (1.0×10^{-4} mg/kg/day) (see Table 25). Remember that calculated exposure doses higher than the health guidelines do not automatically mean harmful health effects. They are instead an indication that ATSDR should examine further the harmful effect levels reported in the scientific literature and more fully review exposure potential. Therefore, ATSDR compared these potential exposure doses with actual health effects levels in the toxicological and epidemiological literature.

Table 25. Estimated Exposure Doses from Consuming EFPC Fish

Species	*Average Concentration (ppm)*	*Estimated Exposure Doses (mg/kg/day)*	
		adult	*child*
Largemouth Bass (Hg in muscle)	0.56	6.0×10^{-5}	1.5×10^{-4}
Redbreast Sunfish (Hg in fillet/muscle)	0.87	9.3×10^{-5}	2.3×10^{-4}
Redbreast Sunfish (MeHg in muscle)	0.92	9.9×10^{-5}	2.5×10^{-4}
Rock Bass (Hg in muscle)	1.0	1.1×10^{-4}	2.7×10^{-4}
Crayfish (Hg in whole body)	3.3	3.5×10^{-4}	8.8×10^{-4}

mg/kg/day: milligrams per kilograms per day
ppm: parts per million
Bold text indicates that the exposure dose is higher than the U.S.EPA RfD of 1.0×10^{-4} mg/kg/day.

The ATSDR chronic MRL of 3×10^{-4} mg/kg/day for ingestion of organic mercury is based on the Seychelles Child Development Study, in which people who were exposed to 1.3×10^{-3} mg/kg/day of methylmercury in their food did not experience any adverse health effects (NOAEL; Davidson et al. 1998). The U.S.EPA RfD of 1×10^{-4} mg/kg/day is based on the Faroe Islands study, in which maternal dietary intakes of 8×10^{-4} mg/kg/day to 1.5×10^{-3} mg/kg/day were associated with performance on standardized neurobehavioral tests involving effects on attention, memory, confrontational naming, and to a lesser extent visual/spatial abilities and fine-motor functions in children (LOAELs; Debes et al. 2006; Grandjean et al. 1997; NRC 2000). These U.S. EPA benchmark dose lower limits (BMDL05) are expected to be associated with a 5 percent increase in the incidence of neurodevelopmental effects in children exposed *in utero*. The U.S. EPA RfD is consistent with the approach used by the NAS which identified a dose of 1.1×10^{-3} mg/kg/day as a dose that results in a 5 percent increase in the incidence of abnormal scores on the Boston Naming Test (a picture-naming, vocabulary test) (NRC 2000).

Women who ate one meal a month of EFPC fish in the 1990s and 2000s were not at risk of harming a developing fetus if they were pregnant. The estimated doses in Table 25 for women are at or below the U.S. EPA RfD and are not at levels associated with harmful effects in the fetus. However, the estimated exposure doses for children eating fish from EFPC once a month are slightly above the U.S. EPA RfD, but are not approaching the NAS dose effect level or the EPA BMDL05. Whether children are as sensitive to the neurotoxic effects of mercury as is the

fetus is uncertain. Even if children were not exposed *in utero*, some children who frequently eat the same fish as their mother ate are also at risk of harmful effects. This conclusion is somewhat uncertain, primarily because a person's mercury response is itself somewhat uncertain. Contributing to that uncertainty is how the body handles mercury, and the sex, genetics, health, and nutritional status of the person who eats the fish, or how mercury is handled in the body.

Only the estimated methylmercury dose for children eating one meal a month of crayfish from the EFPC is above the lowest LOAEL (8×10^{-4} mg/kg/day) from the Faroe Island study and approaching the NAS dose effect level. Therefore, children who ignore the posted EFPC advisory (no fishing and no contact with water) may be at risk of subtle neurodevelopmental effects if they eat one crayfish meal a month. Women who ate one crayfish meal a month have a small increased risk of harming a developing fetus because the estimated methylmercury dose is slightly above the U.S. EPA RfD, but not approaching the NAS dose effect level or the EPA BMDL05. However, it is highly unlikely for adults and children to eat one meal a month of EFPC crayfish because of the posted advisory and EFPC is not a productive fishing location.

EFPC Vegetables (inorganic mercury)

The OREIS Environmental Database contains 16 samples of beet, kale (cabbage), and tomato collected from two locations in the EFPC floodplain in 1992 (OREIS 2009). Mercury was detected in 12 of the 16 samples (75 percent). See Table 26 for a summary of the mercury concentrations detected in each type of plant.

Table 26. Mercury Concentrations in Edible Plants from EFPC

Species	*Portion*	*Minimum (ppm)*	*Maximum (ppm)*	*Average (ppm)*	*Detection Frequency*
Beet	Root	0.63	2.7	1.3	4/4
Kale	Leaves	0.13	3.2	0.80	7/7
Tomato	Fruit	ND	0.42	—	1/5
Overall		ND	3.2	—	12/16

Source: OREIS 2009
ppm: parts per million

Comparison values are not available for inorganic mercury concentrations detected in edible plants. Thus to further evaluate any edible plant exposure, ATSDR calculates exposure doses. The exposure doses for eating plants are calculated slightly different from the other media because a body weight factor is already incorporated into the ingestion rate. Therefore, ATSDR calculated exposure doses using the maximum concentration detected in the plants (3.2 ppm; OREIS 2009) and the following formula:

$$ED = Conc \times IR \times AF^{24}$$

ED: exposure dose
Conc: concentration
IR: ingestion rate
AF: oral bioavailability

[24] 2.27 g/kg/day was converted to 0.00227 kg/kg/day to allow the units to cancel in the formula.

According to *U.S.EPA's Exposure Factors Handbook* people living in the South eat 2.27 grams of homegrown vegetables per kilogram of body weight per day (g/kg/day) (EPA 1997). The total survey population used to calculate this ingestion rate (IR) included adults and children (EPA 1997). As with the past exposure evaluation, ATSDR assumed the oral bioavailabilities (AF) of inorganic mercury in produce are 15 percent for children and 10 percent for adults (see Appendix G. Past Exposure Pathway Parameters).

The resulting exposure doses are 7.3×10^{-4} mg/kg/day for adults and 1.1×10^{-3} mg/kg/day for children, above the RfD of 3.0×10^{-4} mg/kg/day for chronic exposure to inorganic mercury. Mercury exposures through eating vegetables from EFPC gardens were then further evaluated using a more realistic exposure scenario—average concentrations to calculate the exposure doses. By using average concentrations, ATSDR can estimate a more probable exposure. ATSDR used the same equation and assumptions as above but substituted the average mercury concentration for each species for the maximum concentration (see Table 27 for the estimated exposure doses). ATSDR then compared these potential exposure doses to actual health effects levels in the toxicological and epidemiological literature (EPA 2007).

Table 27. Estimated Inorganic Mercury Exposure Doses from EFPC Vegetable Consumption

Species	*Average Concentration (ppm)*	*Estimated Exposure Doses (mg/kg/day)*	
		Adults	*Children*
Beet (root)	1.3	3.0×10^{-4}	4.4×10^{-4}
Kale (leaves)	0.80	1.8×10^{-4}	2.7×10^{-4}
Tomato (fruit)	0.42	9.5×10^{-5}	1.4×10^{-4}

mg/kg/day: milligrams per kilogram per day
ppm: parts per million

The RfD for inorganic mercury was "arrived at from an intensive review and workshop discussions of the entire inorganic mercury data base" (EPA 2007). It is based on a back calculation from U.S.EPA's recommended drinking water equivalent level (DWEL). This level is based on three studies in which autoimmune effects were observed in rats exposed to doses of 0.226, 0.317, and 0.633 mg/kg/day (Andres 1984; Bernaudin et al. 1981; Druet et al. 1978). These health effect levels are at least three orders of magnitude higher than the estimated doses for adults and for children eating vegetables grown in EFPC gardens. Furthermore, plants tend to store metals such as mercury in a form not readily bioavailable to humans (ATSDR 2001). ATSDR does not expect that eating beets, kale, or tomatoes grown in the EFPC floodplain would cause harmful health effects.

Current Oak Ridge Biota

Oak Ridge Vegetables (inorganic mercury)

The OREIS Environmental Database contains only four vegetable samples (three kale samples and one tomato sample) from the city of Oak Ridge (OREIS 2009). In 1992, samples were collected from one garden within the city. Mercury was not detected in any of the samples. The

vegetable data, although minimal, indicate that eating garden vegetables grown in the city of Oak Ridge is not likely to cause harmful health effects.

Current LWBR Biota

Since 1987, fishing advisories for LWBR have been posted warning people to avoid or limit their consumption of fish due to PCB contamination in the reservoir (ORNL and Jacobs Engineering Group 1995).

LWBR Fish (methylmercury)

In a 1996 health consultation on LWBR, ATSDR evaluated exposures to mercury contamination in fish from the reservoir[25] (ATSDR 1996b). ATSDR determined that the levels of mercury in the fish did not present a public health concern. To arrive at this conclusion, ATSDR evaluated the available data using a worst-case scenario that assumed a 70-kg adult ate one 8-ounce fish meal containing the maximum concentration of mercury every week for 30 years (ATSDR 1996b).

In September 1997, ATSDR conducted an exposure investigation to quantify actual exposures from eating moderate to large amounts of fish and turtles from LWBR (ATSDR 1998). Preliminary information about consumption eligibility and willingness to participate was collected from more than 550 potential participants who volunteered information. About 80% of the potential participants did not eat enough fish from LWBR to be included in the exposure investigation. ATSDR chose to measure blood mercury levels from 116 of the participants who during the past year reported eating one or more turtle meals; six or more meals of catfish and striped bass; nine or more meals of white, hybrid, or smallmouth bass; or 18 or more meals of largemouth bass, sauger, or carp. The participants consisted of 58.6 percent male and 41.4 percent female with an age range from 6 to 88 years and a mean age of 52.2 years. About 80 percent of the participants ate fish from LWBR for six or more years and 65 percent ate fish for more than 11 years. The estimated average daily fish and turtle consumption rate for the participants was 66.5 grams per day (g/day) (ATSDR 1998).

For the 116 participants, the total mercury levels in blood ranged from nondetectable to 20 µg/L. Eighty-nine persons had nondetectable levels of mercury in their blood (the detection limit was 3 µg/L). The median value was below the detection limit and the arithmetic mean of the total mercury detections was 5.2 µg/L. Organic mercury levels in blood ranged from nondetectable to 11 µg/L. One hundred and twelve participants (out of 116) had nondetectable levels of organic mercury in their blood (the detection limit was 3 µg/L). The arithmetic mean of the organic mercury detections was 6 µg/L. The ATSDR scientist concluded in the 1998 exposure investigation that only 1 of 116 participants had an elevated blood mercury level and that the overall exposure investigation participants' blood mercury levels were very similar to levels found in the general population (ATSDR 1998).

In this public health assessment on Y-12 mercury releases, ATSDR further analyzed the exposure investigation results by comparing the total blood mercury data to the total blood mercury data from the National Health and Nutrition Examination Survey (NHANES). We wanted to determine if the 116 exposure investigation participants eating moderate to high amounts of LWBR fish were exposed to elevated levels of mercury. The CDC's National Center for Health Statistics began conducting the NHANES in 1999, to obtain health and nutritional related data from a nationally representative sample of adults and children in the United States in

[25] Fish samples were collected prior to the floodplain remediation.

two-year cycles. The survey combines interviews and physical examinations and includes the measurement of 219 chemicals in people's blood or urine. The *Fourth National Report on Human Exposure to Environmental Chemicals 2009* and the *Updated Tables, February 2011* (CDC 2011) provide the most comprehensive assessment of nationally-representative biomonitoring data of environmental chemical exposure in the U.S. population. The report and tables are available at CDC's website http://www.cdc.gov/exposurereport/. The NHANES biomonitoring studies provide physicians and public health officials with reference ranges that can be used to determine whether people have been exposed to higher levels of mercury than are found in the general population (CDC 2009). The 2011 Updated Tables presents the 95th percentile of total blood mercury data and 95 percent confidence interval for the U.S. population from the 2003–2004, 2005–2006, and 2007–2008 NHANES survey periods (CDC 2011). Based on the total blood mercury data from the NHANES, except for the one elevated exposure investigation blood mercury level of 20 µg/L, the distribution of total blood mercury from the 1998 exposure investigation of moderate to high consumers of LWBR fish is similar to the distribution of total blood mercury for the U.S. population.

In 1996, TDEC conducted a screening study to determine the mercury levels in turtles from the LWBR and the Clinch River (TDEC 1997). Muscle tissue from 13 common snapping turtles was analyzed for mercury content. Mercury concentrations ranged from 0.1 to 0.35 ppm, with an average of 0.19 ppm[26] (TDEC 1997). These levels are slightly above the comparison value of 0.14 ppm for fish. TDEC noted, however, that the mercury concentrations were below FDA's action level of 1 ppm for methylmercury in fish.

In 2005, DOE collected three common snapping turtles from Brashear Island (CRM 11, downstream of Poplar Creek) to monitor mercury levels. Composited mercury concentrations were "relatively high" in both muscle (0.465 ppm) and liver tissue (3.341 ppm), and much lower in fat (0.048 ppm). The 2005 samples were similar to, or slightly less than those collected from the same locations in 2000 (SAIC 2007).

The OREIS Environmental Database contains over 387 samples from channel catfish, unspecified catfish species, largemouth bass, striped bass, gizzard shad, bluegill sunfish, unidentified sunfish species, and red-eared sliders[27] collected every year from 1992 to 2009, from 14 locations in the LWBR (OREIS 2009). As shown in Table 28, many of the maximum detected concentrations exceeded the comparison value of 0.14 ppm for fish samples. Of the 387 fish samples collected from the LWBR, 214 samples (55 percent) were detected above the comparison value (OREIS 2009).

[26] These data do not appear to be included in the OREIS database.

[27] Note that the red-eared slider is not one of three species that are legal to harvest: common snapping, midland smooth softshell, and Eastern spiny softshell (TDEC 1997). That anyone is eating this particular turtle species is unlikely. But with no other turtle sampling data available, ATSDR used red-eared sliders as a representative species.

Table 28. Mercury Concentrations in Fish and Turtles from LWBR

Species	*Portion*	*Minimum (ppm)*	*Maximum (ppm)*	*Average (ppm)*	*Detection Frequency*
Channel Catfish	Fillet/muscle	ND	0.48	0.19	40/41
Channel Catfish	Unknown	ND	1.1	0.28	33/39
Channel Catfish	Whole body	0.10	0.58	0.32	8/8
Catfish, Unspecified Species	Fillet	0.05	0.51	0.19	16/16
Catfish, Unspecified Species	Unknown	0.053	0.36	0.17	4/4
Gizzard Shad	Whole body	0.047	0.054	0.051	3/3
Largemouth Bass	Fillet/muscle	ND	0.78	0.33	39/40
Largemouth Bass	Unknown	ND	0.77	0.27	46/54
Largemouth Bass	Whole body	0.13	0.4	0.3	6/6
Striped Bass	Fillet	0.14	0.52	0.29	4/4
Striped Bass	Unknown	0.093	0.14	0.11	2/2
Striped Bass	Whole body	0.13	0.54	0.28	7/7
Bluegill Sunfish	Unknown	ND	0.45	0.087	33/52
Bluegill Sunfish	Muscle	0.069	0.24	0.12	35/35
Sunfish species	Fillet	ND	0.53	0.14	58/59
Sunfish species	Unknown	0.069	0.16	0.11	4/4
Red-eared Slider (turtle)	Muscle	0.058	0.40	0.26	6/6
Red-eared Slider (turtle)	Whole body	0.061	1.07	0.55	7/7
Overall		ND	1.1	—	351/387

Source: OREIS 2009
ppm: parts per million

All of the fish and turtles samples from LWBR were analyzed for total mercury (OREIS 2009). In fish tissue, about 85 percent of mercury is methylmercury (Jones and Slotten 1996). Again, methylmercury is the organic form and is much more harmful than the elemental and inorganic forms (ATSDR 1999). To remain conservative, ATSDR assumed that all the total mercury detected in the fish and turtles was methylmercury.

Because the comparison value was exceeded, ATSDR continued to evaluate exposures to eating fish and turtles from the LWBR. People frequently fish in the reservoir. But since 1987, fishing advisories have warned people to avoid or limit their consumption of fish due to **PCB** contamination in the reservoir (ORNL and Jacobs Engineering Group 1995). To evaluate exposure to mercury through eating fish and turtles from the reservoir, ATSDR calculated

exposure doses using the average concentration detected in fillet and muscle samples[28] and the formula described in Section III.C.3. Comparing Estimated Doses to Health Guidelines. ATSDR evaluated three potential ingestion rates. The first scenario assumed that both adults and children ate one 8-ounce fish meal each month (12 meals/year = 7.5 grams/day). The second assumed that both adults and children at one 8-ounce fish meal each week (52 meals/year = 32 grams/day). The third assumed adults ate 66.5 grams of fish/day (about two 8-ounce fish meals each week), which is the self-estimated consumption based on frequency and meal size for moderate to high consumers of LWBR fish (ATSDR 1998). Turtle consumption is not well documented. For the sake of this evaluation, ATSDR assumed the same consumption rates applied to turtles as to fish, although this likely overestimates actual turtle consumption. ATDSR assumed that adults weighed 70 kg and were exposed for 30 years, and children weighed 28.1 kg and were exposed for 6 years.

The estimated adult and child doses from eating LWBR fish and turtles once a month were below both the U.S.EPA RfD (1.0×10^{-4} mg/kg/day) and the ATSDR MRL (3.0×10^{-4} mg/kg/day) for methylmercury (see Table 29). All of the child and some of the adult estimated exposure doses from eating fish and turtles for the second and third consumption scenarios (one 8-ounce fish meal each week and two 8-ounce fish meals each week) were above both the ATSDR MRL and U.S.EPA RfD (see Table 29). Therefore, ATSDR compared these potential exposure doses to actual health effects levels in the toxicological and epidemiological literature.

Table 29. Estimated Exposure Doses for LWBR Fish and Turtles

Species	*Average Concentration (ppm)*	*Estimated Exposure Doses (mg/kg/day)*				
		Eating fish once a month (7.5 g/day)		*Eating fish once a week (32 g/day)*		*Moderate to high consumption (66.5 g/day)*
		adult	*child*	*adult*	*child*	*adult*
Channel Catfish (fillet/muscle)	0.19	2.0×10^{-5}	5.1×10^{-5}	8.7×10^{-5}	2.2×10^{-4}	1.8×10^{-4}
Catfish, Unspecified Species (fillet)	0.19	2.0×10^{-5}	5.1×10^{-5}	8.7×10^{-5}	2.2×10^{-4}	1.8×10^{-4}
Largemouth Bass (fillet/muscle)	0.33	3.5×10^{-5}	8.8×10^{-5}	1.5×10^{-4}	3.8×10^{-4}	3.1×10^{-4}
Striped Bass (fillet)	0.29	3.1×10^{-5}	7.7×10^{-5}	1.3×10^{-4}	3.3×10^{-4}	2.8×10^{-4}
Bluegill Sunfish (muscle)	0.12	1.3×10^{-5}	3.2×10^{-5}	5.5×10^{-5}	1.4×10^{-4}	1.1×10^{-4}
Sunfish species (fillet)	0.14	1.5×10^{-5}	3.7×10^{-5}	6.4×10^{-5}	1.6×10^{-4}	1.3×10^{-4}
Red-eared Slider (muscle)	0.26	2.8×10^{-5}	6.9×10^{-5}	1.2×10^{-4}	3.0×10^{-4}	2.5×10^{-4}

Bold text indicates that the exposure dose is higher than the U.S.EPA RfD of 1.0×10^{-4} mg/kg/day.
g/day: grams per day
mg/kg/day: milligrams per kilogram per day
ppm: parts per million

The ATSDR chronic MRL of 3×10^{-4} mg/kg/day for ingestion of organic mercury is based on the Seychelles Child Development Study, in which people who were exposed to 1.3×10^{-3} mg/kg/day of methylmercury from eating fish did not experience any adverse health effects

[28] It is standard protocol to analyze fillets/edible portions when evaluating human health concerns.

(NOAEL; Davidson et al. 1998). The U.S.EPA RfD of 1×10^{-4} mg/kg/day for mercury is based on the Faroe Islands study, in which maternal dietary intakes of 8×10^{-4} mg/kg/day to 1.5×10^{-3} mg/kg/day were associated with effects associated with performance on standardized neurobehavioral test involving attention, verbal memory, confrontational naming, and to a lesser extent visual/spatial abilities and fine-motor functions in children born to women who lived on the Faroe Islands (LOAELS; Debes et al. 2006; Grandjean et al. 1997). These U.S. EPA BMDL05 are expected to be associated with a 5 percent increase in the incidence of neurodevelopmental effects in children exposed *in utero*. The U.S. EPA RfD is consistent with the approach used by the NAS which identified a dose of 1.1×10^{-3} mg/kg/day as a dose that results in a 5 percent increase in the incidence of abnormal scores on the Boston Naming Test (a picture-naming, vocabulary test) (NRC 2000).

In Table 29, the estimated methylmercury doses for adults and children from eating one meal a month (12 meals/year) of LWBR fish are below U.S.EPA RfD of 1×10^{-4} mg/kg/day and are not at levels that would cause harmful effects in children or fetuses.

Estimated doses in Table 29 for adults who eat one meal a week (52 meals a year) and two meals a week (104 meals a year) of LWBR fish are at levels near or slightly above the U.S.EPA RfD; however, these estimated doses are not approaching the NAS dose effect level or the EPA BMDL05.Women who eat one and two fish meals a week of LWBR fish have a small increased risk of harming a developing fetus. Possible subtle neurodevelopmental effects identified from studies of children exposed *in utero* involve attention, verbal memory, confrontational naming, and to a lesser extent visual/spatial abilities and fine-motor functions (Debes et al. 2006; Grandjean et al. 1997; NAS 2000).

The estimated doses in Table 29 for children eating one meal a week of LWBR fish are slightly above the U.S.EPA RfD but are not approaching the NAS dose effect level or the EPA BMDL05. Therefore, children who eat up to one LWBR fish meal a week have a small increased risk of subtle neurodevelopmental effects. Whether children are as sensitive to the neurotoxic effects of mercury as is the fetus is uncertain. Even if children were not exposed *in utero*, some children who frequently eat the same fish as their mother ate are also at risk of harmful effects.

V. Health Outcome Data Evaluation

Health outcome data measures disease occurrence in a population. Common sources of health outcome data are existing databases (cancer registries, birth defects registries, and death certificates) that measure morbidity (disease) or mortality (death). Health outcome data can provide information on a community's general health status: where, when, and what types of diseases occur and to whom they occur. Public health officials use health outcome data to look for unusual patterns or trends in disease occurrence by comparing disease occurrences in different populations over periods of years. These health outcome data evaluations are descriptive epidemiologic analyses. They are also exploratory; they provide additional information about human health effects and are useful in that they help identify the need for public health intervention activities such as community health education. But health outcome data cannot—and are not meant to—establish cause-and-effect between environmental exposures to hazardous materials and adverse health effects in a community.

ATSDR scientists generally consider health outcome data evaluation when they see an association between 1) a reasonable expectation of adverse health effects and 2) observed levels of contaminant exposure. In this public health assessment on Y-12 mercury releases, ATSDR scientists determined that because of past mercury released from the Y-12 plant, potential past off-site exposures were possible.

Criteria for Conducting a Health Outcome Data Evaluation

To determine whether to use health outcome data in the public health assessment process, ATSDR scientists consult epidemiologists, toxicologists, environmental scientists, and community involvement specialists. But ultimately the following criteria, based only on site-specific exposure considerations, determine whether a public health assessment should include a health outcome data evaluation.

1. Does the site include at least one current (or past) potential or completed exposure pathway?
2. Can the period of exposure be determined?
3. Can the population that was or is being exposed be quantified?
4. Are the estimated exposure doses(s) and the duration(s) of exposure sufficient for a plausible, reasonable expectation of health effects?
5. Are health outcome data available at a geographic level or with enough specificity to be correlated to the exposed population?
6. Do the validated data sources or databases have information on the specific health outcome(s) or disease(s) of interest—for example, are the outcome(s) or disease(s) likely to occur from exposure to the site contaminants—and are those data accessible?

Using the findings of the exposure evaluation in this public health assessment, ATSDR identified the following completed past exposure pathways to Y-12 mercury.

1. In the past (1950–1963), family members could have inhaled elemental mercury carried from the Y-12 plant by workers on their clothes into their homes.

2. Children ingesting inorganic mercury in EFPC surface water during some weeks in 1956, 1957, and 1958; and adults ingesting inorganic mercury in EFPC surface water during some weeks in 1958 could potentially have experienced renal effects.

3. Children accidentally eating inorganic mercury in EFPC floodplain soils at the NOAA site and Bruner site before soil removal activities in 1996 and 1997 could potentially have experienced renal effects.

Fetuses and babies of nursing women who periodically ate fish at high ingestion rates (three meals per week or higher) from Poplar Creek in the 1970s, 1980s, and 1990 were exposed to organic mercury at levels that may have increased the risk of subtle neurodevelopmental effects in these children. Also, in the 1970s, 1980s, and 1990, children who ate six meals a month of Poplar Creek fish have an increased risk of subtle neurodevelopmental effects. ATSDR then used the above criteria to determine whether any of these completed exposure pathways would support inclusion of health outcome evaluations in this public health assessment. ATSDR was not able to sufficiently quantify the exposed population or document the dose and duration of past exposures sufficiently to identify plausible and reasonable expectation of health effects for any of these completed exposure pathways.

In the mid-1990s, ATSDR documented the completed exposure pathway to mercury via ingestion of fish (ATSDR 1998). ATSDR conducted an exposure investigation to quantify actual exposures from eating moderate to large amounts of fish and turtles from LWBR. ATSDR's exposure investigation determined the body burden or the actual amount of mercury at a specific time, in the bodies of 116 people who ate moderate to large amounts of fish from the Watts Bar Reservoir. For the 116 participants, the total mercury levels in blood ranged from nondetectable to 20 μg/L. Eighty-nine persons had nondetectable levels of mercury in their blood (the detection limit was 3 μg/L). The median value was below the detection limit and the arithmetic mean of the total mercury detections was 5.2 μg/L (ATSDR 1998).

In this public health assessment on Y-12 plant mercury releases, ATSDR analyzed the exposure investigation results by comparing the total blood mercury data to the total blood mercury data from the NHANES to determine if the 116 exposure investigation participants eating moderate to high amounts of LWBR fish were exposed to elevated levels of mercury. The CDC's National Center for Health Statistics began conducting the NHANES in 1999, to obtain health and nutritional related data from a nationally representative sample of adults and children in the United States in two-year cycles. The *Updated Tables, February 2011* presents the 95th percentile of total blood mercury data and 95 percent confidence interval for the U.S. population from the 2003–2004, 2005–2006, and 2007–2008 NHANES survey periods (CDC 2011). Based on the total blood mercury data from the NHANES, except for the one elevated blood mercury level of 20ug/L, the distribution of total blood mercury from the 1998 exposure investigation of moderate to high consumers of LWBR fish is similar to the distribution of total blood mercury for the U.S. population. Because the level of mercury exposure via ingestion of moderate to high amounts of LWBR fish in the mid-1990s is similar to the level expected in the general population and is not expected to cause measurable health effects, no further analysis of health outcome data is appropriate for this exposure pathway.

Given the lack of documentation for any of the other completed exposure pathways, no further analysis of health outcome data is appropriate. Analysis of site-related health outcome data is not scientifically reasonable unless *the level* of estimated exposure is adequately documented to meet the criteria to conduct a health outcome evaluation. ATSDR cannot make such an exposure estimate. Thus the requirement is complete to consider analysis of site-related health outcome data on the basis of exposure.

In addition, many validated health outcome databases or data sources on the public generally are not available. Especially those with data or information on the known specific health effect (subtle neurodevelopmental effects involving attention, verbal memory, confrontational naming, and to a lesser extent visual/spatial abilities and fine-motor functions (Debes et al. 2006; Grandjean et al. 1997; NAS 2000), and renal effects) associated with low level environmental exposure to elemental mercury, inorganic mercury, and organic mercury.

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 those who live or work near the ORR. ATSDR is particularly interested in hearing from area residents, civic leaders, health professionals, and community groups. ATSDR is 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 the 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 also to document ATSDR's responses to these concerns.

Since 2001, ATSDR compiled more than 2,500 community health concerns obtained from the ATSDR/ORRHES community health concerns comment sheets, from written correspondence, phone calls, newspapers, comments made at public meetings (ORRHES and work group 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 public health assessment are those concerns in the database related to mercury releases from the Y-12 plant. Table 30 contains the actual comments and ATSDR's responses, and is organized according to category.

Concerns about cancer

Area residents have also voiced concerns about cancer.[29] Those living in the communities surrounding the ORR have expressed many concerns to the ORRHES about a perceived increase in cancer in areas surrounding the ORR. A 1993 TDOH survey of eight counties surrounding the ORR indicated that cancer was a concern more than twice as much as any other health issue. The survey also showed that 83 percent of the surveyed population in the surrounding counties believed examining the actual occurrence of disease among Oak Ridge area residents was very important.

ORRHES thus requested that ATSDR conduct an assessment of health outcome data (cancer incidence) in the eight counties surrounding the ORR. ATSDR conducted an assessment of cancer incidence using data already collected by the Tennessee Cancer Registry. This assessment is a descriptive epidemiologic analysis providing a general picture of cancer occurrence in each of the eight counties. The assessment's purpose was to provide citizens living in the ORR area with information regarding cancer rates in their county compared with those in the state of Tennessee as a whole. This evaluation only examines cancer 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 does not—and cannot—establish cause and effect.

"Cancer incidence" refers to newly diagnosed cases of cancer reported to the Tennessee Cancer Registry.

[29] Note that DHHS and IARC have not classified mercury as to its human carcinogenicity. U.S.EPA has determined that mercury chloride and methylmercury are possible human carcinogens (ATSDR 1999).

The cancer incidence assessment results were released in 2006. They indicated that when compared with cancer incidence rates for the state of Tennessee generally, both higher and lower rates of certain cancers occurred in some of the counties examined. But no consistent cancer occurrence pattern was identified. The reasons for the increases and decreases of certain cancers are unknown. ATSDR's *Assessment of Cancer Incidence in Counties Adjacent to Oak Ridge Reservation* is available online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html.

In addition, over the last 20 years, local, state, and federal health agencies have conducted public health activities to address and evaluate public health issues and concerns related to chemical and radioactive substances released from the ORR. For more information, please see the Compendium of Public Health Activities at http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html.

1 **Table 30. Community Health Concerns from the ORR Community Health Concerns Database**

	Comment	*ATSDR's Response*
Mercury releases		
1	DOE probably knew that mercury was being released but did not report it. A Subcommittee member is concerned with the loss of 2,025,056 pounds of mercury.	Three major efforts have been made to estimate Y-12 mercury releases to water and air over the years (see Section III.B for more details). The estimates of mercury inventories and releases to air and water in all three of these reports focused on the lithium enrichment production years (1953–1963). ▪ In 1977, Y-12 personnel prepared a classified report called the 1977 Mercury Inventory Report. ▪ DOE appointed a Mercury Task Force to investigate what was known about mercury use and releases at the Y-12 plant. The Mercury Task Force released its report in 1983 (UCCND 1983a, 1983b). The Mercury Task Force studied the 1977 Mercury Inventory Report and adjusted many of its estimates. ▪ The Task 2 report also estimated Y-12 mercury releases. Task 2 did not revisit all of the previous inventory estimates, but it revised the previous estimates of mercury releases to the air and water.
Mercury sampling		
2	The concentration of mercury in plants should be measured. How was it shown that mercury was taken up by the part of the plant above ground?	Plants have been analyzed for mercury. Mercury was detected in above ground portions of the plants. In this public health assessment, ATSDR evaluated eating plants in the past (see Section IV.A.6) and present (see Section IV.B.6). ▪ ATSDR concludes that eating local produce grown in gardens in the EFPC floodplain or in private gardens which contain mercury-contaminated soils from the floodplain is not expected to harm people's health in the past. ▪ ATSDR concludes that currently eating beets, kale, or tomatoes grown in the EFPC floodplain is not expected to harm people's health. ▪ ATSDR concludes that currently eating vegetables from Oak Ridge is not expected to harm people's health.
3	The concentration of mercury in the air should be measured, so air samples should be taken also. Concerned about past mercury releases in the direction of Oliver Springs.	Mercury levels in air have been estimated and measured. ATSDR evaluated the available models and data in this public health assessment. See Section IV.A.2 for the past evaluation and Section IV.B.1 for the current evaluation. ▪ ATSDR concludes that elemental mercury carried from the Y-12 plant by workers on their clothes into their homes could potentially have harmed their families (especially young children) in the past. ▪ ATSDR cannot conclude whether off-site populations breathing mercury releases in the past from the Y-12 plant for a short time could have been harmed because there are no data from outdoor mercury spills. ▪ ATSDR concludes that breathing past (1950–1963) air mercury releases from the Y-12 plant is not expected to have harmed people living in the Wolf Valley area. ▪ ATSDR cannot conclude whether people living off site near the ORR breathing mercury released to the air from the Y-12 plant from 1950 through 1963, could have been harmed. ▪ ATSDR cannot conclude whether people living near the EFPC floodplain breathing mercury vapors from water

	Comment	*ATSDR's Response*
		released from the Y-12 plant from 1950 through 1963, could have been harmed. ▪ ATDSR concludes that air and water mercury releases from the Y-12 plant after 1963, are not expected to have harmed people living off site near the ORR. ▪ ATSDR concludes that currently breathing air near EFPC is not expected to harm people's health. ▪ ATSDR concludes that currently breathing air near LWBR is not expected to harm people's health.
4	Concerned about elevated levels of mercury that have been shown in lab tests.	This public health assessment reviews and evaluates the level of mercury found in the off-site air, surface water, soil, sediment, fish, and vegetation. See Section VIII for ATSDR's conclusions and recommendations.
5	ATSDR should get a topographical map that shows the ridges and valleys as well as the burial ground locations and underground locations where water could have been contaminated by mercury. Concerned about mercury burial grounds and underground locations where water could have been contaminated by mercury.	ATSDR obtained topographical maps of the entire ORR area from the U.S. Geological Survey (USGS). ATSDR conducted a separate public health assessment devoted solely to evaluating potential exposures to contaminated off-site groundwater from the ORR (ATSDR 2006). ATSDR concluded that no human exposures to contaminated groundwater outside the Y-12 boundary have occurred in the past, are currently occurring, or are likely to occur in the future. For a complete evaluation of groundwater, please refer to ATSDR's 2006 *Public Health Assessment: Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation* available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/groundwater/index.html.
6	Concerns about deep channel and shallow sediment sampling.	ATSDR specifically evaluated mercury levels in both deep channel and shallow sediment in LWBR in this public health assessment. ATSDR concludes that coming in contact with mercury in LWBR sediment is not expected to harm people's health. All of the near-shore sediment samples and deep-water sediment samples collected from the LWBR were less than the comparison values. However, a few concentrations of mercury in unspecified depth sediment samples were higher than the comparison value. To evaluate the exposure to sediment further, ATSDR calculated exposure doses for adults and children using the maximum concentration detected in LWBR sediment from unspecified depths. Both the estimated doses were below the health guideline value for chronic exposure. To prevent unnecessary exposures to workers and the public, ATSDR cautions that the sediments should not be disturbed, removed, or disposed of without careful review by the interagency working group.
7	Concerns about homogenizing soil samples. Concerns of higher concentrations of mercury missing when homogenizing soil samples. A Subcommittee member asked how Task 2 accounted for the transfer of mercury from the upper layers to the lower layers. The DOE analyses are not valid; they did not take core samples.	Within this public health assessment, ATSDR scientists considered that the mixing of soil within each core sample (i.e., using composite samples) likely diluted the mercury that was concentrated in narrow bands within the cores. ATSDR accounted for this dilution effect of composite samples by applying an adjusted core sample value, which provides an estimate of the maximum mercury concentration that may have been detected within each core sample. For further explanation, see Section IV.A.4.

	Comment	ATSDR's Response
8	Concerns that the maximum mercury concentration of Poplar Creek Mile 5 is 20 to 40 times higher than any other number.	To answer this concern, ATDSR looked at surface water samples collected from PCM 5.1 and PCM 5.5 (located downstream of where EFPC flows into Poplar Creek, but before entering the K-25 complex). One hundred samples were analyzed for mercury in 1993 and 1994. Concentrations ranged from 0.0002 to 0.67 ppb. The average concentration was 0.14 ppb. The maximum mercury concentration detected in EFPC was 2.8 ppb in 1992. The next highest number detected in EFPC was 0.96 ppb in 2001.Therefore, the maximum mercury concentration detected at Poplar Creek mile 5 is not 20-40 times higher than any other sample. Further, the concentrations at PCM 5.1 and PCM 5.5 are well below the comparison value of 2 ppb for surface water, and therefore, do not warrant a health concern.
Potential exposure to mercury		
9	Mercury was discharged to protect workers but crossed over the hills and exposed the residents. Concerned about mercury exposure from Y-12.	This entire public health assessment discusses residents' potential past and current exposure to mercury released from the Y-12 plant into off-site air, surface water, soil, sediment, fish, and vegetation. See Section VIII for ATSDR's conclusions about whether past or current exposures caused harmful health effects.
10	Buyers of new homes near EFPC are unaware of the possible risk of contamination due to mercury.	While exposures in the past might have caused harmful health effects, the current levels of mercury found in the EFPC and LWBR surface water and sediment are not at levels expected to cause harmful health effects.
11	Concerned about the mercury pathway for children playing in the creek near Jefferson Circle, closer to where East Fork pond was.	ATSDR specifically evaluated whether children would have been in the past (see Sections IV.A.3 and IV.A.4) or are currently (see Sections IV.B.2 and IV.B.5) being harmed by playing in EFPC in this public health assessment. ▪ Children who swallowed water from EFPC for a short time during some weeks in 1956, 1957, and 1958, could have experienced harmful health effects. ▪ There was not enough information to determine whether swallowing water from EFPC during 1953, 1954, and 1955 could have harmed children. ▪ Children who swallowed water from EFPC before 1953, or after the summer of 1958, are not expected to have experienced harmful health effects. ▪ Swallowing water from EFPC over a long time period in the past is not expected to have caused harmful health effects for children. ▪ Children who played at the NOAA site and Bruner site prior to the soil removal activities in 1996 and 1997, may have accidentally eaten inorganic mercury in EFPC floodplain soils that could have caused harmful health effects. ▪ Accidentally eating methylmercury in EFPC floodplain soils in the past is not expected to have caused harmful health effects for children playing in the floodplain soil. ▪ Children who currently swallow surface water while playing in EFPC are not expected to experience harmful health effects. ▪ Children who currently contact EFPC sediment while playing are not expected to experience harmful health effects.

	Comment	*ATSDR's Response*
Potential health effects from mercury		
12	In 1988, a woman was boating in the Clinch River about 12 miles downstream of the K-25 complex. While pushing the boat off the bank, her leg sunk into the sediment. There was a "shiny layer of stuff that looked something like tarnished silver" up to her knee. Even after intense scrubbing it took a week for the substance to finally shed off. It was never determined what the substance was. But the woman suspects it might have been mercury released from the ORR. Ever since the incident, a rash appears unpredictably where the mud once caked her leg. Doctors cannot explain it, leaving her to guess what substances still lay claim to her skin.	It is very difficult to assess what substance this woman might have been exposed to. Mercury exists in three main forms—metallic mercury, inorganic mercury, and organic mercury. Metallic mercury is a shiny, silver-white liquid metal. Most inorganic and organic mercury compounds are powders or crystals. One organic mercury compound, dimethylmercury, is a colorless liquid. Using her description, metallic mercury could be the substance the woman was exposed to. Unless the skin is damaged, very little metallic mercury is absorbed through the skin. Furthermore, metallic mercury is unlikely to adhere to the skin. Dermal exposure to metallic mercury can cause contact dermatitis. Only long-term dermal exposures have resulted in more serious health effects in people. For more information, see ATSDR's Mercury and Your Health Web site at http://www.atsdr.cdc.gov/mercury/.
13	One person said that as a child he played in Poplar Creek and the Clinch River. He was never told that poisons such as toxic mercury were contaminating local creeks and streams. He said that he is scared and angry now that he knows that the "beautiful silver was really mercury and that it was hurting us." He reports having multiple health problems including weight gain; edema; loss of hearing, balance, and vision; rashes; fatigue; headaches; dizziness; sinus and kidney problems; and joint and muscle pain. There are sick people who are still alive that were exposed to mercury.	In addition to contact dermatitis resulting from dermal exposure to mercury, metallic mercury can also become a vapor. Breathing in these vapors might cause fever, fatigue, neuropsychiatric disturbances (e.g., memory loss, irritability, or depression), increased blood pressure, numbness, and discolored hands and feet. For more information, see ATSDR's Mercury and Your Health Web site at http://www.atsdr.cdc.gov/mercury/. ATSDR specifically evaluated childhood exposures to mercury released into EFPC in the past. EFPC drains into Poplar Creek and the Clinch River after it enters the ORR. ▪ Children who swallowed water from EFPC for a short time during some weeks in 1956, 1957, and 1958, could have experienced harmful health effects. ▪ There was not enough information to determine whether swallowing water from EFPC during 1953, 1954, and 1955 could have harmed children. ▪ Children who swallowed water from EFPC before 1953, or after the summer of 1958, are not expected to have experienced harmful health effects. ▪ Swallowing water from EFPC over a long time period in the past is not expected to have caused harmful health effects for children. ▪ Children who played at the NOAA site and Bruner site prior to the soil removal activities in 1996 and 1997, may have accidentally eaten inorganic mercury in EFPC floodplain soils that could have caused harmful health effects. ▪ Accidentally eating methylmercury in EFPC floodplain soils in the past is not expected to have caused harmful health effects for children playing in the floodplain soil.
14	The Dose Reconstruction may have underestimated the effects of mercury because it considered the three	The three types of mercury are evaluated separately because the routes of exposure and health effects are different for each. Therefore, separate doses are calculated for each. Table 7 provides the health guidelines

	Comment	ATSDR's Response
	species of mercury separately. Is it appropriate to add the ingestion and inhalation mercury doses together? Concerned about the additive doses of mercury.	ATSDR uses for mercury. ▪ Inhalation is the most typical route of exposure to metallic mercury. The primary target organ from prolonged exposure to low concentrations is the central nervous system. Exposure to high concentrations can produce effects in the central nervous system and kidneys. ▪ Ingestion is the most typical route of exposure to inorganic mercury. The primary target organs are the kidneys. ▪ Ingestion of fish is the most typical route of exposure to organic mercury. The primary concern is developmental effects in offspring.
15	ATSDR's minimal risk level for elemental mercury should be examined more closely because it is lower that EPA's reference dose.	MRLs undergo a rigorous review process—Health Effects/MRL workgroup reviews within ATSDR's Division of Toxicology; expert panel of external peer reviews; and agency-wide MRL workgroup reviews, with participation from other federal agencies, including U.S.EPA. They are also submitted for public comment before being finalized. Table 7 provides the health guidelines ATSDR uses for mercury.
16	Concerned about methylmercury accumulation in the central nervous system and its possible connection to Alzheimer's disease.	This is a topic that is currently being researched. Some scientists found higher mercury concentrations in brain regions and blood of some patients with Alzheimer's disease (e.g., Mutter et al. 2007. Mercury and Alzheimer's disease. Fortschr Neurol Psychiatr. 2007 Sep; 75(9):528-38). The current evidence seems to be suggestive, but not conclusive.
17	Concerned that mercury poisoning is being misdiagnosed, sometimes as Multiple Sclerosis.	The symptoms of MS (numbness, fatigue, blindness, paralysis) are very similar to the symptoms of mercury poisoning. If you think your symptoms could be caused by exposure to mercury, you should ask your doctor to test your blood, urine, or hair for mercury (as appropriate). These tests can tell you if you have been in contact with mercury. But they cannot show the kind of health effects you might experience, or whether you will become sick. The following are some resources for additional information: ▪ ATSDR's Toxicological Profile for Mercury at http://www.atsdr.cdc.gov/toxprofiles/tp46.html ▪ ATSDR's Mercury and Your Health at http://www.atsdr.cdc.gov/mercury/ ▪ ATSDR's Medical Management Guidelines for Mercury at http://www.atsdr.cdc.gov/MHMI/mmg46.html ▪ ATSDR's ToxFAQs Chemical Agent Briefing Sheets for Mercury at http://www.atsdr.cdc.gov/cabs/mercury/index.html ▪ U.S.EPA's Mercury Web site at http://www.epa.gov/mercury/ ▪ CDC's Emergency Preparedness and Response: Mercury at http://www.bt.cdc.gov/agent/mercury/
18	Concerned about mercury entering the lymph system.	Mercury can enter the lymphatic system, which may play an important role in the transport of mercury to target organs (Hansen and Danscher 1995).
Mercury in fish		
19	During the fish studies did you test for mercury?	Yes. Under the Federal Facility Agreement, DOE, U.S.EPA, and TDEC collected fish and sampled them for mercury during the LWBR RI/FS and the Clinch River/Poplar Creek RI/FS. The OREIS database contains the

	Comment	*ATSDR's Response*
	Many people were constantly eating fish that might have had high levels of mercury.	results of hundreds of fish samples collected during several studies that were analyzed for mercury. ATSDR specifically evaluated mercury in fish during this PHA. See Section IV.A.5 for the past evaluation and Section IV.B.6 for the current evaluation. People should heed the consumption advisories. The advisories are available at http://www.tennessee.gov/environment/wpc/publications/pdf/advisories.pdf. Also, ATSDR conducted the Watts Bar Exposure Investigation (ATSDR 1998) to measure actual mercury levels in the blood of people consuming moderate to large amounts of fish and turtles from the Watts Bar Reservoir, and to determine whether these people were being exposed to high levels of mercury. A brief summarizing the exposure investigation is provided in Appendix C. Summary Briefs and Factsheets. ▪ The participants' blood mercury levels are similar to the distribution of total blood mercury for the U.S. population. ▪ Only one of 116 participants had an elevated total blood mercury level.
20	No one measured the mercury in the fish or in the sediment until 1985, which they then tried to correlate that measurement to DOE plants in other areas to estimate the fish mercury content. Nearly everyone who ate those fish had a higher dose than the minimum risk level.	Fish downstream from the Y-12 plant were first collected and analyzed for mercury in 1970. In this PHA, ATSDR reviewed mercury concentrations in fish samples collected from 1970 through 2009. See Section IV.A.5 for the past evaluation and Section IV.B.6 for the current evaluation. People should heed the consumption advisories.
21	Nobody measured the mercury content of fish in the 1960s.	This is true. Fish were first analyzed for mercury in 1970. Earlier attempt to model the average annual mercury concentrations in fish or exposure doses from eating fish (beginning in 1950) included assumptions that could not be easily verified and may not be appropriate for making public health decisions. Because of this, ATSDR believes that the data are not adequate to characterize the mercury concentrations in fish prior to 1970. Therefore, ATSDR cannot conclude whether eating fish before 1970 could harm people's health (see Section IV.A.5).
22	Concerned about the Clinch River containing fish that are contaminated with mercury.	In this PHA, ATSDR specifically evaluated mercury in the Clinch River/Poplar Creek fish for the past evaluation (see Section IV.A.5) and the Clinch River/LWBR fish for the current evaluation (see Section IV.B.6). People should heed the consumption advisories.
23	Concerned that mercury from East Fork Poplar Creek is being transferred into the fish population.	In this PHA, ATSDR specifically evaluated mercury in EFPC fish for the past evaluation (see Section IV.A.5) and current evaluation (see Section IV.B.6). People should heed the consumption advisories.
24	Concerned that concentrations of mercury in fish of upper East Fork Poplar Creek are not decreasing.	Upper EFPC is located on site within the Y-12 plant. To answer this concern, ATSDR looked at redbreast sunfish collected from Station EFK 24.2 (located on site within the Y-12 plant complex). Samples were collected in 1991, 1992, and from 1996 to 2008 and analyzed for mercury. The average concentration across all the years is 0.6 ppm. The maximum concentration (1.59 ppm) was detected in June 2000. The minimum concentration (0.07 ppm) was detected that same day. The average concentrations for each year sampled range from 0.54 ppm in 1991 to 0.77 ppm in 1996. ATSDR plotted the data with a trend line. There is a very slight decrease (roughly 0.05 ppm) in

Comment		ATSDR's Response
		mercury concentrations from 1991 to 2008.
25	Concerned that the concentrations of mercury in fish are increasing at a greater rate in the fish that are further downstream in East Fork Poplar Creek.	To answer this concern, ATSDR looked at redbreast sunfish collected from Station EFK 6.3 (located near I-95 right before EFPC re-enters the ORR). Samples were collected from 1985 to 2007 and analyzed for mercury. The average concentration across all the years is 0.76 ppm. The maximum concentration (1.72 ppm) was detected in November 1998. The minimum concentration (0.21 ppm) was detected in November 2004. The average concentrations for each year sampled range from 0.4 ppm in 1986 to 1.1 ppm in 2001. ATSDR plotted the data with a trend line. There is an increase (roughly 0.3 ppm) in mercury concentrations from 1985 to 2007. DOE is monitoring the increase in mercury bioaccumulation, and continuing efforts to identify the cause (see Bechtel Jacobs 2010, SAIC 2007, and Southworth et al. 2010).
26	Did ATSDR come to the conclusion that there was no danger from eating one fish for anything other than PCBs when that was all you tested for?	During the 2007 *Evaluation of Current (1990 to 2003) and Future Chemical Exposures in the Vicinity of the Oak Ridge Reservation*, ATSDR evaluated over 16,000 fish samples that were analyzed for 147 different chemicals. Separate public health assessments were written to evaluate mercury and PCBs in fish. ATSDR's public health assessments can be found at http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html. TDOH conducted the Oak Ridge Health Studies, which included extensive reviews of available information and qualitative and quantitative analyses of past (1944 to 1990) releases and off-site exposures to hazardous substances from the entire ORR, including fish from nearby waterways. ATSDR scientists reviewed and analyzed TDOH's Oak Ridge Health Studies to identify contaminants that required further public health evaluation. ATSDR scientists completed public health assessments on Y-12 plant uranium releases (2004); White Oak Creek radionuclide releases (2006); X-10 site iodine 131 releases (2008); X-10 site, Y-12 plant, and K-25 site PCB releases (2009); K-25 site uranium and fluoride releases (2010); Y-12 plant mercury releases (2011); and other issues of community concern, such as contaminant releases from the TSCA Incinerator (2005) and contaminated off-site groundwater (2006).
EFPC cleanup		
27	Did the mercury project ever get completed? What happened?	Yes in 1996 and 1997. EFPC floodplain soils with concentrations greater than 400 ppm of mercury were removed from the floodplain near the NOAA Atmospheric Diffusion Laboratory off Illinois Avenue in 1996, and from the floodplain near the NOAA site and across the Oak Ridge Turnpike from the Bruner's Shopping Center on the Wayne Clark Property in 1997. Close to 35,000 cubic meters (m^3) of soil were removed. Confirmatory samples were taken to ensure that the remediated areas were below the clean-up standard of 400 ppm. Postremediation monitoring was conducted to ensure the effectiveness of the excavation (SAIC 1993, 1998, 2002a).
28	ORHASP has recognized that mercury speciation is still a problem but are not going to address it. We must have independent analysis and research performed by both minority and majority universities.	In April 1993, DOE released the EFPC RI, which evaluated the extent and level of contamination in the 100-year EFPC floodplain (SAIC 1993). In June 1994, DOE released an addendum to the RI, which presented the results of mercury speciation studies in the EFPC floodplain soil (SAIC 1994). In the addendum, DOE stated that several different analytical methods indicated that mercuric sulfide and metallic mercury are likely to be the dominant inorganic mercury forms present and that mercuric chloride (the most easily absorbed and the most toxic inorganic

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		form of mercury) is a minor component of the total mercury in the EFPC floodplain soils (SAIC 1994). Based on these two reports, DOE selected and U.S.EPA and TDEC approved a remedial action to remove soils containing greater than 400 ppm of mercury (DOE 1995b). ATSDR convened a science panel meeting on the bioavailability of mercury in soil in August 1995. The purpose of the science panel was to identify methods and strategies that would enable health assessors to develop data-supported, site-specific estimates of the bioavailability of inorganic mercury and other metals (arsenic and lead) from soils. The panel consisted of private consultants and academicians internationally known for their metal bioavailability research along with experts from ATSDR, CDC, U.S.EPA, and the National Institute for Environmental Health Science. ATSDR used information obtained from the panel meeting to evaluate the EFPC clean-up level. ATSDR also used the findings to characterize and evaluate soil containing mercury at other waste sites. Three technical papers and an ATSDR overview paper on the findings of the panel meeting were published in the International Journal of Risk Analysis in 1997 (Volume 17:5).
29	A community member would like to see the new study that states that mercury is less harmful than previously thought.	This comment is in reference to raising the proposed EFPC floodplain soil cleanup level from 50 ppm to 400 ppm. The cleanup level was changed because additional testing of the soil (see previous comment) determined that the type of mercury present is less absorbed into the body and less toxic than the original cleanup level assumed.
30	Raising the allowable mercury level in residential areas from 50 ppm to 400 ppm appeared to have been an example of special interest.	In response to a request from community members and the city of Oak Ridge, ATSDR evaluated the public health impact of DOE's clean-up level of 400 mg/kg of mercury in the EFPC floodplain soil. ATSDR concluded that the clean-up level of 400 mg/kg of mercury in the soil of the EFPC floodplain would be protective of public health and pose no health threat to adults or children (ATSDR 1996a). The public health consultation discussing this concern can be accessed at http://www.atsdr.cdc.gov/HAC/PHA/efork2/oak_toc.html. ATSDR's science panel meeting on the bioavailability of mercury in soil consisted of private consultants and academicians internationally known for their metal bioavailability research along with experts from ATSDR, CDC, U.S.EPA, and the National Institute for Environmental Health Science.
31	If mercury still leaches out from East Fork Poplar Creek, it may be possible that amounts above trace amounts of mercury are going into the Clinch River.	It is possible that levels of mercury above trace amounts are reaching the Clinch River. However, the mercury levels are so low they would not be a health concern. ATSDR evaluated 647 surface water samples from EFPC in this PHA. Samples were collected in 1991–1994, 1996, 1997, and 1999–2009 from 25 different locations in the creek. Mercury was only detected in 126 samples (about 1 out of 5 samples). Only one mercury concentration (about 0.1 percent) was detected slightly above the comparison value of 2 ppb for surface water in 1992 (prior to the 1996 and 1997 cleanup). This indicates that the vast majority of the concentrations were detected at levels not warranting health concern.
32	Sediment disturbances could be causing mercury levels to rise downstream.	To answer this concern, ATSDR looked at surface water collected from Station EFK 6.3 (located near I-95 right before EFPC re-enters the ORR). Forty-four samples were collected from 2000 to 2009 and analyzed for mercury. The average concentration across all the years is 0.12 ppb. The maximum concentration (1.3 ppb) was detected in June 2008. The minimum concentration (0.009 ppb) was detected in December 2000. ATSDR plotted the data with a trend line. There is a slight increase (roughly 0.05 ppb) in mercury concentrations from 2000 to 2009. However,

	Comment	ATSDR's Response
		all of these concentrations are well below the comparison value of 2 ppb for surface water, and therefore, do not warrant a health concern.
Scarboro		
33	When considering changes in soil and water composition over time, do ATSDR's public health conclusions apply to children who lived in the Scarboro community in the past?	Yes. As part of the public health assessment process, ATSDR evaluates whether people were exposed in the past, are currently being exposed, or will be exposed in the future. ATSDR is committed to evaluating the special interests of children at sites such as the ORR.
34	Concerned about the mercury burial ground on Hampton Road in Scarboro. The known burial sites and seepage points for any type of mercury should be documented and pointed out on maps like the map in the field office, which shows the extent of mercury contamination in EFPC 100 year floodplain. Y-12 used carcinogenic chemicals and we know that the surface and the ground water at Oak Ridge interchange. The community needs the data from the secret well-monitoring done since the 1980s. The community needs the data from the surface and groundwater studies at Y-12 and this data directly impacts the surrounding residents. The springs along the north side of Pine Ridge are contaminated. Small streams near Y12 should be sampled for possible contamination. One example is Mill Branch near the South Hill Golf Course.	There is no evidence of any mercury burial grounds in Scarboro. FAMU conducted the Scarboro Community Environmental Study in 1998 (FAMU 1998) and U.S.EPA conducted the Scarboro Community Environmental Sampling Validation Study in 2001 (EPA 2003). Neither study found elevated levels of mercury in Scarboro soil, sediment, or surface water. ATSDR's 2006 *Public Health Assessment: Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation* evaluated the possibility of someone coming in direct contact with groundwater at seeps or springs in Union Valley. Since the land overlying the known extent of the contaminant plume is zoned as "Industrial District 2", it is unlikely that individuals will come in contact with springs or seeps in this area. Also, most groundwater surfaces as diffuse discharge directly into Scarboro Creek. Indeed, groundwater constitutes the baseflow for Scarboro Creek in Union Valley (see Figure 11 in the Groundwater PHA). So, it is unlikely that individuals will come into direct contact with groundwater in seeps and springs before dilution with surface water occurs. This public health assessment can be found at http://www.atsdr.cdc.gov/HAC/oakridge/phact/groundwater/index.html. Data collected for the *EFPC Floodplain and Sewer Line Beltway Remedial Investigation* (RI) provided a comprehensive view of the distribution of mercury in off-site soils. The RI data are consistent with those collected in the earlier ORAU and TVA studies. The RI sampling data demonstrated that mercury was present in some soils along the entire length of EFPC. Mercury contamination did not typically extend out very far from the creek banks and rarely to the elevation of the 100-year floodplain. The greatest deposition of mercury in the EFPC floodplain was found at the NOAA site and Bruner site. The contamination was removed from these areas in 1996 and 1997, respectively. Scarboro is located outside of the EFPC floodplain. As Figure 7 shows, the elevation of Scarboro is higher than the floodplain. Therefore, the contamination from EFPC could not have reached Scarboro.
35	Groundwater flows from the Y-12 plant to Scarboro.	ATSDR's 2006 *Public Health Assessment: Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation* evaluated this potential exposure scenario. The Y-12 plant plume flows east-northeast along strike, paralleling the underlying geology. Current DOE plume mapping indicates that the plume is entirely in the Maynardville Limestone (part of the Conasauga Group), an aquifer formation with relatively high hydraulic conductivity. The Scarboro community is located on the Rome formation that consists of

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		low-conductivity shales and siltstones. It is unlikely that water will migrate from areas with higher hydraulic conductivity to those with less.
36	It is generally believed by most people who live in Tennessee and perhaps the nation that the Scarboro neighborhood in Oak Ridge, Tennessee is contaminated with mercury... The data showed very high levels of mercury contamination in several areas of Oak Ridge; however, the media primarily focused attention on mercury contamination in the Scarboro neighborhood (where no significant mercury was ever found).	The highest levels of mercury were found in the EFPC floodplain soil. The NOAA and Bruner sites were the only areas along the floodplain that contained mercury at levels above health concern (see Figure 17). The contaminated soil was removed in the 1990s. Because of its proximity to the floodplain, Scarboro was identified as a potentially exposed community in the Task 2 report (ChemRisk 199a). ATSDR specifically evaluated past exposures to Scarboro residents. ▪ Estimated past air concentrations in Scarboro were below the comparison value. ATSDR specifically evaluated current surface water, soil, and sediment data collected by FAMU and U.S.EPA in the Scarboro community. ▪ Mercury has not been detected in any surface water samples collected in the Scarboro community. ▪ All of the surface soil and sediment samples collected in Scarboro were less than the comparison value, and therefore, not a health hazard.
37	Uranium, mercury, and PCBs have been detected in Scarboro.	ATSDR specifically evaluated exposures to uranium, mercury, and PCBs in the Scarboro community in several public health assessments. ATSDR's public health assessments can be found at http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html. ▪ ATSDR concluded that uranium in Scarboro was not and is not at levels causing harmful health effects in the 2004 *Public Health Assessment for Y-12 Uranium Releases*. ▪ In this public health assessment, ATSDR found that mercury levels were either not detected or too low in the Scarboro community to be of health concern. ▪ ATSDR found that PCBs in EFPC sediment and associated floodplain soil near the Scarboro region were at levels too low to affect the most sensitive residents (children playing there on a daily basis) in the 2009 *Public Health Assessment for Polychlorinated Biphenyl (PCB) Releases*. Further, FAMU collected soil and sediment from Scarboro and analyzed 10 percent of the samples for 150 organic and inorganic chemicals in 1998. ATSDR evaluated these data and determined that none of the chemicals detected (over 100 chemicals were not detected) were at concentrations that would cause harmful health effects from exposure to the soil or sediment.
38	Scarboro is the most contaminated residential area. Y-12 and the surrounding area are very contaminated. We know the soil is contaminated and want someone to prove it. (Just tell us the truth.) The city should cover the contaminated ditches.	As stated in previous responses to comments, several agencies, including ATSDR, U.S.EPA, FAMU, and DOE, have assessed environmental contamination in Scarboro and evaluated exposures to Scarboro residents. In addition to the public health assessments for groundwater, uranium, mercury, and PCBs, ATSDR conducted a Scarboro-specific public health evaluation during its *Public Health Assessment: Evaluation of Current (1990 to 2003) and Future Chemical Exposures in the Vicinity of the Oak Ridge Reservations*. ▪ None of the soil, sediment, or surface water samples collected from the Scarboro community contained

	Comment	ATSDR's Response
	An Oak Ridge resident explained that residents here need and want to know if health problems in Scarboro have any link to its location just over a ridge from the nuclear reservation's Y-12 plant. Concerned about Scarboro community health. Concerned about the health of people in Scarboro.	chemicals at levels posing a public health hazard. Also, FAMU (1998) and EPA (2003) are two community specific studies conducted to evaluate contamination in Scarboro. U.S.EPA concluded that the residents of Scarboro are not currently being exposed to harmful levels of substances in the soil, sediment, or surface water. Summaries of these studies are provided in Appendix C. Summary Briefs and Factsheets.
39	Vegetables grown in Scarboro are not safe to eat and changed color.	ATSDR specifically looked at exposures from eating the edible portion of garden vegetables during several of its public health assessments. ATSDR's public health assessments can be found at http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html. ▪ ATSDR concluded that none of the chemicals were detected in vegetables at levels causing harmful health effects during its Public Health Assessment: Evaluation of Current (1990 to 2003) and Future Chemical Exposures in the Vicinity of the Oak Ridge Reservations. ▪ ATSDR concluded that uranium was not and is not causing harmful health effects to Scarboro residents who ate garden vegetables in the 2004 *Public Health Assessment for Y-12 Uranium Releases*. ▪ ATSDR found that eating vegetables grown in EFPC floodplain soil was not expected to harm people's health during the 2009 *Public Health Assessment for Polychlorinated Biphenyl (PCB) Releases*. ▪ Within this public health assessment, ATSDR concluded that eating vegetables currently grown in the EFPC floodplain or Oak Ridge is not expected to harm people's health. ATSDR concluded that eating local produce grown in gardens in the EFPC floodplain or in private gardens which contain mercury-contaminated soils from the floodplain would not have harmed people's health in the past.
40	Scarboro children suffer from too much asthma. The media reported that there were an unusually large number of children with various illnesses (allergies, asthma, ear infections, and respiratory problems) in the Scarboro community. The director of a Scarboro day care center for children ages 2–12 said that "about half of the children here have upper respiratory problems. It does make me concerned to have that many." But the numbers are simply far too high to ignore, even if they are not scientific. These incidents of problems are far too high to be an accident. Because of Scarboro's proximity to the reservation and the exposures that we know exist there, a few of us have been calling for a	The Scarboro Community Health Investigation, which included a community health survey and a follow-up medical evaluation of children less than 18 years of age, was coordinated by TDOH to investigate a reported excess of respiratory illness among children in the Scarboro community (Johnson et al. 2000). This investigation was mainly designed to measure the rates of common respiratory illnesses among children who reside in Scarboro, compare these rates with national rates, and determine if there were any unusual characteristics of these illnesses. The investigation was not designed to find what caused the illnesses. In September 1998, CDC released the preliminary results of the survey. The asthma rate was 13 percent among children in Scarboro, compared to national estimates of 7 percent among all children aged 0–18 years and 9 percent among African American children aged 0–18 years. The Scarboro rate was, however, within the range of rates from 6 to 16 percent reported in similar studies throughout the United States. The wheezing rate among children in Scarboro was 35 percent, compared to international estimates that range from 1.6 to 36.8 percent. After a review of the information obtained in the health investigation survey, 36 children, including those identified in the media report, were invited to receive a physical examination. These examinations were conducted in November and December 1998 to confirm the results of the community survey, to establish whether children with

	Comment	*ATSDR's Response*
	symptomatic survey for quite a long time. This reinforces what we've been saying all along, that there might be a cluster of problems in Scarboro. This certainly warrants the need for members of the medical and scientific community to go into Scarboro to define what type of pattern truly exists. An Anderson County commissioner and another member of the government-sponsored panel studying Oak Ridge area health problems said that an independent investigation is needed. "I am surprised that the numbers of ill children the newspaper found is that large, even in a random sample, I had heard from parents that the children did have some problems, and some of the parents suspect it might be caused by being so close to the reservation, especially since all of the recent studies have started coming out. And these type of respiratory problems can play a role in learning disabilities, which is another large concern of mine. I think that a study is the only way we can be sure about what we seem to be seeing in Scarboro. We need experts to come in and study the population, now, so we can know what we need to do to help." A Scarboro mother has two daughters and a son with respiratory conditions. Referring to her son, she said "but with my son, no matter what we do, he still has breathing troubles. It's like he can get bad off if the wind just changes direction, so being so close to the reservation does concern me. Scarboro is our home, the only place we've ever lived. We love it here and would hate to leave. But sometimes, I wonder if I am killing my children by living here." "Of course the number of sick children alarms me, but we still don't have any answers of why," said a Scarboro resident whose four grandchildren are among those suffering respiratory problems. "We have been microscoped, dissected, you name it, and we're still waiting for answers, even though everybody knows there	respiratory illnesses were getting the medical care they needed, and to determine whether the children reported in the newspaper to have respiratory medical problems really had these problems. In January 1999, a team of physicians representing CDC, TDOH, the Oak Ridge medical community, and the Morehouse School of Medicine, thoroughly reviewed the findings of the physical examinations and the community survey. Of the 23 children who were examined, 22 had evidence of some form of respiratory illness (reported during the nurse interview or discovered during the doctor's examination). Overall, the children appeared healthy and no problems that needed urgent management were identified. Several children had mild respiratory illnesses at the time of the examination; only one child had findings of an abnormality of the lungs at the time of the examination. None of the children had wheezing. The examinations did not indicate any unusual pattern of illness among children in Scarboro. The illnesses that were detected were not more severe than would be expected and were typical of those that might be found in any community. The findings of examinations essentially confirmed the results of the community health survey. The results of the review were presented on January 7, 1999, at a community meeting in Scarboro (Johnson et al. 2000). A more detailed discussion of the Scarboro Community Health Investigation is provided in Appendix B. Summary of Other Public Health Activities. Dr. Redd, Chief of the Air Pollution and Respiratory Health Branch of the CDC, explained in the Y-12 Uranium Releases Video that "We worked for several months with community members to refine the questions that would be asked in the survey. We conducted the survey, and we followed the survey up with physical examinations of children who had asthma or had symptoms consistent with asthma. And these examinations were conducted by Knoxville pediatricians. We then reviewed the results of these examinations, and that review included local physicians and an allergist from Morehouse University. Then we reported the results of these investigations back to the community. The results were that we found a higher rate of asthma in the community than the national average. It wasn't a vastly elevated rate, and it was a rate that might be found in many communities in the United States." The video can be viewed on ATSDR's Oak Ridge Reservation: Public Health web site at: http://www.atsdr.cdc.gov/HAC/oakridge/index.html.

	Comment	ATSDR's Response
	is something bad going on in Scarboro."	
41	There is a high rate of cancer deaths in Scarboro.	ATSDR conducted an assessment of cancer incidence using data already collected by the Tennessee Cancer Registry. This assessment is a descriptive epidemiologic analysis that provides a general picture of the occurrence of cancer in each of the eight counties. The purpose of this evaluation was to provide citizens living in the ORR area with information regarding cancer rates in their county compared to the State of Tennessee. ATSDR's ORR Assessment of Cancer Incidence is available online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html. ▪ The results of the assessment of cancer incidence indicated both higher and lower rates of certain cancers in some of the counties examined when compared to cancer incidence rates for the State of Tennessee. Most of the cancers in the eight-county area occurred at expected levels, and no consistent pattern of cancer occurrence was identified. The reasons for the increases and decreases of certain cancers are unknown.
42	"There is something very, very wrong with the health of the people here," said a pastor in Scarboro. "We need the authority of your leadership and your authentic support to help us address what those problems are and what role the contamination in this community has played in those problems over the years. Unexplained health problems ranging from cancer to neurological disorders appear to plague far too many of the approximately 650 men, women, and children living here, less than a mile from the Y-12 plant."	Since this comment was made in 1997, the pastor's opinion changed. He said the following during an interview on the Y-12 Uranium Releases Video "We just feel that this is the place to be. Oak Valley is the place to be. Scarboro is the place to be. It's healthy. It is safe. It is fun to live here." The video can be viewed on ATSDR's Oak Ridge Reservation: Public Health web site at: http://www.atsdr.cdc.gov/HAC/oakridge/index.html.
43	A recent news article has citizens concerned about the safety of the Scarboro community.	Since 1998, the Joint Center for Political and Economic Studies (with the support of DOE's Oak Ridge Operations) has worked with the Scarboro community to help residents express their economic, environmental, health, and social needs. In 1999, the Joint Center for Political and Economic Studies conducted a survey of the Scarboro community to identify the residents' environmental and health concerns. The surveyors attempted to elicit responses from the entire community, but achieved an 82% response rate. Because Scarboro is a small community, the community assessment provided new information about the area and its residents that would not be available from sources that evaluate more populated areas, such as the Bureau of the Census. In addition, the assessment identified Scarboro's strengths and weaknesses, and illustrated the relative unimportance of environmental and health issues among residents in comparison to other community concerns. The assessment showed that environmental and health issues were not a priority among Scarboro residents, as the community was more concerned about crime, security, children, and economic development. The Joint Center for Political and Economic Studies recommended an increase in active community involvement in city and community planning (Friday and Turner 2001).

	Comment	*ATSDR's Response*
Other chemicals of concern		
44	The public has not been reassured that they have not been exposed to carcinogenic levels of uranium, fluorine, nickel, arsenic, mercury, chromium, neptunium, plutonium, or beryllium. The work groups and the subcommittee need to consider the elements arsenic, cadmium, lead, nickel, mercury, cobalt and strontium in the PHA.	Both TDOH and ATSDR have conducted public health evaluations of these chemicals in numerous reports. ATSDR's public health assessments can be found at http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html. Additionally, ATSDR conducted health consultations on EFPC (ATSDR 1993b) and LWBR (ATSDR 1996b), which evaluated current exposures to all of these chemicals. TDOH's Oak Ridge Health Studies can be found at http://health.state.tn.us/CEDS/OakRidge/ORidge.html. Section II.F.5 of this public health assessment provides a summary of TDOH's Oak Ridge Health Studies. Arsenic ▪ Tasks 3 and 4 of the TDOH Oak Ridge Dose Reconstruction Feasibility Study (Phase I) and Task 7 of the TDOH Oak Ridge Dose Reconstruction (Phase II) further evaluated arsenic. ▪ ATSDR evaluated arsenic during the 2007 *Evaluation of Current (1990 to 2003) and Future Chemical Exposures in the Vicinity of the Oak Ridge Reservation*. Beryllium ▪ Tasks 3 and 4 of the TDOH Oak Ridge Dose Reconstruction Feasibility Study (Phase I) further evaluated beryllium. ▪ Task 7 of the TDOH Oak Ridge Dose Reconstruction (Phase II) concluded that past beryllium releases do not warrant a high priority for further evaluation. ▪ ATSDR evaluated beryllium during the 2007 *Evaluation of Current (1990 to 2003) and Future Chemical Exposures in the Vicinity of the Oak Ridge Reservation*. Cadmium ▪ ATSDR evaluated cadmium during the 2007 *Evaluation of Current (1990 to 2003) and Future Chemical Exposures in the Vicinity of the Oak Ridge Reservation*. Chromium ▪ Tasks 3 and 4 of the TDOH Oak Ridge Dose Reconstruction Feasibility Study (Phase I) further evaluated chromium. ▪ Task 7 of the TDOH Oak Ridge Dose Reconstruction (Phase II) concluded that past hexavalent chromium releases do not warrant a high priority for further evaluation. ▪ ATSDR evaluated chromium during the 2007 *Evaluation of Current (1990 to 2003) and Future Chemical Exposures in the Vicinity of the Oak Ridge Reservation*. Cobalt ▪ Tasks 1 and 2 of the TDOH Oak Ridge Dose Reconstruction Feasibility Study (Phase I) determined that cobalt-57 was not a contaminant of concern. ▪ ATSDR evaluated cobalt during the 2007 *Evaluation of Current (1990 to 2003) and Future Chemical Exposures*

Comment	ATSDR's Response
	in the Vicinity of the Oak Ridge Reservation. Fluorine ▪ Tasks 1 and 2 of the TDOH Oak Ridge Dose Reconstruction Feasibility Study (Phase I) determined that fluorine was not a contaminant of concern. ▪ ATSDR released the *K-25 and S-50 Uranium Fluoride Releases Public Health Assessment* to address releases of fluorine in 2010. Lead ▪ Tasks 3 and 4 of the TDOH Oak Ridge Dose Reconstruction Feasibility Study (Phase I) further evaluated lead. ▪ Task 7 of the TDOH Oak Ridge Dose Reconstruction (Phase II) concluded that further evaluation of blood lead concentrations may not be warranted. ▪ ATSDR evaluated lead during the 2007 *Evaluation of Current (1990 to 2003) and Future Chemical Exposures in the Vicinity of the Oak Ridge Reservation*. Mercury ▪ The TDOH Oak Ridge Dose Reconstruction Feasibility Study (Phase I) identified mercury as one of the highest priority contaminants for further study. ▪ Task 2 of the TDOH Oak Ridge Dose Reconstruction (Phase II) specifically addresses mercury releases from lithium enrichment at the Y-12 plant. ▪ ATSDR specifically addressed exposures to mercury in this public health assessment. Neptunium ▪ Tasks 3 and 4 of the TDOH Oak Ridge Dose Reconstruction Feasibility Study (Phase I) further evaluated neptunium. ▪ Task 7 of the TDOH Oak Ridge Dose Reconstruction (Phase II) concluded that past neptunium-237 releases do not warrant a high priority for further evaluation. Nickel ▪ Tasks 3 and 4 of the TDOH Oak Ridge Dose Reconstruction Feasibility Study (Phase I) further evaluated nickel. ▪ Task 7 of the TDOH Oak Ridge Dose Reconstruction (Phase II) concluded that past nickel releases do not warrant a high priority for further evaluation. ▪ ATSDR evaluated nickel during the 2007 *Evaluation of Current (1990 to 2003) and Future Chemical Exposures in the Vicinity of the Oak Ridge Reservation*. Plutonium ▪ Tasks 3 and 4 of the TDOH Oak Ridge Dose Reconstruction Feasibility Study (Phase I) determined that

	Comment	*ATSDR's Response*
		plutonium was not a contaminant of concern. Strontium ▪ Tasks 3 and 4 of the TDOH Oak Ridge Dose Reconstruction Feasibility Study (Phase I) further evaluated strontium-89, -90. It was not identified as a contaminant that warranted further study. Uranium ▪ The TDOH Oak Ridge Dose Reconstruction Feasibility Study (Phase I) identified uranium as one of the highest priority contaminants for further study. ▪ Task 6 of the TDOH Oak Ridge Dose Reconstruction (Phase II) specifically addresses uranium releases from the ORR. ▪ ATSDR released two public health assessments dealing with exposures to uranium—*Y-12 Uranium Releases* (2004) and *K-25 and S-50 Uranium Fluoride Releases* (2010).
45	There could be many contaminants that were released that DOE did not report. ATSDR needs to look at the big picture-many elements are used.	Several agencies, including U.S.EPA, TDOH, TDEC, FAMU, and ATSDR, independently conducted numerous evaluations for potential contaminants in the environment surrounding ORR. Section II.F.3 and Appendix B. Summary of Other Public Health Activities in this public health assessment summarize all the public health activities that have been conducted for the ORR.
46	Concerned about the synergistic effects of multiple exposures to multiple contaminants. The long-term synergistic effects of multiple combinations are not known. Some suspicious cases that have occurred need to be studied.	ATSDR has reviewed the scientific literature on chemical interactions. 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 (Feron et al. 1995; Seed et al. 1995). Additionally, Jonker et al. (1990) and Groten et al. (1991) demonstrated the absence of interactions at doses tenfold or more below effect thresholds. 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 near their individual thresholds, can produce additive toxic effects. 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 CELs resulted in an increase in cancer. However, Hasegawa et al. (1994) reported no increase in cancer when dosing animals at 1/100 of the CELs for 10 compounds. It should be noted that typical environmental exposures to chemicals (noncarcinogens and carcinogens) are more than 1,000 times below laboratory-induced health effect thresholds.

	Comment	ATSDR's Response
Additional public health activities		
47	Residents should be tested for elements in a cutting-edge treatment center that is set up specifically for affected Oak Ridge residents. Will ATSDR study people who have been found to have mercury poisoning? Should be tests available for mercury like there is for beryllium. Concerned about mercury testing/screening.	The TDOH Oak Ridge Health Studies and ATSDR's public health assessments on the ORR do not indicate there is a need for follow-up public health activities such as testing at community health centers. Using the findings of ATSDR's 1996 Health Consultation on LWBR (ATSDR 1996b), ATSDR conducted the Watts Bar Exposure Investigation (ATSDR 1998) to measure actual PCB and mercury levels in people consuming moderate to large amounts of fish and turtles from the Watts Bar Reservoir, and to determine whether these people were being exposed to high levels of PCBs and mercury. A brief summarizing the exposure investigation is provided in Appendix C. Summary Briefs and Factsheets. ▪ The participants' serum PCB levels and blood mercury levels are very similar to levels found in the general population. ▪ Only one of 116 participants had an elevated total blood mercury level. ▪ Only 5 of the 116 people tested (4 percent) had PCB levels that were higher than 20 μg/L, which is considered to be an elevated level of total PCBs. Of the five participants who exceeded 20 μg/L, four had levels of 20–30 μg/L. Only one participant had a serum PCB level of 103.8 μg/L, which is higher than the general population distribution.
48	A credible procedure for identifying mercury poisoning should be identified and laid out for ORRHES and the community.	There are many sources of information for identifying whether someone has been exposed to mercury. Doctors can test how much mercury is in blood or urine. Methylmercury can also be tested in hair. These tests can tell you if you have been in contact with mercury. But they cannot show the kind of health effects you might experience, or whether you will become sick. ▪ If you breathed in metallic mercury vapors, you might have a fever, fatigue, irritated eyes or lungs, chest tightness, memory loss, being sick to your stomach, increased blood pressure, numbness, discolored hands and feet, renal damage, and chronic central nervous system effects. ▪ If you were exposed to high amounts of inorganic mercury, you might be severely sick to your stomach, have bloody diarrhea, memory loss, increased blood pressure, numbness, discolored hands and feet, and renal damage. ▪ If you were exposed to organic mercury, you might have headaches, sight and hearing loss, numbness, loss of muscle control, and difficulty speaking. Children might experience developmental effects. The following Web sites provide additional information: ▪ ATSDR's Toxicological Profile for Mercury at http://www.atsdr.cdc.gov/toxprofiles/tp46.html ▪ ATSDR's Mercury and Your Health at http://www.atsdr.cdc.gov/mercury/ ▪ ATSDR's Medical Management Guidelines for Mercury at http://www.atsdr.cdc.gov/MHMI/mmg46.html ▪ ATSDR's ToxFAQs Chemical Agent Briefing Sheets for Mercury at http://www.atsdr.cdc.gov/cabs/mercury/index.html

	Comment	*ATSDR's Response*
		▪ U.S.EPA's Mercury Web site at http://www.epa.gov/mercury/ ▪ CDC's Emergency Preparedness and Response: Mercury at http://www.bt.cdc.gov/agent/mercury/
49	Many people cannot afford the costs of Chelation therapy.	Chelation therapy is only warranted when someone has a clear case of acute elemental mercury exposure, and is symptomatic. The decision to chelate should be made by a physician. Chelation therapy becomes less effective as the time since exposure increases. For more information, see ATSDR's Medical Management Guidelines for Mercury at http://www.atsdr.cdc.gov/MHMI/mmg46.html.
Miscellaneous		
50	Scarboro residents and other Afro-Americans do not participate for fear of retaliation. Pollution, environmental contamination, and environmental health issues appear to concern fewer Scarboro residents than other matters. Only 9% of respondents raised these concerns in response to an open question regarding concerns about the Scarboro community. Many of these respondents wanted better information and communication about environmental pollution and environmental health issues.	ATSDR has worked closely with members of the ORR community, including African American Scarboro residents, throughout the entire public health assessment process. ▪ In 1999, the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) was established. The subcommittee consisted of people who represented 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 the ORR. To help ensure citizen participation, the meetings of the subcommittee's work groups were open to the public and everyone could attend and present their ideas and opinions. ▪ From 2001 to 2005, ATSDR maintained a field office in the city of Oak Ridge. The office was opened to promote collaboration between ATSDR and the communities surrounding the ORR by providing community members with opportunities to become involved in ATSDR's public health activities at the ORR ▪ ATSDR created the Oak Ridge Reservation: Public Health web site at http://www.atsdr.cdc.gov/HAC/oakridge/index.html. ▪ ATSDR collected and documented health concerns and issues in the ATSDR Community Health Concerns Database for the ORR. This database allowed ATSDR to record, tract, and address community concerns obtained from written correspondence, phone calls, newspapers, comments made at public meetings (ORRHES and workgroup meetings), and individuals stopping by the ATSDR Oak Ridge Field Office. ATSDR addressed the community health concerns in the public health assessments. ▪ ATSDR released all of the public health assessments for public comment, and held several public availability sessions throughout the ORR area. ▪ ATSDR held physician and community education programs to address health issue and concerns. ▪ ATSDR held Epidemiology Workshops to explain the science of epidemiology and to assist community members develop the skills needed to review and evaluate scientific reports. ▪ Numerous press releases, fact sheets, two videos, and presentations were made to keep the community informed of ATSDR's activities.

Comment		ATSDR's Response
		A local African American pastor said the following during an interview on the Y-12 Uranium Releases Video "We have several members in our congregation have worked with all of the surveys that have been done over the last 10 years…and all of that has proven to be quite helpful. We've been very much a part of all the committees, the subcommittees…I am confident that we have played the kind of role in this – in gathering this data and getting it forward that will prove to be useful." The video can be viewed on ATSDR's Oak Ridge Reservation: Public Health web site at: http://www.atsdr.cdc.gov/HAC/oakridge/index.html.
51	ATSDR and ORRHES seem to only look at old data and studies and put new labels on them, the groups do not help anyone or do anything new.	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 to identify contaminants of concern for further evaluation. Based on this review, ATSDR scientists have completed public health assessments on the following: ▪ Uranium releases from the Y-12 plant (2004) ▪ Contaminant releases from the Toxic Substances Control Act (TSCA) Incinerator (2005) ▪ Off-site groundwater (2006) ▪ Radionuclide releases from White Oak Creek (2006) ▪ Current and future chemical exposures (2007) ▪ Iodine 131 releases from the X-10 site (2008) ▪ PCB releases (2009) ▪ Uranium and fluoride releases from the K-25 site (2010) ▪ Mercury releases from the Y-12 plant (2011) In conducting these PHAs, ATSDR scientists evaluate and analyze the information and findings from previous studies and investigations to assess the public health implications of past and current exposure. When there is a data gap, ATSDR may conduct an Exposure Investigation. For the ORR, ATSDR conducted the Watts Bar Exposure Investigation (ATSDR 1998) to measure actual mercury and PCB levels in people consuming moderate to large amounts of fish and turtles from the Watts Bar Reservoir, and to determine whether these people were being exposed to high levels of mercury and PCBs. A brief summarizing the exposure investigation is provided in Appendix C. Summary Briefs and Factsheets.
52	EFPC has been identified by TDEC as the most contaminated creek in Tennessee according to the Oak Ridger newspaper.	TDEC issued advisories for EFPC because of bacterial contamination in the water, as well as mercury and PCB contamination in fish tissue. The presence of bacteria in the water affects the public's ability to safely swim, wade, and fish in streams and reservoirs. According to TDEC, bacterial sources include failing septic tanks, collection system failure, failing animal waste systems, or urban runoff. Within the State of Tennessee about 147 river miles are posted due to bacterial contamination. Please see the posted advisories at http://www.tennessee.gov/environment/wpc/publications/pdf/advisories.pdf. Note that EFPC is not a productive fishing location.

	Comment	*ATSDR's Response*
53	It will be difficult to separate workers from community members because people often fit into both roles. How do we separate exposures as either off-site or on-site when the exposure could have came from either place?	ATSDR's ORR public health assessments only evaluate off-site exposures to contaminant releases from the ORR. They do not evaluate any exposures potentially occurring on site at the reservation, including exposures to workers and other individuals who may contact contaminants while at the ORR. The Comprehensive Epidemiologic Data Resource (CEDR) is a public-use database that contains information pertinent to health-related studies performed at the ORR and other DOE sites. DOE provides this easily accessible, public-use repository of data (without personal identifiers) collected during occupational and environmental health studies of workers at DOE facilities and nearby community residents. This large resource organizes the electronic files of data and documentation collected during these studies and makes them accessible on the Internet at https://www.orau.gov/cedr/. Most of CEDR's large data collection pertains to about 50 epidemiologic studies of workers at various DOE sites. Of particular interest to Tennessee residents is an additional feature of CEDR that provides searchable text for about 1,800 original government documents (now declassified) used by the TDOH scientists for the Oak Ridge Dose Reconstruction.
54	Any program that is set up should not be associated with any contractor or else the community will not trust it. Any DOE-controlled study will lack credibility.	ATSDR is a federal public health agency of the U.S. Department of Health and Human Services. It is a separate agency from U.S.EPA and DOE. As the lead agency within the Public Health Service for implementing the health-related provisions of CERCLA, ATSDR is charged under the Superfund Act to assess the presence and nature of health hazards at specific Superfund sites, to help prevent or reduce further exposure and the illnesses that result from such exposures, and to expand the knowledge base about health effects from exposure to hazardous substances.

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VII. Child Health Considerations

ATSDR recognizes that infants and children can be more sensitive to environmental exposure than adults in communities faced with contamination of their water, soil, air, or food. Children are not small adults; a child's exposure can differ from an adult's in many ways. Developing fetuses, infants, and children have unique vulnerabilities. This sensitivity is a result of 1) children's higher probability of exposure to certain media because they crawl on the floor, put things in their mouths, play closer to the ground, and spend more time outdoors; 2) children's shorter height, which means that they can breathe dust, soil, and vapors close to the ground; and 3) children's generally smaller stature, which means childhood exposure will result in higher doses of chemical exposure per body weight (i.e., a child drinks more liquid, eats more food, and breathes more air per unit of body weight than an adult). Very young children and infants are also more susceptible because their organs are not fully matured. Also, young children have less ability to avoid hazards because they lack knowledge and depend on adults for decisions. As part of ATSDR's Child Health Initiative, ATSDR is committed to evaluating the special interests of children at sites such as the ORR.

These behaviors can result in longer exposure durations and higher intake rates. Children grow and develop rapidly in the first few months and years of life. In critical periods of development before they are born, and in the early months after birth, fetuses and children are particularly sensitive to the harmful effects of metallic mercury and methylmercury on the nervous system (ATSDR 1999). As with mercury vapors, exposure to methylmercury is more dangerous for young children than for adults, because more methylmercury easily passes into the developing brain of young children and may interfere with the development process. During critical periods of structural and functional development in both prenatal and postnatal life, children are especially vulnerable to the toxic effects of mercury (ATSDR 1999).

Methylmercury is the form of mercury most commonly associated with a risk for developmental effects.

Methylmercury eaten or swallowed by a pregnant woman or metallic mercury that enters her body from breathing contaminated air can also pass into the fetus. Inorganic mercury and methylmercury can also pass from a mother's body into breast milk and into a nursing infant. The amount of mercury in the milk will vary, depending on the degree of exposure and the amount of mercury that enter the nursing woman's body. There are significant benefits to breast feeding, so any concern that a nursing woman may have about mercury levels in her breast milk should be discussed with her doctor. Methylmercury can also accumulate in an unborn baby's blood to a concentration higher than the concentration in the mother (ATSDR 1999).

Methylmercury Exposures in Children

Several human studies have evaluated the neurological effects of methylmercury exposure in children.

A long-term human study of children from the Faroe Islands, a small group of islands in the North Atlantic Ocean affiliated with Denmark, began in 1986 and focused on children born to women who lived on the islands. This population relies heavily on seafood and whales as a protein source. The investigators used various tests that monitor child development. They concluded that at birth, cord blood mercury levels in the mother were associated with harmful effects in children at age 7 years involving language, attention and memory, and to a lesser

extent visual/spatial and motor functions (Grandjean et al. 1997). Follow-up studies at age 14 years showed similar findings (Debes et al. 2006).

In 1978, New Zealand was the site of another human study. It focused on 61 children who were exposed *in utero* to high mercury levels that resulted from their mother's consumption of four or more fish meals a week. If the authors omitted one outlier, the data showed a decrease in children's intelligence quotient (IQ) at age 6 with increasing exposure to methylmercury as measured by their mother's hair mercury levels at birth (Crump et al. 1998).

The third study came from the Republic of Seychelles, where 85 percent of the population relied on local seafood for protein. Average ocean fish consumption in this population was 12 meals a week (Davidson et al. 1998). The Seychelles study initially did not find harmful effects in children as they grew older. In one recent publication, the investigators reported that two of 21 endpoints (one positive and one negative) were associated with prenatal methylmercury exposure. The authors stated that these outcomes were probably due to chance and conclude that their data did not support a neurodevelopment risk from prenatal methylmercury exposure from eating fish (Myers et al. 2003). In another paper, the authors reported that they found several associations between postnatal methylmercury exposure and children's developmental endpoints. However, the investigators concluded that no consistent pattern of associations emerged to support a causal relationship (Myers et al. 2009).

Past Evaluation (1950–1990)

During the past evaluation, ATSDR specifically addressed childhood sensitivity to mercury in the air, surface water, soil and sediment, fish, and edible plants.

- Exposure to elemental mercury carried from the Y-12 plant by workers into their homes could potentially have harmed their families (especially young children) in the past (1950–1963).
- Air and water mercury releases from the Y-12 plant after 1963, are not expected to have harmed people living off site near the ORR. But insufficient information is available for ATSDR to determine whether releases from 1950 through 1963 could have caused harmful health effects.
- Breathing past (1950–1963) air mercury releases from the Y-12 plant is not expected to have harmed children living in the Wolf Valley area.
- Children who swallowed water from EFPC for a short time during some weeks in 1956, 1957, and 1958, could potentially have experienced renal effects due to mercury.
- Insufficient information is available to determine whether children who swallowed water containing mercury from EFPC during 1953, 1954, and 1955 could have been harmed.
- Children who swallowed water containing mercury from EFPC before 1953, or after the summer of 1958, are not expected to have experienced harmful health effects.
- Children who swallowed water from EFPC over a long time period in the past are not expected to have experienced harmful health effects from mercury exposure.

- Children who played at the NOAA site and Bruner site prior to the soil removal activities in 1996 and 1997, may have accidentally eaten inorganic mercury in EFPC floodplain soils that could potentially have caused renal effects.
- Accidentally eating methylmercury in EFPC floodplain soils in the past is not expected to have caused harmful health effects for children playing in the floodplain soil.
- Insufficient information is available to determine whether children who ate fish from EFPC during the 1950s, 1960s, and 1970s could have been harmed by methylmercury.
- Children who periodically ate fish from EFPC (up to nine meals from EFPC per year) in the 1980s and children born to women who ate EFPC fish are not expected to have experienced harmful health effects.
- Insufficient information is available to determine whether children who ate fish from Poplar Creek during the 1950s and 1960s could have been harmed by methylmercury.
- Fetuses and nursing babies of women who ate 12 meals a month (3 meals a week) of fish from Poplar Creek in the 1970s, 1980s, and 1990 are at an increased risk of subtle neurodevelopmental effects.
- Children who ate fish at high ingestion rates of 6 fish meals a month from Poplar Creek in the 1970s, 1980s, and 1990 have an increased risk of subtle neurodevelopmental effects.
- Women who ate 3 meals a month (average consumption rate) of Poplar Creek fish in the 1970s, 1980s, and 1990 had a small increased risk of harming a developing fetus.
- Children who ate less than 2 Poplar Creek fish meals a month in the 1970s, 1980s, and 1990 have a small increased risk of neurodevelopmental effects.
- Insufficient information is available to determine whether children who ate fish from Clinch River during the 1950s and 1960s could have been harmed by methylmercury.
- Fetuses and nursing babies of women who ate 12 meals a month (3 meals a week) of fish from Clinch River in the 1970s, 1980s, and 1990 have a small increased risk of developing subtle neurodevelopmental effects.
- Children who ate fish at high ingestion rates of 6 meals a month of fish from Clinch River in the 1970s, 1980s, and 1990 have a small increased risk of subtle neurodevelopmental effects.
- Fetuses and nursing babies of women who ate up to three Clinch River fish meals per month are not expected to have been harmed.
- Children who ate less than two Clinch River fish meals a month are not at risk of harmful neurodevelopmental effects.
- Insufficient information is available to determine whether children who ate fish from Watts Bar Reservoir during the 1950s, 1960s, and 1970s could have been harmed by methylmercury.
- Fetuses and nursing babies of women who ate 20 meals a month (5 meals a week) from Watts Bar Reservoir in the 1980s and 1990 have a small increased risk of developing subtle neurodevelopmental effects.

- Children who ate fish at high ingestion rates of 10 meals a month from Watts Bar Reservoir in the 1980s and 1990 have a small increased risk of subtle neurodevelopmental effects.
- Fetuses and nursing babies of women who ate up to five Watts Bar Reservoir fish meals per month are not expected to have been harmed.
- Children who ate less than three Watts Bar Reservoir fish meals a month are not at risk of harmful neurodevelopmental effects.
- Eating produce grown in the city of Oak Ridge and the EFPC floodplain in private gardens that contain mercury-contaminated soils is not expected to have harmed people's health.

Current Evaluation (1990–2009)

During the current evaluation, ATSDR specifically addressed childhood sensitivity to mercury from exposures through breathing the air; incidentally ingesting surface water, soil, and sediment; and eating fish, crayfish, turtles, and vegetables.

- None of the ambient air samples detected mercury at levels of public health concern for children, or for fetuses and nursing infants of mothers.
- The majority of the surface water samples either did not detect mercury or found mercury well below levels of health concern for children, fetuses of pregnant women, or infants of nursing mothers incidentally ingesting (or being exposed to) the surface water.
- Incidentally ingesting mercury in the soil around the ORR is not expected to cause harmful health effects for non-pica children, or for fetuses and nursing infants of mothers.
- Incidentally ingesting mercury in the sediment around the ORR is not expected to cause harmful health effects for non-pica children, fetuses of pregnant women, or infants of nursing mothers.
- Ignoring the posted warning signs and eating one or more crayfish meals a month from EFPC can cause children to be at increased risk of subtle neurodevelopmental effects. Children who ignore the posted warning signs and eat one EFPC fish a month also have a small increased risk of subtle neurodevelopmental effects.
- Pregnant women who eat one EFPC fish a month are not at risk of harming a developing fetus. Children, pregnant women, and nursing mothers should heed the fish consumption advisories for EFPC.
- Eating one or two fish meals a week from LWBR can cause children and fetuses of pregnant women to have a small increased risk of subtle neurodevelopmental effects. Adults

Fish Advisories for Waterways near the ORR

Tennessee River

Catfish, striped bass, and hybrid (striped bass-white bass) bass should not be eaten due to elevated levels of PCBs. Children, pregnant women, and nursing mothers should not consume white bass, sauger, carp, smallmouth buffalo, and largemouth bass, but other people can safely consume one meal per month of these species.

Clinch River

Striped bass should not be eaten due to elevated levels of PCBs. Children, pregnant women, and nursing mothers should not consume catfish and sauger, but other people can safely consume one meal per month of these species.

East Fork Poplar Creek

No fish should be eaten due to elevated mercury and PCB levels. Avoid contact with the water due to bacterial contamination.

For the advisories, see http://www.tennessee.gov/environment/wpc/publications/pdf/advisories.pdf.

and children who eat one LWBR fish meal a month are not at risk of developing harmful effects in children or fetuses of pregnant women. Children, pregnant women, and nursing mothers should heed the fish consumption advisories for LWBR.

- Eating beets, kale, or tomatoes grown in the EFPC floodplain and eating garden vegetables grown in the city of Oak Ridge are not likely to cause harmful health effects for children, fetuses, and nursing children.

Pica Children

One additional assessment ATSDR conducts is to evaluate hazards to children displaying pica behavior (a craving for nonnutritive substances like soil). Information on the incidence of soil pica behavior is limited. A study described in U.S.EPA's *Exposure Factors Handbook* (EPA 1997) showed that the incidence of soil pica behavior was approximately 16 percent among children from a rural black community in Mississippi. This behavior, however, was described as a cultural practice among the community surveyed. Thus 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 of other children. Although these studies did not include data for all populations and represented short-term ingestion only, the assumption remains that the incidence rate of child pica behavior in the general population is low.

Little information is available on the amount of soil ingested (measured in mg/day) by children with pica behavior (EPA 1997). Intake 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/sediment intake 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 of age (weighing 10 kg). ATSDR considers this a health-protective assumption that likely overestimates soil/sediment consumption. In the case of pica behavior, estimated exposure doses were calculated using the maximum surface soil or sediment concentration detected in an area of likely exposure (see Table 31). ATSDR then compared these doses to acute health effect levels—this exposure pattern can be episodic and short-term.

Table 31. Estimated Exposure Doses for Pica Children

Location	*Maximum Concentrations (ppm)*		*Estimated Exposure Doses (mg/kg/day)*	
	Soil	*Sediment*	*Soil*	*Sediment*
EFPC	3,420	2,240	2.4×10^{-1}	1.6×10^{-1}
Oak Ridge	158	35.7	1.1×10^{-2}	2.5×10^{-3}
Scarboro	0.3	0.12	All concentrations were below the comparison value of 20 ppm.	
LWBR	Soil was not sampled.	160	Not available	1.1×10^{-2}

Sources: OREIS 2009; SAIC 1993
ppm: parts per million

All of the estimated exposure doses for potential pica child exposures are below the health effect levels available in the toxicological and epidemiological literature (the acute MRL is based on a study in which no renal effects were observed in rats administered 0.93 mg/kg/day once daily for 14 days; NTP 1993). ATSDR does not expect that children exhibiting pica behavior would experience adverse health effects from exposure to the current levels of mercury in soil/sediment around the ORR.

VIII. Conclusions and Recommendations

Past Evaluation (1950–1990)

Air (elemental mercury)

ATSDR concludes

- Elemental mercury carried from the Y-12 plant by workers into their homes could potentially have harmed their families (especially young children) in the past (1950–1963).
- Elemental mercury releases into the air from the Y-12 plant after 1963 are not expected to have harmed people living off site near the ORR.
- Elemental mercury vaporizing into the air from the water released from the Y-12 plant after 1963 is not expected to have harmed people living off site near the ORR.
- Breathing elemental mercury from past (1950–1963) airborne releases from the Y-12 plant is not expected to have harmed people living in the Wolf Valley area.

ATSDR cannot conclude

- Whether people living off site near the ORR who breathed airborne releases of elemental mercury from the Y-12 plant from 1950 through 1963 could have been harmed.
- Whether people living near the EFPC floodplain who breathed elemental mercury vapors from Y-12 releases to the water from 1950 through 1963 could have been harmed.

Surface Water (inorganic mercury)

ATSDR concludes

- Children who swallowed water from EFPC with inorganic mercury for a short period of time (acute exposure: less than 2 weeks) during some weeks in 1956, 1957, and 1958 could potentially have experienced renal effects.
- Adults who swallowed water from EFPC with inorganic mercury for a short time during some weeks in 1958 could also potentially have experienced renal effects.
- Swallowing water from EFPC with inorganic mercury for a short time before 1953 or after the summer of 1958 is not expected to have harmed people's health.
- Intermittently (intermediate exposure: more than 2 weeks and less than 1 year) swallowing water from EFPC containing inorganic mercury is not expected to have harmed people's health during any year.
- Swallowing water from EFPC with inorganic mercury contamination over a long period of time (chronic exposure: more than 1 year) in the past is not expected to have harmed people's health during any year.
- Swallowing water from EFPC containing methylmercury is not expected have harmed people's health during any year.

ATSDR cannot conclude

- Whether swallowing water from EFPC with inorganic mercury for a short time during 1953, 1954, and 1955 could have harmed people's health.

Soil and Sediment (inorganic mercury)

ATSDR concludes

- Children who played at the NOAA site and Bruner site before soil removal activities in 1996 and 1997 may have incidentally eaten inorganic mercury in EFPC floodplain soils that could potentially have caused renal effects. Adults are not expected to have been harmed.
- Methylmercury in EFPC floodplain soils in the past is not expected to have caused harmful health effects for anyone contacting the floodplain soil.

Fish (methylmercury)

ATSDR concludes

- Periodically eating methylmercury-contaminated fish from EFPC (up to nine meals per year for adults and four meals per year for children) in the 1980s is not expected to have harmed people's health, including children who ate fish, nursing infants whose mothers ate fish, and children born to women who ate fish.
- Children born to or nursing from women who ate approximately 12 fish meals per month from Poplar Creek in the 1970s, 1980s, and 1990 have an increased risk of subtle neurodevelopmental effects from exposure to methylmercury..

Due to other contamination in the fish, people should heed the fish consumption advisories. For the advisories, go to http://www.tennessee.gov/environment/wpc/publications/pdf/advisories.pdf.

- Children who ate up to six meals a month of Poplar Creek fish have an increased risk of subtle neurodevelopmental effects from exposure to methylmercury.
- Children born to or nursing from women who ate approximately three meals a month of Poplar Creek fish in the 1970s, 1980s, and 1990 have a small increased risk of subtle neurodevelopmental effects.
- Children who ate less than two meals a month of Poplar Creek fish have a small increased risk of neurodevelopmental effects.
- Children born to or nursing from women who ate 12 fish meals per month (three fish meals a week) from the Clinch River in the 1970s, 1980s, and 1990 have a small increased risk of subtle neurodevelopmental effects.
- Children born to or nursing from women who ate up to three Clinch River fish meals per month were not harmed from exposure to methylmercury.
- Children who ate approximately six fish meals a month from the Clinch River have a small increased risk of subtle neurodevelopmental effects.
- Children who ate less than two Clinch River fish meals a month are not at risk of harmful neurodevelopmental effects.

- Children born to or nursing from women who ate 20 fish meals per month (five fish meals a week) from Watts Bar Reservoir in the 1980s and 1990 have a small increased risk of subtle neurodevelopmental effects.
- Children born to or nursing from women who ate up to five Watts Bar Reservoir fish meals per month were not harmed from exposure to methylmercury.
- Children who ate approximately 10 fish meals a month from Watts Bar Reservoir have a small increased risk of subtle neurodevelopmental effects.
- Children who ate less than three Watts Bar Reservoir fish meals a month are not at risk of harmful neurodevelopmental effects.

ATSDR cannot conclude

- Whether eating fish from EFPC, Poplar Creek, Clinch River, or Watts Bar Reservoir during the 1950s and 1960s could have harmed people's health.
- Whether eating fish from EFPC and Watts Bar Reservoir during the 1970s could have harmed people's health.

Edible Plants (inorganic mercury)

ATSDR concludes

- Eating local produce grown in gardens in the EFPC floodplain or in private gardens that contain mercury-contaminated soils from the floodplain would not have harmed people's health in the past.

Current Evaluation (1990–2009)

Air (elemental mercury)

ATSDR concludes

- Breathing air near EFPC is not expected to harm people's health. All of the EFPC ambient air sample elemental mercury results (collected near the areas with the highest level of contamination during the summer) were less than the comparison value for elemental mercury in air.
- Breathing air near LWBR is not expected to harm people's health. Despite a lack of analysis of LWBR ambient air samples for elemental mercury concentrations, the occurrence of harmful health effects from exposure to mercury vapor from contaminated soil is not a concern for the LWBR. The mercury contamination accumulated in the sediments of the deep river channel; the contamination is buried under cleaner sediment. The near-shore sediment concentrations in the LWBR are much lower than those found in the EFPC floodplain

Surface Water (inorganic mercury)

ATSDR concludes

- Accidentally swallowing surface water from EFPC is not expected to harm people's health. Only one EFPC surface water mercury concentration was detected slightly above the mercury comparison value. To assess the exposure further, ATSDR evaluated two scenarios: 1) a farm family member's exposure and 2) a child's exposure if the bacterial advisory to avoid contact with water is ignored. The calculated inorganic mercury exposure doses for both scenarios were below the chronic exposure health guideline value.
- Accidentally swallowing surface water from Oak Ridge is not expected to harm people's health. Only one concentration of mercury in Oak Ridge surface water was higher than the comparison value. To evaluate the exposure further, ATSDR calculated inorganic mercury exposure doses for adults and children using the maximum concentration detected in Oak Ridge surface water. Both estimated inorganic mercury doses were below the chronic exposure health guideline value.
- Accidentally swallowing surface water from Scarboro ditches will not harm people's health. Mercury has not been detected in any surface water samples collected from the Scarboro community.
- Accidentally swallowing surface water from LWBR is not expected to harm people's health. All of the LWBR surface water samples were less than the mercury comparison value.

Soil (inorganic mercury)

ATSDR concludes

- Floodplain soils with concentrations greater than 400 ppm of mercury were removed in 1996 and 1997. Children who played in the EFPC floodplain at the NOAA and Bruner sites before soil removal activities, may have incidentally eaten inorganic mercury in soil that could potentially have caused renal effects. Adults are not expected to have been harmed. ATSDR evaluated exposure to floodplain soils with up to 400 ppm of inorganic mercury and determined that this clean-up level is safe. People who come in contact with EFPC floodplain soil after cleanup activities are not being harmed from exposure to mercury.
- Coming in contact with mercury in Oak Ridge soil is not expected to harm people's health. Some of the concentrations of inorganic mercury in Oak Ridge soil were higher than the comparison value. To evaluate the exposure further, ATSDR calculated inorganic mercury exposure doses for adults and children using the maximum concentration detected in Oak Ridge soil. Both the estimated inorganic mercury doses were well below health effect levels.
- Coming in contact with mercury in Scarboro soil is not expected to harm people's health. All of the surface soil samples collected in Scarboro had mercury concentrations that were less than the comparison value.
- Coming in contact with mercury in the soil near the LWBR is not expected to harm people's health. The soil near LWBR has not been contaminated with mercury from ORR operations. Mercury from the ORR was released into EFPC and traveled through Poplar Creek and the Clinch River to the LWBR. The mercury accumulated in LWBR deep river channel

sediments, buried under cleaner sediment. The near-shore sediment mercury concentrations in the LWBR were much lower than the comparison value for mercury in soil. Despite the absence of soil samples collected from the LWBR, the occurrence of harmful health effects from exposure to mercury in soil along the LWBR shoreline is not a concern.

Sediment (inorganic mercury)

ATSDR concludes

- Coming in contact with mercury in EFPC sediment is not expected to harm people's health. Some of the concentrations of mercury in EFPC sediment were higher than the comparison value. To assess the exposure further, ATSDR evaluated two scenarios: 1) a farm family member's exposure and 2) a child's exposure if the bacterial advisory to avoid contact with water is ignored. The calculated inorganic mercury exposure doses for both scenarios were below the health guideline value for chronic exposure.
- Coming in contact with mercury in Oak Ridge sediment is not expected to harm people's health. Some of the concentrations of mercury in Oak Ridge sediment were higher than the comparison value. To evaluate the exposure further, ATSDR calculated inorganic mercury exposure doses for adults and children using the maximum concentration detected in Oak Ridge sediment. Both the estimated doses were below the health guideline value for chronic exposure.
- Coming in contact with mercury in Scarboro sediment is not expected to harm people's health. All of the sediment samples collected in Scarboro had mercury concentrations that were less than the comparison value.
- Coming in contact with mercury in LWBR sediment is not expected to harm people's health. All of the near-shore sediment samples and deep-water sediment samples collected from the LWBR had mercury concentrations that were less than the comparison values. A few concentrations of mercury in unspecified depth sediment samples, however, were higher than the comparison value. To evaluate further the exposure to sediment, ATSDR calculated inorganic mercury exposure doses for adults and children using the maximum concentration detected in LWBR sediment from unspecified depths. Both the estimated inorganic mercury doses were below the health guideline value for chronic exposure.

Biota (methylmercury and inorganic mercury)

ATSDR concludes

- EFPC is not a productive fishing location, and a fish consumption advisory is in place. That anyone is actually eating fish from EFPC is unlikely. Nevertheless, ATSDR evaluated a *potential* exposure scenario and assumed people would ignore the posted advisory. ATSDR assumed that both adults and children ate one 8-ounce fish meal each month.
    - Women who eat fish are not at risk of harming a developing fetus. However, eating crayfish increases the risk for children born to or nursing from women who ignore the posted warning signs.
    - Children who eat fish have a small increased risk of subtle neurodevelopmental effects. Eating crayfish increases that risk.

- People frequently fish in LWBR. But since 1987, fishing advisories have warned people to avoid or limit their consumption of fish due to PCB contamination in the reservoir. ATSDR evaluated three potential exposure scenarios: 1) adults and children eating one fish meal with the average concentration of mercury each month, 2) adults and children eating one fish meal with the average concentration of mercury each week, and 3) adults eating about two fish meals with the average concentration of mercury each week.
  - Adults and children who eat one LWBR fish meal a month are not at risk of developing harmful effects.
  - Children who eat fish from LWBR once a week have a small increased risk of subtle neurodevelopmental effects from methylmercury.
  - Children born to or nursing from women who eat one or two LWBR fish meals a week have a small increased risk of subtle neurodevelopmental effects.
  - Adults and children who eat the edible portion of turtles from LWBR once or twice a week have a small increased risk of subtle neurodevelopmental effects.

Fish Advisories for Waterways near the ORR

Tennessee River

Catfish, striped bass, and hybrid (striped bass-white bass) bass should not be eaten due to elevated levels of PCBs. Children, pregnant women, and nursing mothers should not consume white bass, sauger, carp, smallmouth buffalo, and largemouth bass, but other people can safely consume one meal per month of these species.

Clinch River

Striped bass should not be eaten due to elevated levels of PCBs. Children, pregnant women, and nursing mothers should not consume catfish and sauger, but other people can safely consume one meal per month of these species.

East Fork Poplar Creek

No fish should be eaten due to elevated mercury and PCB levels. Avoid contact with the water due to bacterial contamination.

For the advisories, see http://www.tennessee.gov/environment/wpc/publications/pdf/advisories.pdf.

- Eating beets, kale, or tomatoes grown in the EFPC floodplain is not expected to harm people's health. Comparison values are not available for screening concentrations detected in edible plants. ATSDR thus further evaluated exposure to eating them by calculating inorganic mercury exposure doses using the average concentrations. The health effect levels available in the toxicological and epidemiological literature are at least two orders of magnitude higher than the estimated inorganic mercury doses for adults and children eating vegetables grown in EFPC gardens. And plants tend to store metals such as mercury in a form that is not readily bioavailable to humans.
- Eating vegetables from Oak Ridge is not expected to harm people's health. Only four vegetable samples were collected and analyzed for mercury from one garden within the city of Oak Ridge. Mercury was not detected in any of the samples.

Recommendations

- DOE should maintain long-term oversight of the mercury-contaminated soil at the spot in the EFPC floodplain east of the Horizon Center and, if the property is transferred to another party, consider remediation of the spot or deed restrictions.
- To prevent unnecessary exposures to workers and the public, ATSDR cautions that the LWBR sediments not be disturbed, removed, or disposed of without careful review by the interagency working group.

- People, particularly children, pregnant women, and nursing mothers, should heed the fish consumption advisories in waterways near the ORR.

IX. Public Health Action Plan

The public health action plan for the 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 health assessment 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 the ORR are completed or ongoing:

Completed Actions

Section II.F.3 contains a summary of public health activities pertaining to Y-12 plant mercury releases. Several additional public health activities conducted at the ORR by ATSDR, TDOH, and other agencies are described in Appendix B. Summary of Other Public Health Activities.

- In 1991, TDOH began a two-phase research project to determine whether environmental releases from the ORR harmed people who lived nearby. Phase I focused on assessing the feasibility of doing historical dose reconstruction and identifying contaminants most likely to have public health effects. Phase II efforts included full dose reconstruction analyses of iodine 131, mercury, PCBs, and radionuclides, as well as a more detailed health effects screening analysis for releases of uranium and other toxic substances. Phase II was completed in January 2000.
- In 2004, ATSDR released the final ORR Public Health Assessment for Y-12 Uranium Releases. The document is available from http://www.atsdr.cdc.gov/HAC/oakridge/phact/y12/index.html.
- In 2005, ATSDR released the final ORR Public Health Assessment for the TSCA Incinerator. The document is available from http://www.atsdr.cdc.gov/HAC/oakridge/phact/tsca/index.html.
- In 2006, ATSDR released the final ORR Public Health Assessment for Contaminated Off-site Groundwater Exposures. The document is available from http://www.atsdr.cdc.gov/HAC/oakridge/phact/groundwater/index.html.
- In 2006, ATSDR released the final ORR Public Health Assessment for White Oak Creek Radionuclide Releases. The document is available from http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html.
- In 2007, ATSDR released the final ORR Public Health Assessment for the Evaluation of Current (1990 to 2003) and Future Chemical Exposures in the Vicinity of the Oak Ridge Reservation. The document is available from http://www.atsdr.cdc.gov/HAC/oakridge/phact/screening/index.html.
- In 2008, ATSDR released the final ORR Public Health Assessment for Iodine 131 Releases. The document is available from http://www.atsdr.cdc.gov/HAC/oakridge/phact/iodine/index.html.
- In 2009, ATSDR released the final ORR Public Health Assessment for Polychlorinated Biphenyl (PCB) Releases.

- In 2010, ATSDR released the final ORR Public Health Assessment for K-25 and S-50 Uranium Fluoride Releases.

Ongoing Actions

- On public request, ATSDR will evaluate whether providing additional environmental health education materials would help community members understand this public health assessment's findings and implications.

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APPENDICES

Appendix A. ATSDR Glossary of Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (U.S.EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health. This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call the agency's toll-free telephone number, 1-800-CDC-INFO (1-800-232-4636).

Absorption
The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acute
Occurring over a short time [compare with chronic].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems

Aerobic
Requiring oxygen [compare with anaerobic].

Ambient
Surrounding (for example, ambient air).

Anaerobic
Requiring the absence of oxygen [compare with aerobic].

Analytic epidemiologic study
A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Body burden
The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

Cancer
Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

Central nervous system
The part of the nervous system that consists of the brain and the spinal cord.

CERCLA [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980]

Chronic
Occurring over a long time [compare with acute].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see exposure pathway].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances. This law was later amended by the Superfund Amendments and Reauthorization Act (SARA).

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Dermal
Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see route of exposure].

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease registry
A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

DOE
United States Department of Energy.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose-response relationship
The relationship between the amount of exposure [dose] to a substance and the resulting changes in body function or health (response).

Environmental media
Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism
Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction
A method of estimating the amount of people's past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure investigation
The collection and analysis of site-specific information and biologic tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Exposure registry
A system of ongoing follow up of people who have had documented environmental exposures.

Feasibility study
A study by U.S.EPA to determine the best way to clean up environmental contamination. A number of factors are considered, including health risk, costs, and what methods will work well.

Geographic information system (GIS)
A mapping system that uses computers to collect, store, manipulate, analyze, and display data. For example, GIS can show the concentration of a contaminant within a community in relation to points of reference such as streets and homes.

Grand rounds
Training sessions for physicians and other health care providers about health topics.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

Health education
Programs designed with a community to help it know about health risks and how to reduce these risks.

Health investigation
The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to evaluate the possible association between the occurrence and exposure to hazardous substances.

Health promotion
The process of enabling people to increase control over, and to improve, their health.

Health statistics review
The analysis of existing health information (i.e., from death certificates, birth defects registries, and cancer registries) to determine if there is excess disease in a specific population, geographic area, and time period. A health statistics review is a descriptive epidemiologic study.

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Medical monitoring
A set of medical tests and physical exams specifically designed to evaluate whether an individual's exposure could negatively affect that person's health.

Metabolism
The conversion or breakdown of a substance from one form to another by a living organism.

Metabolite
Any product of metabolism.

mg/kg
Milligram per kilogram.

mg/m^3
Milligram per cubic meter; a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

Morbidity
State of being ill or diseased. Morbidity is the occurrence of a disease or condition that alters health and quality of life.

Mortality
Death. Usually the cause (a specific disease, a condition, or an injury) is stated.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
U.S.EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

National Toxicology Program (NTP)
Part of the Department of Health and Human Services. NTP develops and carries out tests to predict whether a chemical will cause harm to humans.

No-observed-adverse-effect level (NOAEL)
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

NPL [see National Priorities List for Uncontrolled Hazardous Waste Sites]

Pica
A craving to eat nonfood items, such as dirt, paint chips, and clay. Some children exhibit pica-related behavior.

Plume
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

ppb
Parts per billion.

ppm
Parts per million.

Prevalence
The number of existing disease cases in a defined population during a specific time period [contrast with incidence].

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public availability session
An informal, drop-by meeting at which community members can meet one-on-one with ATSDR staff members to discuss health and site-related concerns.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action
A list of steps to protect public health.

Public health advisory
A statement made by ATSDR to U.S.EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health statement
The first chapter of an ATSDR toxicological profile. The public health statement is a summary written in words that are easy to understand. The public health statement explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public meeting
A public forum with community members for communication about a site.

Radionuclide
Any radioactive isotope (form) of any element.

RCRA [see Resource Conservation and Recovery Act (1976, 1984)]

Receptor population
People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)
A U.S.EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Registry
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see exposure registry and disease registry].

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Resource Conservation and Recovery Act (1976, 1984) (RCRA)
This Act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RfD [see reference dose]

Risk
The probability that something will cause injury or harm.

Risk reduction
Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

Risk communication
The exchange of information to increase understanding of health risks.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Safety factor [see uncertainty factor]

SARA [see Superfund Amendments and Reauthorization Act]

Sample
A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample size
The number of units chosen from a population or an environment.

Solvent
A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Special populations
People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Statistics
A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Substance
A chemical.

Superfund [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)]

Superfund Amendments and Reauthorization Act (SARA)
In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Survey
A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people.

Toxic agent
Chemical or physical (for example, radiation, heat, cold, microwaves) agents that, under certain circumstances of exposure, can cause harmful effects to living organisms.

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Uncertainty factor
Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

U.S.EPA
United States Environmental Protection Agency.

Volatile organic compounds (VOCs)
Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:

U.S. Environmental Protection Agency (http://www.epa.gov/OCEPAterms/)
National Library of Medicine (NIH) (http://www.nlm.nih.gov/medlineplus/mplusdictionary.html)

For more information on the work of ATSDR, please contact:

Office of Policy and External Affairs
Agency for Toxic Substances and Disease Registry
1600 Clifton Road, N.E. (MS E-60)
Atlanta, GA 30333
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Appendix B. Summary of Other Public Health Activities

Summary of the Agency for Toxic Substances and Disease Registry (ATSDR) Activities

Health Consultation on the Lower Watts Bar Reservoir (LWBR), February 1996. ATSDR concluded that polychlorinated biphenyls (PCBs) detected in fish from LWBR pose a public health concern. Frequent and long-term ingestion of fish from the reservoir poses a moderately increased risk of cancer. It could also increase the possibility of developmental effects in infants whose mothers consume fish regularly during gestation and while nursing. ATSDR found that current contaminant levels in the reservoir surface water and sediment are not a public health concern. The reservoir is safe for swimming, skiing, boating, and other recreational purposes. Additionally, water from the municipal water systems is safe to drink. ATSDR also reported that U.S. Department of Energy's (DOE) selected remedial actions would protect public health. These actions include maintaining the fish consumption advisories; continuing environmental monitoring; implementing institutional controls to prevent disturbance, resuspension, removal, or disposal of contaminated sediment; and providing community and health professional education regarding PCB contamination (ATSDR 1996b).

Community and Physician Education, September 1996. To follow up on the recommendations in the ATSDR LWBR Health Consultation, ATSDR developed community and physician education programs on PCBs in the Watts Bar Reservoir. At a community health education meeting in Spring City, TN on September 11, 1996, Daniel Hryhorczuk, MD, MPH, ABMT, of the Great Lakes Center, University of Illinois at Chicago, presented on the health risk associated with PCBs in fish. On September 12, 1996, health care providers in the vicinity of the LWBR met for a physician and health professional education meeting at the Methodist Medical Center in Oak Ridge. ATSDR, in collaboration with local citizens, organizations, and state officials, developed an instructive brochure on the Tennessee Department of Environment and Conservation's (TDEC) fish consumption advisories for the Watts Bar Reservoir (ATSDR et al. 2000).

Coordination with other parties. Since 1992, ATSDR has consulted regularly with representatives of other parties involved with the Oak Ridge Reservation (ORR). Specifically, ATSDR has coordinated efforts with the Tennessee Department of Health (TDOH), TDEC, the National Center for Environmental Health (NCEH), the National Institute for Occupational Safety and Health (NIOSH), and DOE. This effort led to the establishment of the Public Health Working Group in 1999, which further led to the establishment of the Oak Ridge Reservation Health Effects Subcommittee (ORRHES). ATSDR also provided some assistance to TDOH in its study of past public health issues. ATSDR has also obtained and interpreted studies prepared by academic institutions, consulting firms, community groups, and other parties (ATSDR et al. 2000).

Oak Ridge Reservation Health Effects Subcommittee. In 1999, ATSDR and the Centers for Disease Control and Prevention (CDC), under authority of the Federal Advisory Committee Act (FACA), established the ORRHES 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 comprised people with diverse interests, expertise, backgrounds, and communities, as well as liaison members from federal and state agencies. It became a forum for communication and collaboration between the citizens and those agencies

that evaluate public health issues and conduct public health activities at the ORR. To help ensure citizen participation, the meetings of the subcommittee's work groups were open to the public. Everyone was invited to attend and present ideas and opinions. The subcommittee

- Served as a citizen advisory group to CDC and ATSDR and made recommendations on matters related to public health activities and research at the ORR.
- Allowed citizens to collaborate with agency staff members and to learn more about the public health assessment process and other public health activities.
- Helped to prioritize the public health issues and community concerns evaluated by ATSDR.

ATSDR Field Office. From 2001 to 2005, ATSDR maintained a field office in the city of Oak Ridge. Office staff promoted collaboration between ATSDR and the communities surrounding the ORR. Staff for example provided community members with opportunities to become involved in ATSDR's public health activities at the ORR.

Clinical Laboratory Analysis. In June 1992, an Oak Ridge physician reported to the TDOH and the Oak Ridge Health Agreement Steering Panel (ORHASP) that approximately 60 of his patients may have been exposed, either occupationally or from the environment, to several heavy metals. The physician felt that these exposures had resulted in a number of adverse health outcomes. Such outcomes included but were not limited to increased incidence of cancer, chronic fatigue syndrome, neurological diseases, autoimmune disease, and bone marrow damage. In 1992 and 1993, ATSDR and NCEH assisted with clinical laboratory support by NCEH's Environmental Health Laboratory for patients the Oak Ridge physician referred to Howard Frumkin, M.D., Dr.PH., Emory University School of Public Health.

Because of patient-to-physician and physician-to-physician confidentiality, results of the clinical analysis have not been released to public health agencies. Dr. Frumkin, however, recommended (in an April 26, 1995 letter to the TDOH Commissioner) that one should "not evaluate the patients seen at Emory as if they were a cohort for whom group statistics would be meaningful. This was a self-selected group of patients, most with difficult to answer medical questions (hence their trips to Emory), and cannot in any way be taken to typify the population at Oak Ridge. For that reason, I have consistently urged [physician name], each of the patients, and officials of the CDC and the Tennessee Health Department, not to attempt group analyses of these patients."

Review of Clinical Information on Persons Living In or Near Oak Ridge. In addition to the above Clinical Laboratory Analysis, an ATSDR physician reviewed the clinical data and medical histories provide by the Oak Ridge physician on 45 of his patients. The purpose of this review was to evaluate clinical information on persons tested for heavy metals and to determine whether exposure to metals was related to these patients' illnesses. ATSDR concluded that this case series did not provide sufficient evidence to associate low levels of metals with these diseases. TDOH came to the same conclusion. ATSDR sent a copy of its review to the Oak Ridge physician in September 1992.

Health Professional Education on Cyanide. In 1996, a physician education program provided information regarding the health effects of possible cyanide intoxication. The program was intended to assist community health care providers in responding to health concerns expressed by employees working at the East Tennessee Technology Park (formerly the K-25 facility). ATSDR provided the local physicians with copies of the ATSDR Case Studies in Environmental Medicine publication "Cyanide Toxicity," the NIOSH final health hazard evaluation, and the

ATSDR public health statement for cyanide. Further, ATSDR instituted a system through which local physicians could make patient referrals to the Association of Occupational and Environmental Clinics (AOEC). Finally, ATSDR conducted an environmental health education session for physicians at the Methodist Medical Center in Oak Ridge, Tennessee. The medical staff grand rounds provided the venue for conducting this session. The workshop focused on providing local physicians and other health care providers with information to help them diagnose chronic and acute cyanide intoxication and to answer patient questions.

Workshops on Epidemiology. At the request of ORRHES members, ATSDR held two workshops on epidemiology for the subcommittee. The first epidemiology workshop was presented at the June 2001 ORRHES meeting. Ms. Sherri Berger and Dr. Lucy Peipins of ATSDR's Division of Health Studies provided an epidemiology overview. The second epidemiology workshop was presented at the December 2001 ORRHES meeting and was designed to help subcommittee members develop the skills needed to review and evaluate scientific reports. At the August 28, 2001, meeting of the Public Health Assessment Work Group (PHAWG), Dr. Peipins guided the work group and community members through a systematic, scientific approach as they critiqued a report by J. Mangano entitled "Cancer Mortality Near Oak Ridge, Tennessee" (Int. J. of Health Services, V. 24 #3, 1994, p. 521). Using the PHAWG critique, the ORRHES made the following conclusions and recommendation to ATSDR.

- The Mangano paper is not an adequate, science-based explanation of any alleged anomalies in cancer mortality rates of the off-site public.
- The Mangano paper fails to establish that radiation exposures from the ORR are the cause of any such alleged anomalies of cancer mortality rates in the public generally.
- The ORRHES recommends to the ATSDR exclusion of the Mangano paper from consideration in the ORR public health assessment process.

Health Education Needs Assessment. Throughout the public health assessment process, ATSDR staff members have gathered concerns from people in the communities around the ORR. Through a cooperative agreement with ATSDR, AOEC began a community health education needs assessment in 2000 to aid in developing a community health education action plan. George Washington University and MCP Hahnemann University are conducting the assessment for the AOEC. The needs assessment will help in planning, implementing, and evaluating the health education program for the site. It will also help health educators identify key people, cultural norms, attitudes, beliefs, behaviors, and practices in the community—information that will aid in developing effective health education activities. Information on the needs assessment was presented at several ORRHES meetings.

Site visits. To better understand site-specific exposure conditions, ATSDR scientists have conducted site visits to the ORR and visited surrounding areas numerous times since 1992. The site visits included guided tours of the ORR operation areas, as well as tours of the local communities to identify how community members might come into contact with environmental contamination.

Summary of TDOH Activities

The Oak Ridge Health Agreement Steering Panel (ORHASP) is a panel of experts and local citizens. They were appointed to direct and oversee the Oak Ridge Health Studies and provide

liaison with the community. Drawing on the findings of the Oak Ridge Health Studies and what is generally known about the health risks posed by exposures to various toxic chemicals and radioactive substances, ORHASP concluded that past releases from ORR were likely to have affected the health of some people. Two groups most likely to have been harmed were 1) local children who drank milk produced by a "backyard" cow or goat in the early 1950s and 2) fetuses of women who in the 1950s and early 1960s routinely ate fish from contaminated creeks and rivers downstream of ORR. For additional information on the ORHASP findings, please see the final report of the ORHASP titled *Releases of Contaminants from Oak Ridge Facilities and Risks to Public Health* (ORHASP 1999).

Feasibility of Epidemiologic Studies. TDOH and ORHASP contracted with a physician from Vanderbilt University's Department of Preventive Medicine to explore the feasibility of initiating analytical (for example, case-control or cohort) epidemiological studies. These studies would address potential health concerns in the off-site populations surrounding the ORR. A study was released in July 1996. It concluded that the feasibility and desirability of initiating future analytical epidemiologic studies would be significantly influenced by the findings of the dose reconstruction studies. Those studies would clarify the extent and magnitude of releases and possible human exposure from past releases of radioactive iodine, mercury, PCBs, uranium, and other radionuclides, including cesium 137 (ATSDR et al. 2000).

Public Meetings. Between January 1992 and December 1999, TDOH and ORHASP held open meetings in Oak Ridge (more than 40 meetings), Nashville (5 meetings), Harriman (2 meetings), and Knoxville (3 meetings). In addition, the ORHASP held two meetings in the Scarboro area to update the residents on Phase II of the Oak Ridge Health Studies. The first meeting was held at the Oak Valley Baptist Church in November 1995; the second meeting was held at the Scarboro Community Center in September 1997 (ATSDR et al. 2000).

Health Statistics Review. In June 1992, an Oak Ridge physician reported to TDOH and ORHASP that he believed approximately 60 of his patients had experienced occupational and environmental exposures to several heavy metals. The physician suggested these exposures had resulted in increased cancer, immunosuppression, chronic fatigue syndrome, neurologic diseases, autoimmune disease, bone marrow damage, and hypercoagulable state including early myocardial infarctions and stroke. In 1992, The TDOH conducted a health statistics review to compare cancer incidence rates for the period of 1988 to 1990 for counties surrounding the ORR to rates from the rest of the state. Review findings are in a TDOH memorandum dated October 19, 1992, from Mary Layne Van Cleave to Dr. Mary Yarbrough. The memorandum details an Oak Ridge physician's concerns about the health status of Oak Ridge area residents. Also available from TDOH are the minutes and handouts from a December 14, 1994 presentation given by Ms. Van Cleave at the ORHASP meeting.

Health Statistics Review. In 1994, local residents reported many community members with amyotrophic lateral sclerosis (ALS) and multiple sclerosis (MS). TDOH in consultation with Peru Thapa, MD, MPH, from the Vanderbilt University School of Medicine, conducted a health statistics review of mortality rates for ALS, MS, and other selected health outcomes. TDOH found that because ALS and MS are not reportable diseases, it is impossible to calculate reliable incidence rates. Mortality rates for the period of 1980 to 1992 were reviewed for the 10 counties surrounding the ORR and compared with mortality rates for the state of Tennessee. On August 18, 1994, at the ORHASP public meeting, TDOH reported the following results.

- No significant ALS mortality differences surfaced in any of the counties in comparison to the rest of the state.
- For Anderson County, the rate of age-adjusted deaths from chronic obstructive pulmonary disease was significantly higher than rates in the rest of the state. But rates for total deaths, deaths from stroke, deaths from congenital anomalies, and deaths from heart disease were significantly lower for the period from 1979 to 1988. No significant differences surfaced in the rates of deaths due to cancer for all sites in comparison with rates in the rest of state. Rates of deaths from uterine and ovarian cancer were significantly higher than the rates in the rest of the state. The rate of deaths from liver cancer was significantly lower in comparison to the rest of the state.
- For Roane County for the period 1979–1988, the rates of total deaths and deaths from heart disease were significantly lower than the rates in the rest of the state. Although the total cancer death rate was significantly lower than the rate in the rest of the state, the rate of deaths from lung cancer was significantly higher than the rate in the rest of the state. Rates of deaths from colon cancer, female breast cancer, and prostate cancer were also significantly lower than the rates in the rest of the state.
- For Knox County, the rates for total deaths and deaths from heart disease were significantly lower than the rates in the rest of the state. TDOH found no significant difference in the total cancer death rate in comparison to the rest of the state.
- TDOH found no significant exceedances for any cause of mortality studied in Knox, Loudon, Rhea, and Union counties in comparison to the rest of the state.
- Rates of total deaths were significantly higher in Campbell, Claiborne, and Morgan counties in comparison with the rest of the state.
- Cancer mortality was significantly higher in Campbell County in comparison to the rest of the state. The excess in number of deaths from cancer appeared to be attributed to the earlier part of period 1980–1985; the rate of deaths from cancer was not higher in Campbell County in comparison with the rest of the state for the periods 1986–1988 and 1989–1992.
- From 1980 to 1982, cancer mortality was significantly higher in Meigs County in comparison with the rest of the state. This excess in cancer deaths did not persist from 1983 to 1992.

Knowledge, Attitude, and Beliefs Study. TDOH coordinated a study in an eight-county area surrounding Oak Ridge, Tennessee. The study's purpose was to 1) investigate public perceptions and attitudes about environmental contamination and public health problems related to the ORR, 2) ascertain the public's level of awareness and assessment of ORHASP, and 3) make recommendations for improving public outreach programs. The report was released in August 1994. Following is a summary of the findings.

- A majority of the respondents regard their local environmental quality as better than the national environmental quality. Most rate the quality of the air and their drinking water as good or excellent. Almost half rate the local groundwater as good or excellent.
- A majority of the respondents think that activities at the ORR created some health problems for people living nearby. A majority think that activities at ORR created health problems for people who work at the site. Most feel that researchers should examine the actual occurrence

of disease among Oak Ridge residents. Twenty-five percent know of a specific local environmental condition they believe has adversely affected public health, but many of these appear to be unrelated to ORR. Less than 0.1 percent has personally experienced a health problem that they attribute to the ORR.

- About 25 percent have heard of the Oak Ridge Health Study. Newspapers are the primary source of information about the study. Roughly 33 percent rate the performance of the study as good or excellent, and 40 percent think the study will improve public health. Also, 25 percent feel that communication about the study has been good or excellent.

Health Assessment. TDOH's East Tennessee Region conducted a health assessment of the East Tennessee region to evaluate the health status of the population, assess the availability and use of health services, and develop priorities in resource allocation. In December 1991, the East Tennessee Region released the first edition of *A Health Assessment of the East Tennessee Region*, which included data generally from 1986 to 1990. The second edition, released in 1996, included data generally from 1990 through 1995 (TDOH 1996). A copy of the document is available from the TDOH East Tennessee Region.

Presentation. At the February 16, 1995 ORHASP public meeting, Dr. Joseph Lyon of the University of Utah presented to ORHASP and to the public multiple studies related to fallout from the Nevada Test Site, including the study of leukemia and thyroid disease. TDOH sponsored the presentation.

Summary of TDEC Activities

Watts Bar Reservoir and Clinch River Turtle Sampling Survey, May 1997. For several years, TDEC issued fish consumption advisories for the Watts Bar Reservoir warning of PCB contamination in fish. Because of the concern regarding PCBs in fish and the recognition that people were also eating turtles from the reservoirs, TDEC sampled snapping turtles from the Watts Bar Reservoir and Clinch River to determine the body burdens of contaminants in the turtles. Many agencies were consulted and involved in the project, including ATSDR, DOE, TDOH, Tennessee Valley Authority (TVA), and the Tennessee Wildlife Resources Agency.

The results of the survey indicate that turtles in the Watts Bar Reservoir and Clinch River do accumulate PCBs and other contaminants. Using data from the fish consumption advisories for the area, PCB concentrations in turtle tissue were found at levels of concern for human consumption. But as with fish, most of the PCB contamination was found in fat tissue. Methods of food preparation, therefore, especially tissue selection, can greatly affect the amount of PCBs consumed with the turtle meat (ATSDR et al. 2000; TDEC 1997).

Summary of Joint Center for Political and Economic Studies Activities

Scarboro Community Assessment Report. In 1999, the Joint Center for Political and Economic Studies conducted a survey of the Scarboro community to identify environmental and health concerns of the residents. The surveyors attempted to elicit responses from the whole community and achieved an 82 percent response rate. Additionally, with support from DOE Oak Ridge Operations, the Joint Center has been working with the community since 1998 to help residents articulate their environmental, health, economic, and social needs. Because Scarboro is small, the community assessment provided new information not available through sources such as the U.S. Census Bureau. It also identified Scarboro's strengths and weaknesses and illustrated the relative

unimportance of environmental health issues to other community concerns. Environmental and health issues are not a priority for most Scarboro residents; rather, the community is more concerned about crime and security, children, and economic development. The Joint Center recommended more active community involvement in city and community planning (Friday and Turner 2001).

Summary of CDC Activities

Scarboro Community Health Investigation, July 2000. In November 1997, a Nashville newspaper published an article about illnesses among children living near the nuclear weapons facility at the ORR in eastern Tennessee. The article described a high rate of respiratory illness among residents of the nearby community of Scarboro—16 children had repeated episodes of "severe ear, nose, throat, stomach, and respiratory illnesses." Among those respiratory illnesses were asthma, bronchitis, sinusitis, allergic rhinitis, and otitis media. The article implied that exposure to the ORR caused these illnesses, especially given the proximity of these children's' residences to ORR facilities. In response, the TDOH Commissioner asked CDC to work with the department to investigate the Scarboro situation. TDOH coordinated the Scarboro Community Health Investigation to investigate a reported excess of respiratory illness among children in the Scarboro community; the investigation included a community health survey and a follow-up medical evaluation of children less than 18 years of age (Johnson et al. 2000). Both the survey and the examination components were designed to measure the rates of common respiratory illnesses among children who reside in Scarboro, compare these rates with national rates, and determine any unusual characteristics of these illnesses. The investigation was not designed to find what caused the illnesses.

In 1998, a study protocol was developed and a community health survey was administered to the members of each household in the Scarboro community. The purpose of the survey was to determine whether the rates of certain diseases were higher in Scarboro than elsewhere in the United States and to determine whether exposure to various factors increased residents' risk for health problems. In addition, information regarding occupations, occupational exposures, and general health concerns was collected for adults. The participation/response rate of the health investigation survey was 83 percent (220/264 households) and included 119 questionnaires about children living in these households and 358 questionnaires about adults.

In September 1998, CDC released the preliminary results of the survey. The asthma rate was 13 percent among children in Scarboro, compared with national estimates of 7 percent among all children aged 0–18 years and 9 percent among African American children aged 0–18 years. The Scarboro rate was, however, within the range of rates from 6 to 16 percent reported in similar studies throughout the United States. The wheezing rate among children in Scarboro was 35 percent, compared with international estimates ranging from 1.6 to 36.8 percent. With the exception of unvented gas stoves, no statistically significant association was found between exposure to common environmental asthma triggers and asthma or wheezing illness (Johnson et al. 2000). Common environmental asthma triggers might include pests, environmental tobacco smoke, and the presence of dogs or cats in the home. Or they might include potential occupational exposures such as living with an adult who works at the ORR or living with an adult who works with dust and fumes and brings exposed clothes home for laundering. In any event, the survey found no asthma trigger/wheezing illness link.

Using the information obtained in the health investigation survey, 36 children, including those identified in the media report, were invited to receive a physical examination. These examinations were conducted in November and December 1998 to confirm the results of the community survey, to establish whether children with respiratory illnesses were getting the medical care they needed, and to determine whether the children reported in the newspaper to have respiratory medical problems really had these problems. Children who were invited to participate met one or more conditions:

1. Severe asthma, defined as more than 3 episodes of wheezing or visiting an emergency room because of these symptoms;
2. Severe undiagnosed respiratory illness, defined as more than 3 episodes of wheezing and visiting an emergency room because of these symptoms;
3. Respiratory illness and no regular source of medical care; or
4. Identified as having respiratory illness in newspaper reports.

Of the 36 children invited, 23 participated in the physical examination. Some of the eligible 36 children had moved out of Scarboro; others either were not available or decided not to participate.

During the physical examination, nurses asked children and their parents a series of questions about the child's health. Volunteer pediatricians reviewed the results of the nurse interview and examined the children. In addition to direct physical examinations, children also underwent a blood test and a special breathing test. If the examining doctor thought the child needed an x-ray to complete the assessment, this was done. All examinations, tests, and transportation to and from Knoxville were provided free of charge.

Immediately after the examinations, the results were reviewed. None of the children had findings that needed immediate intervention. A number of laboratory tests were found to be either above or below the normal range, such as blood calcium level, blood hemoglobin level, or breathing test abnormality. Following the initial review of results, laboratory results were communicated by letter or telephone to the parents of the children and their doctors. If the parents did not want the results sent to a doctor, the results were given to the parents by telephone. The parents of children with any health concern identified as a result of the examination were sent a personal letter from Paul Erwin, M.D., of the East Tennessee Regional Office of the TDOH, informing them of the need for follow-up with their medical provider. If they did not have a medical provider, they were to contact Brenda Vowell, RNC, Public Health Nurse, East Tennessee Regional Office of the TDOH, for help in finding a provider and possible TennCare or Children's Special Service.

In January 1999, a team of physicians representing CDC, TDOH, the Oak Ridge medical community, and the Morehouse School of Medicine reviewed the findings of the physical examinations and the community survey. Of the 23 children who were examined, 22 had evidence of some form of respiratory illness (reported during the nurse interview or discovered during the doctor's examination). Overall, the children appeared healthy and no problems that needed urgent management were identified. Several children had mild respiratory illnesses at the time of the examination; only one child had findings of an abnormality of the lungs at the time of the examination. None of the children had wheezing. The examinations did not indicate any unusual pattern of illness among children in Scarboro. The illnesses that were detected were not

more severe than would be expected and were typical of those that might be found in any community. The findings of examinations essentially confirmed the results of the community health survey. The results of the review were presented on January 7, 1999, at a community meeting in Scarboro (Johnson et al. 2000).

Three months after the letters went to the parents and physicians about the findings, attempts were made to telephone the parents of children who participated. Eight parents were successfully contacted. Because some of the parents had more than one child who was examined, questions addressed the health of 14 children. Parents of nine children could not be contacted despite attempts on several days to contact them by telephone.

Of the 14 children whose parents had been contacted, seven had seen a doctor since the examinations. In most cases, the health of the child was the about the same, although one child had been hospitalized because of asthma, and another child's asthma medication had been increased to treat a worsening asthma condition. Several children had nasal allergies, and several parents mentioned difficulties in obtaining medicines because of cost and lack of coverage by TennCare for the particular medicines. Health department nurses subsequently have assisted these parents in getting the needed medicines (Johnson et al. 2000).

Appendix C. Summary Briefs and Factsheets

ATSDR's Health Consultation on the Y-12 Weapons Plant Chemical Releases Into East Fork Poplar Creek

ATSDR's Exposure Investigation, Serum PCB and Blood Mercury Levels in Consumers of Fish and Turtles from Watts Bar Reservoir

TDOH's Phase I Dose Reconstruction Feasibility Study

TDOH's Task 2 Study: Mercury Releases from Lithium Enrichment at the Oak Ridge Y-12 Plant—A Reconstruction of Historical Releases and Off-Site Doses and Health Risks

FAMU's Scarboro Environmental Study

U.S.EPA's September 2001 Sampling Report for the Scarboro Community

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

Public Health Consultation, Y-12 Weapons Plant Chemical Releases into East Fork Poplar Creek, Oak Ridge, Tennessee, April 5, 1993

Site: Oak Ridge Reservation

Conducted by: Agency for Toxic Substances and Disease Registry

Time Period: Early 1990s

Location: East Fork Poplar Creek and Floodplain Area

Purpose

The purpose of the health consultation was to evaluate published environmental data and to assess health risks associated with Y-12 Weapons Plant releases at the Oak Ridge Reservation.

Background

Between 1950 and 1963, the Department of Energy (DOE) Y-12 Weapons Plant used mercury in a lithium separation process. DOE officials estimate that 110 metric tons of mercury were released to the East Fork Poplar Creek (EFPC), and that an additional 750 metric tons of mercury used during that period could not be accounted for. Releases of mercury to the creek contaminated instream sediments, and periodic flooding contaminated floodplain soils along the creek. Land uses along the floodplain are residential, commercial, and recreational. Furthermore, residents used the sediment to enrich private gardens, and the city of Oak Ridge used creek sediment as fill material on sewer belt lines. In 1983, the state of Tennessee publicly disclosed that sediment and soil in the EFPC floodplain were contaminated with mercury. That same year, the Oak Ridge Task Force initiated remediation of public and private lands within the city of Oak Ridge.

In 1992, during Phase IA of the EFPC remedial investigation, DOE conducted preliminary sampling of soil, sediment, surface water, and groundwater from the EFPC floodplain area. During 1990 and 1991, DOE sampled for contaminants in EFPC fish through its Biological Monitoring and Abatement Program.

Study design and method

This was a health consultation conducted by the Agency for Toxic Substances and Disease Registry (ATSDR). An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, chemical release, or the presence of hazardous material. In this case, DOE requested that ATSDR comment on the health threat posed by past and present chemical releases from the Y-12 Weapons Plant to the East Fork Poplar Creek. To conduct the consultation, ATSDR evaluated DOE's preliminary environmental sampling data for metals, volatile and semivolatile organic compounds, radionuclides, and polychlorinated biphenyls (PCBs).

Health consultations may lead to specific actions, such as environmental sampling, restricting site access, or removing contaminated material, or ATSDR may make recommendations for other activities to protect the public's health.

Study group

ATSDR did not conduct a study.

Exposures

ATSDR estimated human exposure to contaminated EFPC floodplain soil, sediments, surface water, groundwater, fish, and air.

Outcome measure

ATSDR did not review health outcome data.

Results

Only mercury in soil and sediment, and PCBs and mercury in fish, are at levels of public health concern. Other contaminants, including radionuclides found in soil, sediment, and surface water, are not at levels of public health concern. Data were not available on radionuclides in fish.

Elevated levels of mercury, up to 2,240 parts per million (ppm), were found in a few soil and sediment samples from all three creek areas sampled. The mercury in the EFPC soil consisted primarily of some

relatively insoluble inorganic forms of mercury (mercury salts and metallic mercury), with less than 1% of the mercury in organic form.

Mercury Salts in Soil

The primary routes of inorganic mercury exposure for people (particularly for children) who fish, play, or walk along the creek and floodplain, are through ingestion of soil from hand-to-mouth activities and from excessive dermal exposure. Following ingestion, absorption of inorganic mercury compounds across the gastrointestinal tract to the blood is low in both people and animals. Long-term exposure to the EFPC floodplain soil containing elevated levels of mercury may result in body burdens of mercury that could result in adverse health effects. The kidney is the organ most sensitive to the effects of ingestion of inorganic mercury salts. Effects on the kidney include increased urine protein levels and, in more severe cases, a reduction in the glomerular filtration rate, which is a sign of decreased blood-filtering capacity.

Metallic Mercury in Soil

The metallic mercury vapor levels in the ambient air at the three creek areas sampled are not at levels of public health concern. However, excavation of contaminated soil may result in mercury vapor being released from the soil, especially as the air temperature increases. Such releases may increase ambient air levels of mercury vapor, which could pose a health risk to unprotected workers and the public. Once inhaled, metallic mercury vapors are readily absorbed across the lungs into the blood; however, metallic mercury is poorly absorbed through dermal and oral routes. Exposure to mercury vapor may elicit consistent and pronounced neurologic effects.

Organic Mercury in Fish

Organic mercury is the primary form of mercury found in fish. Frequent ingestion of EFPC fish over the long term may result in neurotoxic effects. Concentrations of mercury in EFPC fish samples ranged from 0.08 ppm to 1.31 ppm. Studies on the retention and excretion of mercury have shown that approximately 95% of an oral dose of organic mercury is absorbed across the gastrointestinal tract. Neurodevelopmental effects have been seen in infants following prenatal exposure via maternal ingestion of organic mercury in fish.

PCBs in Fish

Frequent and long-term ingestion of EFPC fish could result in a moderate increased risk of developing cancer. Concentrations of PCBs in EFPC fish samples ranged from 0.01 ppm to 3.86 ppm. PCBs are widely distributed environmental pollutants commonly found in blood and fat tissue of the general population. PCBs are classified as a probable human carcinogen by the U.S. Environmental Protection Agency. PCBs have been shown to produce liver tumors in mice and rats following intermediate and chronic oral exposure. Groundwater samples collected from shallow monitoring wells along the EFPC floodplain were shown to contain elevated levels of metals and volatile organic compounds. There was no evidence, however, that groundwater from shallow aquifers was being used for domestic purposes. The municipal water system, which is used by most Oak Ridge residents, receives water from Clinch River upstream of the DOE reservation.

Conclusions

In some locations along the creek, mercury levels in soil and sediment pose a threat to people (especially children) who ingest, inhale, or have dermal contact with contaminated soil, sediment, or dust while playing, fishing, or taking part in other activities along the creek's floodplain.

Mercury and PCBs were found in fish fillet samples collected from the creek. Although people who eat fish from the creek are not at risk for acute health threats, people who frequently ingest contaminated fish over a prolonged period have a moderate increased risk of (1) adverse effects to the central nervous system and kidney and (2) developing cancer.

ATSDR did not have enough information on groundwater use along the East Fork Poplar Creek to comment on the contamination of groundwater in shallow, private wells along the creek. However, contamination detected in wells along the creek does not pose a threat to people who receive municipal water.

ATSDR made the following recommendations.

- Determine the depth and extent of mercury contamination in the EFPC sediments and floodplain soil.
- As an interim measure, restrict access to the contaminated soil and sediment, or post advisories to warn the public of the hazards.
- Continue the Tennessee Department of Environment and Conservation EFPC fish advisory.
- Continue monitoring fish from the creek for the presence of mercury and PCBs.
- Complete the survey of well water use along the EFPC floodplain.
- Sample shallow private wells near the creek for PCBs, volatile organic compounds, and total and dissolved metals.

Exposure Investigation
ORRHES Brief
Oak Ridge Reservation Health Effects Subcommittee

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Exposure Investigation, Serum PCB and Blood Mercury Levels in Consumers of Fish and Turtles from the Watts Bar Reservoir, March 5, 1998

Site: Oak Ridge Reservation
Conducted by: ATSDR
Time period: 1997
Study area: Watts Bar Reservoir

Purpose

The purpose of this exposure investigation was to determine whether people consuming moderate to large amounts of fish and turtles from the Watts Bar Reservoir were being exposed to elevated levels of polychlorinated biphenyls (PCBs) or mercury.

Background

Previous investigations of the Watts Bar Reservoir and Clinch River evaluated many contaminants, but identified only PCBs in reservoir fish as a possible contaminant of current health concern. The U.S. Department of Energy (DOE) and the Tennessee Department of Environment and Conservation (TDEC) detected PCBs at levels up to approximately 8 parts per million (ppm) in certain species of fish from the reservoir. PCBs were detected in turtles at levels up to 3.3 ppm in muscle tissue and up to 516 ppm in adipose tissue. Mercury is a historical contaminant of concern for the reservoir due to the large quantities released from the Oak Ridge Reservation. However, recent studies have not detected mercury at levels of health concern in surface water, sediments, or fish and turtles from the Watts Bar Reservoir.

The 1994 DOE remedial investigation for the Lower Watts Bar Reservoir and the 1996 DOE remedial investigation for Clinch River/Poplar Creek concluded that the fish ingestion pathway had the greatest potential for adverse human health effects. The Agency for Toxic Substance and Disease Registry's (ATSDR's) 1996 health consultation of the Lower Watts Bar Reservoir reached a similar conclusion. These investigations based their conclusions on estimated PCB exposure doses and estimated excess cancer risk for people consuming large amounts of fish over an extended period of time. Fish ingestion rates, however, provide large uncertainty to these risk estimates. In addition, these estimated exposure doses and cancer risks do not consider consumption of reservoir turtles because of the uncertainties regarding turtle consumption.

ATSDR conducted this investigation primarily because of the uncertainties involved in estimating exposure doses and excess cancer risk from ingestion of reservoir fish and turtles. Also, previous investigations did not confirm that people are actually being exposed or that they have elevated levels of PCBs or mercury. In addition, a contractor for the Tennessee Department of Health (TDOH) recommended that an extensive region-wide evaluation be conducted of relevant exposures and health effects in counties surrounding the Watts Bar Reservoir. Prior to the initiation of such evaluations, ATSDR believed that it was important to determine whether mercury and PCBs were actually elevated in individuals who consumed large amounts of fish and turtles from the reservoir. Mercury was included in this exposure investigation because it was a historical contaminant of concern released from the Oak Ridge Reservation.

Study Design and Methods

This exposure investigation was cross-sectional in design as it evaluated exposures of the fish and turtle consumers at the same point in time. However, because serum PCB and mercury blood levels are indicators of chronic exposure, the results of this investigation provide information on both past and current exposure for each study participant.

Exposure investigations are one of the approaches that ATSDR uses to develop better characterization of past, present, or possible future human exposure to hazardous substances in the environment. These investigations only evaluate exposures and do not assess whether exposure levels resulted in adverse health effects. Furthermore, this investigation was not designed as a research study (for example, participants were not randomly selected for inclusion in the study and there was no comparison group), and the results of this investigation are only applicable to the participants in the study and cannot be extended to the general population.

Specific objectives of this investigation included measuring levels of serum PCBs and blood mercury in people consuming moderate to large amounts of fish or turtles, identifying appropriate health education activities and follow-up health actions, and providing new information to help evaluate the need for future region-wide assessments.

Study Group

The target population was persons who consumed moderate to high amounts of fish and turtles from the Watts Bar Reservoir. ATSDR recruited participants through a variety of means, including newspaper, radio, and television announcements, as well as posters and flyers placed in bait shops and marinas. ATSDR representatives also made an extensive, proactive attempt to reach potential participants by telephoning several hundred individuals who had purchased fishing licenses in the area.

ATSDR interviewed more than 550 volunteers. Of these, 116 had eaten enough fish to be included in the investigation. To be included in the investigation, volunteers had to report eating one or more of the following during the past year: 1 or more turtle meals; 6 or more meals of catfish and striped bass; 9 or more meals of white, hybrid, or smallmouth bass; or 18 or more meals of largemouth bass, sauger, or carp.

Exposures

Human exposures to PCBs and mercury from fish and turtle ingestion were evaluated.

Outcome Measure

Outcome measures included serum PCB and total blood mercury levels. ATSDR also collected demographic and exposure information from each participant (for example, length of residency near the reservoir; species eaten, where caught, and how prepared).

Results

The 116 participants resided in eight Tennessee counties and several other states. The mean age was 52.5 years and 58.6% of the participants were male and 41.4% were female. A high school education was completed by 65%. Eighty percent consumed Watts Bar Reservoir fish for 6 or more years, while 65.5% ate reservoir fish for more than 11 years. Twenty percent ate reservoir turtles in the last year. The average daily consumption rate for fish or turtles was 66.5 grams per day.

Serum PCB levels above 20 parts per billion (ppb) were considered elevated, and only five individuals had elevated serum PCB levels. Of the five participants with elevated PCB levels, four had levels between 20 and 30 ppb. One participant had a serum PCB level of 103.8 ppb, which is higher than levels found in the general population. None of the participants with elevated PCB levels had any known occupational or environmental exposures that might have contributed to the higher levels.

Only one participant had an elevated blood mercury level—higher than 10 ppb. The remaining participants had mercury levels up to 10 ppb, which is comparable to levels found in the general population.

Conclusions

Serum PCB levels and blood mercury levels in participants were similar to levels found in the general population.

Based on the screening questionnaire, most of the people who volunteered for the study (over 550) ate little or no fish or turtles from the Watts Bar Reservoir. Those who did eat fish or turtles from the reservoir indicated that they would continue to do so even though they were aware of the fish advisory.

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

Dose Reconstruction Feasibility Study Oak Ridge Health Study Phase I Report

Site: Oak Ridge Reservation
Study area: Oak Ridge Area
Time period: 1942–1992
Conducted by: Tennessee Department of Health and the Oak Ridge Health Agreement Steering Panel

Purpose

The Dose Reconstruction Feasibility Study had two purposes: first, to identify past chemical and radionuclide releases from the Oak Ridge Reservation (ORR) that have the highest potential to impact the health of the people living near the ORR; and second, to determine whether sufficient information existed about these releases to estimate the exposure doses received by people living near the ORR.

Background

In July 1991, the Tennessee Department of Health initiated a Health Studies Agreement with the U.S. Department of Energy (DOE). This agreement provides funding for an independent state evaluation of adverse health effects that may have occurred in populations around the ORR. The Oak Ridge Health Agreement Steering Panel (ORHASP) was established to direct and oversee this state evaluation (hereafter called the Oak Ridge Health Studies) and to facilitate interaction and cooperation with the community. ORHASP was an independent panel of local citizens and nationally recognized scientists who provided direction, recommendations, and oversight for the Oak Ridge Health Studies. These health studies focused on the potential effects from off-site exposures to chemicals and radionuclides released at the reservation since 1942. The state conducted the Oak Ridge Health Studies in two phases. Phase 1 is the Dose Reconstruction Feasibility Study described in this summary.

Methods

The Dose Reconstruction Feasibility Study consisted of seven tasks. During Task 1, state investigators identified historical operations at the ORR that used and released chemicals and radionuclides. This involved interviewing both active and retired DOE staff members about past operations, as well as reviewing historical documents (such as purchase orders, laboratory records, and published operational reports). Task 1 documented past activities at each major facility, including routine operations, waste management practices, special projects, and accidents and incidents. Investigators then prioritized these activities for further study based on the likelihood that releases from these activities could have resulted in off-site exposures.

During Task 2, state investigators inventoried the available environmental sampling and research data that could be used to estimate the doses that local populations may have received from chemical and radionuclide releases from the ORR. These data, obtained from DOE and other federal and state agencies (such as the U.S. Environmental Protection Agency, Tennessee Valley

Authority, and the Tennessee Division of Radiological Health), were summarized by environmental media (such as surface water, sediment, air, drinking water, groundwater, and food items). As part of this task, investigators developed abstracts which summarize approximately 100 environmental monitoring and research projects that characterize the historical presence of contaminants in areas outside the ORR.

Based on the results of Tasks 1 and 2, investigators identified a number of historical facility processes and activities at ORR as having a high potential for releasing substantial quantities of contaminants to the off-site environment. These activities were recommended for further evaluation in Tasks 3 and 4.

Tasks 3 and 4 were designed to provide an initial, very rough evaluation of the large quantity of information and data identified in Tasks 1 and 2, and to determine the potential for the contaminant releases to impact the public's health. During Task 3, investigators sought to answer the question: How could contaminants released from the Oak Ridge Reservation have reached local populations? This involved identifying the exposure pathways that could have transported contaminants from the ORR site to residents.

Task 3 began with compiling a list of contaminants investigated during Task 1 and Task 2. These contaminants are listed in Table 1. The contaminants in the list were separated into four general groups: radionuclides, nonradioactive metals, acids/bases, and organic compounds. One of the first steps in Task 3 was to eliminate any chemicals on these lists that were judged unlikely to reach local populations in quantities that would pose a health concern. For example, acids and bases were not selected for further evaluation because these compounds rapidly dissociate in the environment and primarily cause acute health effects, such as irritation. Likewise, although chlorofluorocarbons (Freon) were used in significant quantities at each of the ORR facilities, they were judged unlikely to result in significant exposure because they also rapidly disassociate. Also, some other contaminants (see Table 2) were not selected for further evaluation because they were used in relatively small quantities or in processes that are not believed to be associated with significant releases. Investigators determined that only a portion of contaminants identified in Tasks 1 and 2 could have reached people in the Oak Ridge area and potentially impacted their health. These contaminants, listed in Table 3, were evaluated further in Tasks 3 and 4.

The next step in Task 3 was to determine, for each contaminant listed in Table 3, whether a complete exposure pathway existed. A complete exposure pathway means a plausible route by which the contaminant could have traveled from ORR to off-site populations. Only those contaminants with complete exposure pathways would have the potential to cause adverse health effects. In this feasibility study, an exposure pathway is considered complete if it has the following three elements:

- A source that released the contaminant into the environment;
- A transport medium (such as air, surface water, soil, or biota) or some combination of these media (e.g., air → pasture → livestock milk) that carried the contaminant off the site to a location where exposure could occur; and
- An exposure route (such as inhalation, ingestion, or—in the case of certain radionuclides that emit gamma or beta radiation—immersion) through which a person could come into contact with the contaminant.

In examining whether complete exposure pathways existed, investigators considered the characteristics of each contaminant and the environmental setting at the ORR. Contaminants that lacked a source, transport medium, or exposure route were eliminated from further consideration because they lacked a complete exposure pathway. Through this analysis, investigators identified a number of contaminants with complete exposure pathways.

During Task 4, investigators sought to determine qualitatively which of the contaminants with complete exposure pathways appeared to pose the greatest potential to impact off-site populations. They began by comparing the pathways for each contaminant individually. For each contaminant, they determined which pathway appeared to have the greatest potential for exposing off-site populations, and they compared the exposure potential of the contaminant's other pathways to its most significant pathway. They then divided contaminants into three categories—radionuclides, carcinogens, and noncarcinogens—and compared the contaminants within each category based on their exposure potential and on their potential to cause health effects. This analysis identified facilities, processes, contaminants, media, and exposure routes believed to have the greatest potential to impact off-site populations. The results are provided in Table 4.

The Task 4 analysis was intended to provide a preliminary framework to help focus and prioritize future quantitative studies of the potential health impacts of off-site contamination. These analyses are intended to provide an initial approach to studying an extremely complex site. However, care must be taken in attempting to make broad generalizations or draw conclusions about the potential health hazard posed by the releases from the ORR.

In Task 5, investigators described the historical locations and activities of populations most likely to have been affected by the releases identified in Task 4. During Task 6, investigators compiled a summary of the current toxicologic knowledge and hazardous properties of the key contaminants. Task 7 involved collecting, categorizing, summarizing, and indexing selected documents relevant to the feasibility study.

Study Group

A study group was not selected.

Exposures

Seven completed exposure pathways associated with air, six completed exposure pathways associated with surface water, and ten completed exposure pathways associated with soil/sediment were evaluated for radionuclides and chemical substances (metals, organic compounds, and polycyclic aromatic hydrocarbons) released at the ORR from 1942 to 1992.

Outcome Measures

No outcome measures were studied.

Conclusions

The feasibility study indicated that past releases of the following contaminants have the greatest potential to impact off-site populations.

- **Radioactive iodine**
  The largest identified releases of radioactive iodine were associated with radioactive lanthanum processing from 1944 through 1956 at the X-10 facility.

- **Radioactive cesium**
  The largest identified releases of radioactive cesium were associated with various chemical separation activities that took place from 1943 through the 1960s.

- **Mercury**
  The largest identified releases of mercury were associated with lithium separation and enrichment operations that were conducted at the Y-12 facility from 1955 through 1963.

- **Polychlorinated biphenyls**
  Concentrations of polychlorinated biphenyls (PCBs) found in fish taken from the East Fork Poplar Creek and the Clinch River have been high enough to warrant further study. These releases likely came from electrical transformers and machining operations at the K-25 and Y-12 plants.

State investigators determined that sufficient information was available to reconstruct past releases and potential off-site doses for these contaminants. The steering panel (ORHASP) recommended that dose reconstruction activities proceed for the releases of radioactive iodine, radioactive cesium, mercury, and PCBs. Specifically they recommended that the state should continue the tasks begun during the feasibility study, and should characterize the actual release history of these contaminants from the reservation; identify appropriate fate and transport models to predict historical off-site concentrations; and identify an exposure model to use in calculating doses to the exposed population.

The panel also recommended that a broader-based investigation of operations and contaminants be conducted to study the large number of ORR contaminants released that have lower potentials for off-site health effects, including the five contaminants (chromium VI; plutonium-239, -240, and -241; tritium; arsenic; and neptunium-237) that could not be qualitatively evaluated during Phase 1 due to a lack of available data. Such an investigation would help in modifying or reinforcing the recommendations for future health studies.

Additionally, the panel recommended that researchers explore opportunities to conduct epidemiologic studies investigating potential associations between exposure doses and adverse health effects in exposed populations.

TABLE 1

LIST OF CONTAMINANTS INVESTIGATED DURING TASK 1 AND TASK 2

X-10	K-25	Y-12
Radionuclides		
Americium-241 Argon-41 Barium-140 Berkelium Californium-252 Carbon-14 Cerium-144 Cesium-134,-137 Cobalt-57,-60 Curium-242,-243,-244 Einsteinium Europium-152,-154,-155 Fermium Iodine-129, -131, -133 Krypton-85 Lanthanum-140 Niobium-95 Phosphorus-32 Plutonium-238, -239, -240, -241 Protactinium-233 Ruthenium-103, -106 Selenium-75 Strontium-89, -90 Tritium Uranium-233,-234, -235, -238 Xenon-133 Zirconium-95	Neptunium-237 Plutonium-239 Technetium-99 Uranium-234, -235, -238	Neptunium-237 Plutonium-239, -239, -240, -241 Technetium-99 Thorium-232 Tritium Uranium-234, -235, -238
Nonradioactive Metals		
None initially identified	Beryllium Chromium (trivalent and hexavalent) Nickel	Arsenic Beryllium Chromium (trivalent and hexavalent) Lead Lithium Mercury
Acids/Bases		
Hydrochloric acid Hydrogen peroxide Nitric acid Sodium hydroxide Sulfuric acid	Acetic acid Chlorine trifluoride Fluorine and fluoride compounds Hydrofluoric acid Nitric acid Potassium hydroxide Sulfuric acid	Ammonium hydroxide Fluorine and various fluorides Hydrofluoric acid Nitric acid Phosgene
Organic Compounds		
None initially identified	Benzene Carbon tetrachloride Chloroform Chlorofluorocarbons (Freons) Methylene chloride Polychlorinated biphenyls 1,1,1-Trichloroethane Trichloroethylene	Carbon tetrachloride Chlorofluorocarbons (Freons) Methylene chloride Polychlorinated biphenyls Tetrachloroethylene 1,1,1-Trichloroethane Trichloroethylene

TABLE 2

CONTAMINANTS NOT WARRANTING FURTHER EVALUATION IN TASK 3 AND TASK 4

Radionuclides
Americium-241
Californium-252
Carbon-14
Cobalt-57
Cesium-134
Curium-242, -243, -244
Europium-152, -154, -155
Phosphorus-32
Selenium-75
Uranium-233
Berkelium
Einsteinium
Fermium
Nonradioactive Metals
Lithium
Organic Compounds
Benzene
Chlorofluorocarbons (Freons)
Chloroform
Acids/Bases
Acetic acid
Ammonium hydroxide
Chlorine trifluoride
Fluorine and various fluoride compounds
Hydrochloric acid
Hydrogen peroxide
Hydrofluoric acid
Nitric acid
Phosgene
Potassium hydroxide
Sulfuric acid
Sodium hydroxide

TABLE 3

CONTAMINANTS FURTHER EVALUATED IN TASK 3 AND TASK 4

Radionuclides	Nonradioactive Metals	Organic Compounds
Argon-41	Arsenic	Carbon tetrachloride
Barium-140	Beryllium	Methylene chloride
Cerium-144	Chromium (trivalent and hexavalent)	Polychlorinated biphenyls
Cesium-137	Lead	Tetrachloroethylene
Cobalt-60	Mercury	1,1,1-Trichloroethane
Iodine-129, -131, -133	Nickel	Trichloroethylene
Krypton-85		
Lanthanum-140		
Neptunium-237		
Niobium-95		
Plutonium-238, -239, -240, -241		
Protactinium-233		
Ruthenium-103, -106		
Strontium-89, 90		
Technetium-99		
Thorium-232		
Tritium		
Uranium-234 -235, -238		
Xenon-133		
Zirconium-95		

TABLE 4

HIGHEST PRIORITY CONTAMINANTS, SOURCES, TRANSPORT MEDIA, AND EXPOSURE ROUTES

Contaminant	Source	Transport Medium	Exposure Route
Iodine-131, -133	X-10 Radioactive lanthanon (RaLa) processing (1944-1956)	Air to vegetable to dairy cattle milk	Ingestion
Cesium-137	X-10 Various chemical separation processes (1944-1960s)	Surface water to fish Soil/sediment Soil/sediment to vegetables; livestock/game (beef); dairy cattle milk	Ingestion Ingestion Ingestion
Mercury	Y-12 Lithium separation and enrichment operations (1955-1963)	Air Air to vegetables; Livestock/game (beef); dairy cattle milk Surface water to fish Soil/sediment to livestock/game (beef); vegetables	Inhalation Ingestion Ingestion Ingestion
Polychlorinated biphenyls	K-25 and Y-12 Transformers and machining	Surface water to fish	Ingestion

Mercury Releases from Lithium Enrichment at the Oak Ridge Y-12 Plant—a Reconstruction of Historical Releases and Off-Site Doses and Health Risks, Reports of the Oak Ridge Dose Reconstruction, Vol. 2, July 1999 (Task 2 Report)

Site: **Oak Ridge Reservation**

Conducted by: **ChemRisk/ORHASP for the Tennessee Department of Health**

Time Period: **1950–1990**

Purpose

The purpose of the Task 2 study was to conduct a detailed investigation of potential off-site doses and health risks from historical releases of mercury from the Y-12 plant on the Oak Ridge Reservation (ORR) in Oak Ridge, Tennessee. Specifically, the study quantified past mercury releases from the Y-12 plant, characterized environmental concentrations from these releases, defined potential pathways of human exposure in neighboring communities, and estimated human exposure doses and human health hazards between 1950 and 1990.

Background

In July 1991, the Tennessee Department of Health in cooperation with the U.S. Department of Energy initiated a Health Studies Agreement to evaluate the potential for exposures to chemical and radiological releases from past operations at the ORR. The Oak Ridge Does Reconstruction Feasibility Study, conducted in 1992–1993, recommended that dose reconstructions be conducted for several contaminants with potential negative health effects, including mercury releases from the Y-12 plant.

The ORR is located in eastern Tennessee, approximately 25 miles west-northwest of Knoxville. The Y-12 plant was built in 1945 as part of the Manhattan Project. Located at the eastern end of Bear Creek Valley, the Y-12 plant is within the corporate limits of the city of Oak Ridge and is separated from the main residential areas of the city by Pine Ridge. The East Fork Poplar Creek (EFPC) originates from a spring beneath the Y-12 plant and flows northeasterly through the plant and through residential and commercial sections of the city of Oak Ridge.

From the early 1950s to the early 1960s, the Y-12 plant released large quantities of mercury into the environment. These releases resulted from lithium enrichment operations using a process known as Colex (column-based exchange process), during which lithium isotopes are separated by transferring them between water-based solutions of lithium hydroxide and lithium in mercury. Between the early 1950s, when two large-scale production facilities were built, and 1962, when production of enriched lithium ceased, approximately 24 million pounds of mercury were used. During this time, the Y-12 plant released mercury to the air and surface water; more than 200 individual Y-12 waste water outfalls drained into EFPC.

In response to public concern over the potential for adverse health effects from mercury exposure, Y-12 mercury emissions and contamination of off-site environments have been investigated. EFPC has been routinely sampled and analyzed for mercury since 1953, producing what might be the longest record of mercury release from any site in the world. Additional investigations of the off-site environment beginning around 1970, showed high concentrations of mercury in soils, sediments, and fish downstream from the Y-12 plant. For example, in 1983, members of the Mercury Task Force conducted an analysis of Y-12 quantified mercury releases; which acted as the foundation for the Task 2 investigation.

Methods

The project team's review of mercury releases and environmental concentrations began with an examination of records assembled by members of the 1983 Mercury Task Force. However, the Task 2 investigation differed from the 1983 Mercury Task Force in that it 1) conducted a more thorough records review; 2) verified data used to calculate historical mercury releases and adjusted the variables used to estimate mercury releases, including ventilation rates, air and water concentrations, and water flow rates; and 3) revised mercury release estimates.

Additionally, the Task 2 team estimated mercury concentrations—including elemental mercury (the dominant form in air), inorganic mercury (the dominant form in water, soil, and food), and organic mercury or methylmercury (the dominant form in fish)—in different environmental media:

- The Task 2 team estimated mercury concentrations in the waters of EFPC at locations downstream from the Y-12 plant between 1950 and 1990, based on independently verified measurements of concentrations and flow rates. These estimates accounted for downstream reductions in concentrations due to dilution by additional water and mercury loss to other media (e.g., adherence to sediment and volatilization to air).

- The Task 2 team calculated mercury concentrations in air based on estimates of annual releases from Y-12 between 1953 and 1962. Estimates of mercury concentrations in air focused on the Wolf Valley and Scarboro communities and were based on wind direction and proximity to the Y-12 plant, respectively. Mercury concentrations in air were further examined through measurements of mercury in tree rings of red cedars growing in the EFPC floodplain, and by modeling the volatilization of mercury from EFPC and the dispersion of mercury in air to neighboring communities.

- The Task 2 team estimated concentrations of mercury in soil and EFPC sediment for multiple populations based on sampling conducted as part of the EFPC Floodplain Remedial Investigation in 1991–1992. Mercury concentration estimates included adjustment factors to account for higher concentrations in the past than during more recent data collection. Additional soil concentration data were based on limited soil sampling conducted in Scarboro by Oak Ridge Associated Universities in 1984.

- The Task 2 team also estimated concentrations of mercury in edible plants using measurements of airborne mercury deposition to vegetation (samples collected near the city of Oak Ridge in the late 1980s) and transfer of mercury from soil to below-ground vegetables and pasture grass (measurements collected in the Oak Ridge area in the mid-1980s and in 1993). The project also estimated the transfer of mercury to milk and meat after intake by cattle based on studies from the literature.

- Finally, the Task 2 team estimated historical annual consumption of fish collected from EFPC and from locations downstream, including the Clinch River, Poplar Creek, and Watts Bar Reservoir, from 1950 to 1990. Estimates were based on measured mercury concentrations in fish collected after 1970, mercury concentrations measured in fish at other sites with comparable mercury levels in water and sediments, studies of possible mercury content in live fish, and data from sediment cores collected during the mid-1980s.

Based on historical and current environmental measurements, Task 2 estimated mercury doses through all applicable exposure pathways to off-site populations who lived near the Y-12 plant between 1950 and 1990. Dose estimates were also based on historical release information, demographic data, and published information on rates of intake—either deliberate or incidental—of air, water, soil, and food. Exposure doses to mercury in fish were evaluated based on the number of fish meals consumed per year: >1 to 2.5 meals/week (category 1), >0.33 to 1 meal/week (category 2), and 0.04 to 0.33 meal/week (category 3). The Task 2 team used established toxicity benchmark values for comparison with estimated doses, including U.S. Environmental Protection Agency (EPA) reference doses (RfDs), Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs), and lowest or no observed adverse effects levels (LOAELs or NOAELs).

Exposures

The Task 2 team considered multiple exposure routes that were most likely to contribute to human exposure to mercury, including:

- Inhalation of contaminated air due to direct releases from the Y-12 plant and volatilization from EFPC.

- Dermal contact with contaminated surface water from EFPC.

- Incidental ingestion of contaminated surface water from EFPC.

- Consumption of contaminated fish found in EFPC, the Clinch River, Poplar Creek, and the Watts Bar Reservoir.

- Dermal contact with contaminated sediment and floodplain soil from EFPC.

- Incidental ingestion of contaminated soil.

- Consumption of homegrown fruits and vegetables contaminated by mercury in the air and/or soil.

- Consumption of beef tissue and/or milk due to local cattle consumption of pasture grass contaminated by mercury in the air, soil, and/or surface water.

Study Subjects

Multiple populations live in proximity to the Y-12 plant, as well as along EFPC, which flows through residential and commercial sections of the city of Oak Ridge. The Task 2 team identified six off-site populations who could potentially be exposed to mercury via one or more of the exposure pathways identified above:

- Oak Ridge community residents who lived near the EFPC floodplain may have been exposed to mercury from the air or garden-grown produce.

- Scarboro community residents, located approximately one-third mile north of the ORR border, may have been exposed to mercury from various sources due to air, water, sediment, and/or fish contamination. Scarboro has historically been the closest residential area to the Y-12 plant.

- Students at the Robertville Junior High School, located along the banks of EFPC, may have been exposed to mercury from air, water, sediment, and/or soil contamination.

- Residents of the Wolf Valley area, approximately 5 miles downwind from the Y-12 plant, may have been exposed to mercury in direct airborne releases from the plant.

- Residents who lived and farmed along the EFPC floodplain may have been exposed to mercury from contaminated air, garden-grown produce, dairy cattle, water, sediment, and/or fish.

- The angler population who caught and consumed fish from waterways downstream from the Y-12 plant, including EFPC, Poplar Creek, the Clinch River, and the Watts Bar Reservoir may have been exposed to mercury in the fish.

The size of potentially affected populations varied greatly. During the Task 2 period of study, the early 1950s to early 1990s, the angler fishing population was estimated to be less than 100 individuals. However, the population size of the Oak Ridge community was estimated between 15,000 and 30,000 individuals.

Results

Mercury releases from the Y-12 plant to the air and the EFPC were found to be greater than previously estimated by the 1983 Mercury Task Force. The Task 2 team estimated that the Y-12 plant released approximately 73,000 pounds of mercury to the air during the period of enriched lithium production (1953–1962) and 280,000 pounds of mercury to the EFPC from 1950 to

1993—an increase of 43 and 18 percent, respectively, more than the estimates of the 1983 Mercury Task Force.

The Task 2 team assessed doses based on the type and route of mercury exposure:

- ***Air (elemental mercury):*** The 95% upper confidence limit (UCL) for the estimated elemental mercury doses from inhalation exceeded the RfD for Scarboro community children during the mid- to late-1950s and for EFPC floodplain families (adults and children) during the mid-1950s to early 1960s. During all years, estimated doses for Scarboro residents were between 10 and 40 percent of the inhalation doses estimated for farm families along the EFPC floodplain. This difference is due to the closer proximity of EFPC floodplain residents to the creek. Average elemental mercury doses for all populations during all years did not exceed the NOAEL.

- ***Ingestion and contact (inorganic mercury):*** Estimated 95% UCL total inorganic mercury doses, from all pathways except inhalation and fish consumption, exceeded the RfD during the mid- to late- 1950s at all communities of concern for at least one year. Average inorganic mercury doses for all populations during all years did not exceed the NOAEL. At five of the six locations, excluding the Robertsville School, estimated doses were largely contributed to by ingestion of contaminated homegrown produce.

  For residents living in the EFPC floodplain, estimated doses also exceeded the RfD through the mid-1960s and early-1970s, particularly for children. Doses to these individuals were estimated to be high because they were assumed to live close to EFPC on the edge of the floodplain and to be exposed through multiple pathways, including consumption of contaminated produce, contact with surface water and soil, etc. Although the EFPC floodplain farm family population was relatively small, between 10 and 50 individuals per year, it is likely that mercury doses to some individuals posed a potential health risk.

- ***Ingestion of fish (methylmercury):*** Estimated 95% UCL methylmercury doses from consumption of fish exceeded the methylmercury RfD (based on *in utero* exposure) at all locations. Depending on the number of fish meals per week, estimated doses exceeded the RfD for several years in the 1950s and 1960s (category 3: 0.04-0.33 meal/week) to all years of examination, 1950-1990 (category 1: >1-2.5 meals/week). At Watts Bar Reservoir, Clinch River, and Poplar Creek, estimated doses for category 1 fish consumers exceeded the RfD even at the lower bound of the annual average dose (2.5^{th} percentile) during multiple years. Estimated doses for fish consumption also exceeded the NOAEL for methylmercury (based on *in utero* exposure) for category 1 consumers from the Watts Bar Reservoir (1956–1960) and for all categories of consumers from the Clinch River and Poplar Creek (category 1: 1950–1975, category 2: 1950–1964, category 3: 1957).

For all exposure pathways of interest, the highest annual average mercury doses are estimated to have occurred during the mid- to late-1950s. These were the years of highest releases of mercury from the Y-12 plant to the air and EFPC. Overall, estimated total mercury doses to farm families who lived near the EFPC floodplain, particularly children, are the highest of all evaluated exposure populations due to their proximity to the creek. The estimated doses are due

predominantly to a combination of inhalation of volatilized mercury from EFPC and consumption of locally grown fruits and vegetables contaminated from airborne mercury. Estimated total doses for other populations are lower. For example, highest estimated doses for Wolf Valley and Scarboro community residents are 30- to 40-times and 9-times lower, respectively, than the highest doses estimated for farm families living near the EFPC floodplain. Estimated methylmercury doses to fish consumers are also relatively high. Estimated doses for residents consuming fish from the Clinch River and Poplar Creek were about 4-fold higher than doses for consumers eating fish from the Watts Bar Reservoir.

Conclusions

Estimates of mercury releases previously reported by the 1983 Mercury Task Force were incomplete and have been revised by the Task 2 team to reflect larger historic releases of mercury to the air and surface water than previously thought.

Based on dose reconstructions, multiple exposure pathways may have resulted in exposures to mercury at potentially harmful annual average doses. Specifically, the Task 2 report highlights several high exposure-risk activities:

- Consumption of any fish from EFPC, the Clinch River, or Poplar creek, and consumption of more than 3–4 meals of fish per year from the Watts Bar Reservoir, during the mid- to late-1950s. These limits on fish consumption are based on childhood methylmercury exposure.

- Consumption of fruits or vegetables that grow above-ground from backyard gardens in the Scarboro community or within several hundred yards of the EFPC floodplain.

- Recreational use of EFPC (e.g., fishing and wading) for more than 10–15 hours per year.

- Living or attending school within several hundred yards of the EFPC floodplain or in the Scarboro community (from inhalation of airborne mercury). The highest estimated elemental (airborne) mercury doses were for children living in these communities.

While multiple exposure pathways may have resulted in mercury intake above the RfDs, the likelihood of this was greatest during the period of highest mercury releases from the Y-12 plant in the mid-1950s to early 1960s.

Furthermore, results show that the annual average doses through some exposure pathways were likely insignificant, given the distance from contamination sources, small populations sizes, and/or low ingestion rates, even during the years of highest mercury releases from the Y-12 plant. Based on this information, the Task 2 team concluded that the following behaviors were not likely to have resulted in exposure to mercury at annual average doses above RfDs:

- Consumption of beef from cattle that grazed in downwind/downstream from the Y-12 plant,

- Consumption of produce from backyard gardens located more than one mile from the EFPC floodplain (excluding the Scarboro community in the 1950s and early 1960s), and

- Living or attending school more than one mile from the EFPC floodplain (excluding the Scarboro community in the 1950s and early 1960s).

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

Scarboro Environmental Study

Site: Oak Ridge Reservation

Conducted by: Environmental Sciences Institute at Florida Agricultural and Mechanical University, Environmental Radioactivity Measurement Facility at Florida State University, Bureau of Laboratories of the Florida Department of Environmental Protection, Jacobs Engineering, DOE subcontractors in the Neutron Activation Analysis Group at Oak Ridge National Laboratory

Time Period: 1998

Location: Scarboro, Tennessee

Purpose

The purpose of the study was to address community concerns about environmental monitoring in the Scarboro neighborhood.

Background

This study was conducted in response to Scarboro community residents' concern about the validity of measurements taken at air monitoring station 46 located in the Scarboro community and external radiation results from past aerial surveys.

The study was designed to incorporate community input and meet the requirements of an EPA investigation of this type. The analytical component of the study was conducted by the Environmental Sciences Institute at Florida Agriculture and Mechanical University (FAMU) and its contractual partners at the Environmental Radioactivity Measurement Facility at Florida State University and the Bureau of Laboratories of the Florida Department of Environmental Protection, and by DOE subcontractors in the Neutron Activation Analysis Group at the Oak Ridge National Laboratory.

Method

Soil, sediment and surface water samples were collected in the Scarboro neighborhood and analyzed for mercury, radionuclides, and organic and inorganic compounds. Initial radiological walkover surveys were conducted to identify hot spots prior to sample collection, and some samples were collected from these areas with the highest radiological counts.

A total of 48 samples were collected; 40 were surface soil samples (within top 2 inches) and 8 were sediment/surface water samples. All samples were analyzed for mercury, gross alpha/beta content, uranium, and gamma emitting radionuclides. Gross alpha-beta content was conducted to screen samples for further analysis. Gamma-ray spectroscopy measurements were made to check for the presence of naturally occurring and man made radionuclides. Neutron activation analysis was used to analyze all soil and sediment samples for uranium isotopes (U-238 and U-235).

Approximately 10% of the samples collected (4 soil, 1 sediment and 1 surface water sample) were tested for the presence of analytes on the target compound list (TCL), the target analyte list (TAL), and Strontium-90. Alpha spectroscopy was also used to test these samples for isotopes of uranium, plutonium, and thorium.

To determine whether a sample measurement was within normal background levels, the value was compared to the 95th percentile of the distribution of results obtained in the Background Soils Characterization Project (BSCP) study. Scarboro data were specifically compared to results from the Chickamauga Bethel Valley group in the BSCP study because this geologic formation best approximates the geologic formation underlying the Scarboro community.

[1] The 95th percentile value is the value at or below which 95% of the samples fall in a distribution. For example, if 100 soil samples were collected and tested for mercury, and the 95th percentile value was found to be 0.5 parts per billion (ppb), 95 of the samples would have a value of 0.5 ppb or less.

Study Subjects

No groups were studied.

Exposures

Exposures studied included mercury, gamma-ray emitting radionuclides, TCL organics, TAL inorganics, Strontium-90, and uranium, thorium, and plutonium isotopes.

Outcome Measures

Health outcomes were not studied.

Results

Mercury: Mercury values in the Scarboro soil samples ranged from 0.021 milligrams per kilogram (mg/kg) to 0.30 mg/kg, with a median value of 0.11 mg/kg. Two samples (192 S. Benedict Ave and Parcel 570, Wilberforce) exceeded the 95th percentile value for mercury for the Bethel Valley Chickamauga Group, but were less than the 95th percentile for the K-25 Chickamauga Group.

Mercury was not detected in surface water samples. Mercury values in Scarboro sediment ranged from 0.018 mg/kg to 0.12 mg/kg. Comparison of sediment values to BSCP data was not possible.

Gamma-ray spectroscopy measurements: Most gamma-ray emitting radionuclides fell within the range of expected values. In a few cases the radioisotopes U-238 (Th-234) and U-235 exceeded the 95th percentile values for the BSCP formations; however, the mean values for U-235 and U-238 were within one standard deviation of the BSCP medians. This means that, on average, it is unlikely that uranium was present in Scarboro soil at elevated concentrations.

Uranium Isotopic Analysis by Neutron Activation Analysis: The average Uranium-238 value (1.39 PicoCurie per microgram (pCi/µg) for the Scarboro samples fell within the range of values determined by both alpha spectroscopy and gamma-ray spectroscopy in the BSCP study. The mean ratio of uranium-235 to uranium-238 was 0.0093 + 0.0021. Five soil samples (4 in Parcel 570, and 117/119 Spellman Ave) contained U-235/U-238 weight ratios greater than might be expected, suggesting enrichment in uranium-235.

10% samples: Antimony, selenium, silver, sodium and thallium were rarely detected in any of the samples. Lead and zinc concentrations in one soil sample (117/119 Spellman Avenue) exceeded the 95th percentile for all BSCP geologic formations.

The pesticides alpha-chlordane (1700 ppb), gamma-chlordane (2800 ppb), heptachlor (190 ppb), and heptachlor epoxide (970 ppb) were detected in one soil sample (117/119 Spellman Avenue). No other organic contaminants were detected in Scarboro samples.

The maximum Strontium-90 value fell within the 95th percentile from the BSCP study.

Using alpha-spectroscopy analysis, most of the concentrations and ratio values for uranium, thorium, and plutonium isotopes were within expected ranges when compared to results from the BSCP study. However, one soil sample (117/119 Spellman Avenue) showed enrichment of both U-234 and U-235 relative to U-238.

Conclusions

Mercury concentrations measured in this study ranged from 0.021 mg/kg to 0.30 mg/kg. These values are generally within the range of values given in the BSCP report.

Radionuclide results including total uranium concentrations were within expected ranges. However, approximately 10% of soil samples showed evidence of enrichment in uranium-235.

One of 6 samples contained organic compounds on the TCL (alpha- and gamma-chlordane, heptachlor and heptachlor epoxide) above detection limits. In this same sample, lead and zinc concentrations exceeded typical values obtained in the BSCP study by a factor of two.

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief
Oak Ridge Reservation Health Effects Subcommittee

September 2001 Sampling Report for the Scarboro Community, Oak Ridge, Tennessee, April 2003

Site: Oak Ridge Reservation
Conducted by: U.S. EPA
Time Period: 2001
Location: Scarboro, Tennessee

Purpose

The purpose of the U.S. Environmental Protection Agency (EPA) sampling event was to re-sample 20% of the sampling locations investigated by the Environmental Sciences Institute at Florida Agricultural and Mechanical University (FAMU) for the U.S. Department of Energy (DOE) in 1998. The results of these samples were to be compared to those collected by FAMU. By comparing the results, EPA would:

- Verify the 1998 chemical, metal, and radiological data collected and analyzed by DOE,
- Identify any substance(s) not analyzed by DOE and evaluate those analytical data gaps,
- Determine the source(s) of uranium and other radionuclides, and
- Evaluate whether unreasonable risk to human health may be present.

Background

Beginning in 1997, the Scarboro Chapter of the National Association for the Advancement of Colored People (NAACP) contacted EPA with concerns that the Scarboro community was possibly being exposed to emissions from the Y-12 plant located at DOE's Oak Ridge Reservation (ORR). They were concerned that the community could be experiencing negative health impacts.

In May 1998, DOE responded to the concerns of the citizens by contracting with FAMU to conduct the *Scarboro Community Environmental Study*. FAMU and its contractual partners at the Environmental Radioactivity Measurement Facility at Florida State University, the Bureau of Laboratories of the Florida Department of Environmental Protection, and the Neutron Activation Analysis Group at the Oak Ridge National Laboratory collected and analyzed samples from 48 locations in the Scarboro community. Forty soil and eight sediment and/or surface water samples were collected. The results of the *Scarboro Community Environmental Study* were released in September 1998. However, EPA states they did not receive the DOE sampling and analysis plan for review prior to its implementation nor was EPA able to participate in or observe the FAMU and DOE field sampling. Therefore, to verify the FAMU and DOE's sampling, EPA developed a draft sampling plan, *EPA Proposed Sampling and Analysis Plan for the Scarboro Community*, in July 1999, and presented it to the Oak Ridge Site Specific Advisory Board at its September 1, 1999, meeting. The EPA solicited and received comments from the Oak Ridge community-at-large.

Methods

On September 25, 2001, representatives of the EPA (specifically, Region 4, Science and Ecosystem Division (SESD), Enforcement Investigation Branch (EIB) personnel) collected a total of 10 environmental samples from eight separate properties within the Scarboro community. Six surface soil samples (6 inch interval), two sediment samples, and two surface water samples were collected from nine separate locations (two samples were collected at one

of the eight properties). Additionally, at the request of local residents, core soil samples (12 inch interval) were taken from two locations to determine the depth at which uranium is present. Sample sites were selected based on:

- The May 1998 DOE study,
- Reconnaissance performed in February 23, 1999, by SESD-EIB personnel,
- Information gathered during the February 1999 and September 2001 public meetings held in Oak Ridge, and
- Professional judgment regarding where an unreasonable risk to human health might be found, if such were to exist.

All samples were collected and handled in accordance with the EPA, Region 4, SESD's *Environmental Investigations Standard Operating Procedures and Quality Assurance Manual*, May 1, 1996. Surface soil was collected using a pre-cleaned 3-inch diameter stainless steel hand auger from the interval of 0-6 inches. Core samples were taken at a depth of 0-12 inches to determine the presence of uranium. Samples for volatile organic compounds (VOCs) were not homogenized prior to being placed in the sample container. Because wading was possible in each surface water body, surface water samples were collected directly into the sample container, prior to taking sediment samples. Surface water samples were not filtered in the field. Sediment samples were collected with a stainless steel scoop or spoon and were homogenized.

The samples were analyzed by the EPA National Air and Radiation Environmental Laboratory (NAREL) located in Montgomery, Alabama, for the following contaminants: radionuclides, metals (including mercury), VOCs, semi-volatile organic compounds (SVOCs), pesticides, and polychlorinated biphenyls (PCBs). In order to evaluate the presence of lithium in the samples, the laboratory Lithium Internal Standard for trace metal analysis was used as evidence that there is little, if any, lithium present in the samples collected by EPA.

In addition, personnel from the EPA, Region 4, Office of Technical Services conducted a radiation walkover (a qualitative screening) of the areas selected for sampling to determine whether radiation existed above background levels. The survey was performed using a sodium iodide detector and GM Pancake probe to identify the presence of uranium isotopes and other gamma-emitting isotopes.

Study Subjects: No groups were studied.

Exposures: No exposures were studied.

Outcome Measures: Health outcomes were not studied.

Results: To evaluate the results of the analytical sampling EPA used the following guidance and standards:

- Under the *Safe Drinking Water Act (SDWA)* standards were created to control the level of contaminants that are in drinking water. EPA used this guidance for the surface water samples that were collected. Maximum contaminant limits (MCLs) are legally enforceable health protective standards (National Primary Drinking Water Standards). National Secondary Drinking Water Standards (NSDWS) are non-enforceable standards that provide guidance on cosmetic effects a contaminant might have on the quality of the water.
- *Preliminary Remediation Goals (PRGs)* are risk-based values used for screening soil and sediment samples at contaminated sites. The PRG is a number that represents the lowest risk level of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) protective risk range (1×10^{-6} to 1×10^{-4}) for cancer effects. For non-cancer effects the PRG represents the Hazard Index (HI) value of 1.0 (see next bullet).
- The *Hazard Quotient/Hazard Index (HQ/HI)* is a ratio of the exposure level for a single toxic substance to the reference dose of that substance over the same exposure period.

The HI is the sum of all HQ values from all toxic substances that a person is exposed to from a common source. A HQ or HI less than 1.0 indicates that the exposure is not sufficient to yield a health concern for a lifetime (70 years) of daily exposure.

- *Gamma Spectroscopy* was used as a screen to analyze gamma-emitting isotopes which indicate radioactive decay.

- *Gross Alpha/Gross Beta* levels were used as a screen to determine if individual radionuclides should be sampled.

Radionuclides

The qualitative walkover screening did not detect radiation above background levels. None of the radionuclide analytical values exceeded normal background levels, MCLs, or PRGs. The two core samples collected from 0 to 12 inches below the ground surface indicate that uranium levels are below the PRG or background levels within the U.S.

The uranium results indicated that there was uncertainty associated with uranium enrichment due to the uranium isotope levels being at either background levels and/or detection limits. However, even if there is potentially some uranium enrichment in the uranium isotopes in the Scarboro soil and sediment, the actual levels of uranium isotopes are still within the U.S. and Oak Ridge background ranges.

Lithium. The laboratory results could not support a positive presence of lithium in the samples collected by EPA. The evidence indicates there is little, if any, lithium present in the samples.

Metals

All metals, including mercury, in the surface water, sediment, and soil samples were undetected or below MCLs, NSDWS, or PRGs with the following exceptions:

- *Aluminum.* The NSDWS of 50-200 µg/L for aluminum was exceeded in both surface water samples (1,030 µg/L and 1,640 µg/L).

- *Arsenic.* The PRG of 0.39 mg/kg for arsenic was exceeded in both sediment samples (1.62 mg/kg and 5.17 mg/kg) and four soil samples (5.64 mg/kg, 3.66 mg/kg, 4.68 mg/kg, and 6.39 mg/kg).

- *Iron.* The NSDWS of 300 µg/L for iron was exceeded in both surface water samples (769 µg/L and 1,160 µg/L). The PRG of 23,000 mg/kg for iron was exceeded in three soil samples (23,100 mg/kg, 25,400 mg/kg, and 25,400 mg/kg).

- *Manganese.* The NSDWS of 50 µg/L for manganese was exceeded in one of the surface water samples (65.5 µg/L). The PRG of 1,800 mg/kg for manganese was exceeded in one soil sample (1,930 mg/kg).

VOCs and SVOCs

No VOCs were detected in the surface water samples. The following VOCs were detected in the soil and/or sediment samples: cyclotetrasiloxane, benzoic acid, acetic acid, 1R-alpha-pinene, and dodecane. The following SVOCs were detected in the surface water, soil, or sediment samples: butyl benzyl phthalate, di-n-butyl phthalate, and dibutyl phthalate. These VOCs and SVOCs are generally attributed to sampling and/or laboratory activities and are not considered to be related to the ORR or the Scarboro area.

Pesticides and PCBs

All pesticides and PCBs in the surface water, sediment, and soil samples were undetected or below MCLs, NSDWS, or PRGs with the following exceptions:

Alpha-chlordane and gamma-chlordane were detected in one sediment sample (0.50 J µg/kg and 0.75 J µg/kg, respectively). Alpha-chlordane was detected in two soil samples (11 µg/kg and 14 µg/kg). Gamma-chlordane was also detected in two soil samples (12 µg/kg and 30 µg/kg). Heptachlor was detected in one soil sample (13 µg/kg). Heptachlor epoxide was detected in one soil sample (11 µg/kg).

Conclusions

EPA stated that the results of the analysis did not reveal any chemicals or radionuclides at levels that warrant a health or environmental concern.

- The level of radiation was below background levels and the radionuclide analytical values did not indicate a level of health concern. Uranium levels in the core soil samples were also below background levels. There is no indication that lithium was present in the analyzed samples at levels that would warrant health concern.

- Aluminum, iron, and manganese are naturally occurring in the geologic formations of the Oak Ridge area, indicating that these are not related to releases from DOE operations. Regardless, they are not present at levels of health hazard.

- Arsenic has both carcinogenic and noncarcinogenic health effects. The HI value for arsenic indicates that an assumed exposure level could be above the protective level for noncarcinogenic effects. However, the value did not exceed the CERCLA protective risk range (1×10^{-4}) for its carcinogenic effects.

- The detected VOCs and SVOCs are plasticizers, solvents, softening agents, and/or column artifacts and their presence is generally attributed to sampling and/or laboratory activities. Therefore, they are not considered to be site related and no further evaluation was conducted.

- The presence of pesticides indicates possible past use by the homeowner/resident. They are not considered to be site related and no further evaluation was conducted.

The results of both the EPA and DOE sampling effort are consistent in their findings. These results confirm that existing soil, sediment, and surface water quality pose no risk to human health within the Scarboro community. There is not an elevation of chemical, metal, or radionuclides above a regulatory health level of concern. The Scarboro community is not currently being exposed to substances from the Y-12 facility in quantities that pose an unreasonable risk to health or the environment. The EPA does not propose to conduct any further environmental sampling in the Scarboro community.

If additional environmental information becomes available, EPA proposes that the following recommendations be implemented:

1. DOE should develop a written procedure to receive citizen and community complaints regarding discharges, emissions, or other releases originating from the ORR. The procedure should identify and provide for a timely response and follow-up action. Additionally, DOE should develop a communication strategy to inform the residents and other community members or stakeholders of its findings.

2. If additional environmental information becomes available regarding Scarboro that warrants an investigation by DOE, the sampling plan, if developed, should be reviewed and approved by the EPA and the Tennessee Department of Environment and Conservation (TDEC), as regulatory oversight agencies to the Federal Facility Agreement (FFA).

3. Any future health investigations conducted by DOE of the impacts of its operations on the Scarboro or the greater Oak Ridge community should be coordinated with the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) of the Agency for Toxic Substances and Disease Registry (ATSDR).

4. Upon the release of recommendations by the ORRHES to the ATSDR, DOE, EPA, and TDEC with stakeholder involvement will scope the off-site (off DOE reservation) operable unit. The results of this activity will be the preparation of a Preliminary Assessment/Site Inspection, which is currently planned for September 30, 2005. This commitment is a DOE FFA milestone.

Appendix D. Toxicologic Implications of Mercury Exposure

ATSDR's toxicological profiles (ToxProfiles) identify and review the key peer-reviewed literature that describes the toxicologic properties of particular hazardous substances ToxProfiles also present other pertinent literature, but describe it in less detail than do the key studies. ToxProfiles are not intended as exhaustive documents, but they do reference more comprehensive sources of specialty information.

In 1999, ATSDR published an updated ToxProfile for mercury (ATSDR 1999). This document, like all such profiles, characterizes the toxicologic and adverse health effects information for the hazardous substance it describes. The discussion below is drawn from the updated profile for mercury, except where otherwise noted.

What is mercury?

Mercury occurs naturally in the environment. It is found in three forms: metallic mercury (also known as elemental mercury), inorganic mercury, and organic mercury. Metallic mercury is a shiny, silver-white metal that is a liquid at room temperature. Metallic mercury is the elemental or pure form of mercury—it is not combined with other elements. Metallic mercury metal is the familiar liquid metal used in thermometers and some electrical switches. At room temperature, some of the metallic mercury will evaporate and form mercury vapors. Mercury vapors are colorless and odorless.

Inorganic mercury compounds occur when mercury combines with elements such as chlorine, sulfur, or oxygen. These mercury compounds are also called mercury salts. Most inorganic mercury compounds are white powders or crystals, except for mercuric sulfide (also known as cinnabar), which is red and turns black after exposure to light.

When mercury combines with carbon, the compounds formed are called "organic" mercury compounds or organomercurials. The environment contains a potentially large number of organic mercury compounds; however, by far the most common organic mercury compound in the environment is methylmercury. Like the inorganic mercury compounds, methylmercury is a "salt" (for example, methylmercuric chloride). When pure, most forms of methylmercury are white crystalline solids.

Several forms of mercury occur naturally in the environment. The most common natural forms are metallic mercury, mercuric sulfide (cinnabar ore), mercuric chloride, and methylmercury. Some microorganisms (bacteria and fungi) and natural processes can change the mercury in the environment from one form to another. The most common organic mercury compound that microorganisms and natural processes generate from other forms is methylmercury.

How can mercury enter and leave my body?

A person can be exposed to mercury from breathing in contaminated air, from swallowing or eating contaminated water or food, or from having skin contact with mercury. Not all forms of mercury easily enter your body, even if they come in contact with it. To know which form of mercury you have been exposed to is important, as is by which route (air, food, or skin).

When you swallow small amounts of metallic mercury, for example from a broken oral thermometer, virtually none (less than 0.01 percent) of the mercury will enter your body through the stomach or intestines, unless they are diseased. When you breathe in mercury vapors,

however, most (about 80 percent) of the mercury enters your bloodstream directly from your lungs, and then rapidly goes to other parts of your body, including the brain and kidneys. Once in your body, metallic mercury can stay for weeks or months. When metallic mercury enters the brain, it is readily converted to an inorganic form and is "trapped" for a long time. Metallic mercury in the blood of a pregnant woman can enter her developing child. Most of the metallic mercury will accumulate in your kidneys, but some metallic mercury can also accumulate in the brain. Most of the metallic mercury absorbed into the body eventually leaves in the urine and feces, while smaller amounts leave the body in the exhaled breath.

Inorganic mercury compounds do not generally vaporize at room temperatures as will elemental mercury. And if inorganic mercury compounds are inhaled, they are not expected to enter your body as easily as inhaled metallic mercury vapor. When inorganic mercury compounds are swallowed, generally less than 10 percent is absorbed through the intestinal tract; however, up to 40 percent may enter the body through the stomach and intestines in some instances. Some inorganic mercury can enter your body through the skin, but only a small amount will pass through your skin compared with the amount that gets into your body from swallowing inorganic mercury. Once inorganic mercury enters the body and gets into the bloodstream, it moves to many different tissues. Inorganic mercury leaves your body in the urine or feces over a period of several weeks or months. A small amount of the inorganic mercury can be changed in your body to metallic mercury and leave in the breath as a mercury vapor. Inorganic mercury accumulates mostly in the kidneys and does not enter the brain as easily as metallic mercury. Inorganic mercury compounds also do not move as easily from the blood of a pregnant woman to her developing child. In a nursing woman, some of the inorganic mercury in her body will pass into her breast milk.

Methylmercury is the form of mercury most easily absorbed through the gastrointestinal tract (about 95 percent absorbed). After you eat fish or other foods contaminated with methylmercury, it enters your bloodstream easily and goes rapidly to other parts of your body. Only small amounts of methylmercury enter the bloodstream directly through the skin. Organic mercury compounds may evaporate slowly at room temperature and may enter your body easily if you breathe in the vapors. Once organic mercury is in the bloodstream, it moves easily to most tissues and readily enters the brain. Methylmercury in the blood of a pregnant woman will easily move into the blood of the developing child and then into the child's brain and other tissues. Like metallic mercury, methylmercury can be changed by your body to inorganic mercury. When this happens in the brain, the mercury can remain there for a long time. When methylmercury does leave your body after you have been exposed, it leaves slowly over a period of several months, mostly as inorganic mercury in the feces. As with inorganic mercury, some of the methylmercury in a nursing woman's body will pass into her breast milk.

How can mercury affect my health?

The nervous system is very sensitive to mercury. In poisoning incidents that occurred in other countries, some people who ate fish contaminated with large amounts of methylmercury or seed grains treated with methylmercury or other organic mercury compounds developed permanent damage to the brain and kidneys. Permanent damage to the brain has also been shown to occur from exposure to sufficiently high levels of metallic mercury. Whether exposure to inorganic mercury results in brain or nerve damage is not as certain, given that it does not easily pass from the blood into the brain.

Metallic mercury vapors or organic mercury may affect many different areas of the brain and their associated functions, resulting in a variety of symptoms. These include personality changes (irritability, shyness, nervousness), tremors, changes in vision (constriction (or narrowing) of the visual field), deafness, loss of muscle coordination, loss of sensation, and difficulties with memory.

Because different forms of mercury do not all move through the body in the same way, they have different effects on the nervous system. When metallic mercury vapors are inhaled, they readily enter the bloodstream and are carried throughout the body and can move into the brain. Breathing in or swallowing large amounts of methylmercury also results in some of the mercury moving into the brain and affecting the nervous system. Inorganic mercury salts, such as mercuric chloride, do not enter the brain as readily as does methylmercury or metallic mercury vapor.

The kidneys are also sensitive to the effects of mercury. It accumulates in the kidneys and causes higher exposures to these tissues, and thus more damage. If large enough amounts enter the body, all mercury forms can cause kidney damage. If the damage caused by the mercury is not too great, the kidneys are likely to recover once the body clears itself of the contamination.

Short-term exposure (hours) to high levels of metallic mercury vapor in the air can damage the lining of the mouth and irritate the lungs and airways. This can cause tightness of the chest, a burning sensation in the lungs, and coughing. Other effects from exposure to mercury vapor include nausea, vomiting, diarrhea, increases in blood pressure or heart rate, skin rashes, and eye irritation. Damage to the lining of the mouth and lungs can also occur from exposure to lower levels of mercury vapor over longer periods (for example, in some occupations where workers were exposed to mercury for many years). Most studies of humans who breathed metallic mercury for a long time indicate that mercury from this type of exposure does not affect the ability to have children. Studies in workers exposed to metallic mercury vapors have also not shown any mercury-related increase in cancer. Skin contact with metallic mercury has been shown to cause an allergic reaction (skin rashes) in some people.

In addition to kidney effects, inorganic mercury can damage the stomach and intestines. If swallowed in large amounts, inorganic mercury can produce symptoms of nausea, diarrhea, or severe ulcers. Effects on the heart have also been observed in children after accidentally swallowing mercuric chloride. Symptoms included rapid heart rate and increased blood pressure. Little information is available on the effects in humans from long-term, low-level exposure to inorganic mercury.

Animal studies provide limited information about whether mercury causes cancer in humans (ATSDR 1999). U.S.EPA has determined that mercuric chloride and methylmercury are possible human carcinogens (EPA 2011a, 2011b). International Agency for Research on Cancer (IARC) has determined that methylmercury compounds are possibly carcinogenic to humans (Group 2B), and metallic mercury and inorganic mercury compounds are not classifiable as to their carcinogenicity to humans (Group 3) (IARC 1997).

How can mercury affect children?

Methylmercury eaten or swallowed by a pregnant woman or metallic mercury that enters her body from breathing contaminated air can also pass into the developing child. Inorganic mercury and methylmercury can also pass from a mother's body into breast milk and into a nursing

infant. Methylmercury can also accumulate in an unborn baby's blood to a concentration higher than the concentration in the mother.

For similar exposure routes and forms of mercury, the harmful health effects seen in children are similar to the effects seen in adults. High exposure to mercury vapor causes lung, stomach, and intestinal damage, and, in severe cases, death due to respiratory failure. These effects are similar to those seen in adult groups who inhale metallic mercury vapors at work.

Children who breathe metallic/elemental mercury vapors, eat foods or other substances containing phenylmercury or inorganic mercury salts, or use mercury-containing skin ointments for an extended period may develop a disorder known as acrodynia, or pink disease. Acrodynia can result in severe leg cramps; irritability; and abnormal redness of the skin, followed by peeling of the hands, nose, and soles of the feet. Itching, swelling, fever, fast heart rate, elevated blood pressure, excessive salivation or sweating, rashes, fretfulness, sleeplessness, weakness, or a combination of these symptoms, may also be present. This syndrome was once thought to occur only in children, but recent reported cases in teenagers and adults have shown that they too can develop acrodynia.

In critical periods of development before children and fetuses are born, and in the early months after birth, they are particularly sensitive to the harmful effects of metallic mercury and methylmercury on the nervous system. Harmful developmental effects may occur when a pregnant woman is exposed to metallic mercury and some of the mercury is transferred into her developing child.

As with mercury vapors, exposure to methylmercury is more dangerous for young children than for adults, because more methylmercury easily passes into the developing brain of young children and may interfere with the development process. The effects on the infant may be subtle or more pronounced, depending on the amount to which the fetus or young child was exposed.

Is there a medical test to determine whether I have been exposed to mercury?

Reliable and accurate ways to measure mercury levels in the body are available. These tests involve taking blood, urine, or hair samples, and must be performed in a doctor's office or in a health clinic. Nursing women may have their breast milk tested for mercury levels, if any of the other samples tested are found to contain significant amounts of mercury. Most of these tests, however, do not determine the form of mercury to which you were exposed. Mercury levels found in blood, urine, breast milk, or hair may be used to determine whether adverse health effects are likely to occur. Mercury in urine is used to test for exposure to metallic mercury vapor and to inorganic mercury forms. Measurement of mercury in whole blood or scalp hair is used to monitor exposure to methylmercury. Urine is not useful for determining methylmercury exposure. Levels found in blood, urine, and hair may be used together to predict health effects possibly caused by the different forms of mercury.

What recommendations has the federal government made to protect human health?

The U.S. Environmental Protection Agency (U.S.EPA) and the U.S. Food and Drug Administration (FDA) have set a limit of 2 parts inorganic mercury per billion (ppb) parts of water in drinking water. U.S.EPA has determined that a daily exposure (for an adult of average weight) to inorganic mercury in drinking water at a level up to 2 ppb is not likely to cause any significant adverse health effects. FDA has set a maximum permissible level of 1 part of

methylmercury in a million parts (ppm) of seafood products sold through interstate commerce (1 ppm is a thousand times more than 1 ppb).

Occupational Safety and Health Administration (OSHA) regulates levels of mercury in the workplace. It has set limits of 0.1 milligrams of mercury per cubic meter of air (mg/m^3) for organic mercury and 0.05 mg/m^3 for metallic mercury vapor in workplace air to protect workers during an 8-hour shift and a 40-hour work week. National Institute for Occupational Safety and Health (NIOSH) recommends limiting that the amount of metallic mercury vapor in workplace air be to an average level of 0.05 mg/m^3 during a 8-hour work shift (DHHS and DOL 1978).

Appendix E. Task 2 Pathway Discussions

The Task 2 Air Mercury Concentration Models

The earliest off-site ambient air mercury concentrations were measured in 1986, but the highest Y-12 mercury releases to air occurred during the period from 1953 through 1962.[30] Therefore, the Task 2 team used models to estimate historic off-site air mercury concentrations. Different models were used to estimate air mercury concentrations for receptor populations in Wolf Valley, Scarboro, and people living near the East Fork Poplar Creek (EFPC) floodplain.

Wolf Valley residents were chosen as an affected population. Historically, they were the closest population to the Y-12 plant in the predominant downwind direction in the chain of valleys—Bear Creek Valley, Union Valley, and Wolf Valley—that includes the Y-12 plant. Scarboro is the closest residential population to the Y-12 plant, but it is separated from the Y-12 buildings by Pine Ridge. Still, air emissions from the Y-12 plant windows, vents, and roof stacks could have migrated over Pine Ridge.

Studies of mercury in trees growing in or near the EFPC floodplain conducted during the 1990s suggested that EFPC was a source of significant mercury releases to the air. The Task 2 team modeled air mercury concentrations resulting from the volatilization of mercury from the EFPC floodplain to the following receptor locations and "near-floodplain" resident populations:

- Scarboro community
- Robertsville School
- Oak Ridge community population #1
- Oak Ridge community population #2
- EFPC floodplain farm family

The Task 2 team considered the Scarboro community as the only receptor population whose air was affected by both direct mercury releases to the atmosphere from the Y-12 plant and volatilization of mercury to the air from EFPC. The Task 2 team used three models (or combinations of models)—the U.S. Environmental Protection Agency (U.S.EPA) ISCST3 dispersion model, the χ/Q model, and the EFPC volatilization model—to estimate mercury concentrations in air at each potentially exposed community.

Wolf Valley Residents

The Task 2 team modeled air concentrations of mercury for the years from 1953 through 1962 for Wolf Valley residents using the U.S.EPA ISCST3.[31] This model uses a Gaussian dispersion equation to calculate air concentrations at a remote location from the releases. It is an appropriate model to use in relatively flat terrain.

A separate source term (mass per unit time) was estimated for each of 114 Y-12 building emission points (windows, stacks, and vents) for each year that the buildings were known to have been in operation. The U.S.EPA model predicted mercury concentrations in Wolf Valley

[30] Lithium separation at the Y-12 plant using the Colex process ended in June 1963. The Task 2 team estimated air source terms from 1953 through 1962.

[31] USEPA Industrial Source Complex Short Term dispersion model (Version 96113, 1995)

for each year from each source term. The sum of contributions from each point source resulted in the total annual mercury air concentrations (in units of milligrams of mercury per cubic meter of air, mg/m^3) in Wolf Valley. The estimated air mercury concentrations in Wolf Valley for 1953 through 1962 ranged from 0.0000008 to 0.000014 mg/m^3 (ChemRisk 1999a). The peak value (0.000014 mg/m^3) was in 1955.

Task 2 estimated that the total uncertainty in the estimated annual average mercury concentrations in Wolf Valley was ± 44 percent (ChemRisk 1999a). This figure included uncertainties in the source buildings' air mercury concentrations, emission rates from the building sources, and in the air dispersion model.

The selection of the U.S. EPA model for this application appears to be appropriate. ATSDR considers that Task 2 team's reported estimates of air mercury concentrations in Wolf Valley resulting from this model are reasonable.

Scarboro Community: Emissions from Y-12 Buildings

The Task 2 team recognized that the U.S.EPA ISCST3 dispersion model was not appropriate for the Scarboro community—the terrain is not flat between the Y-12 plant and Scarboro. The Task 2 team considered other dispersion models but did not find any suitable models that could adequately predict air concentrations over Pine Ridge. Consequently, Task 2 used a different kind of model based on uranium data to estimate air mercury concentrations in Scarboro.

The model is based on the assumption that the relationship between air mercury concentrations in Scarboro and mercury release quantities from the Y-12 plant is the same as the relationship between air uranium concentrations in Scarboro and uranium release quantities from Y-12. If the assumption is correct, then annual average air mercury concentrations in Scarboro can be calculated by multiplying annual mercury release quantities times the ratio of uranium concentrations in Scarboro divided by uranium releases from the Y-12 plant.[32]

Model Equation

C = Raa χ Empirical (χ/Q) (s/m^3)

C = Concentration of mercury at Scarboro (mg/m^3)

Raa = Annual average release rate of mercury from Y-12 (mg/s)

Empirical χ/Q (s/m^3) = Annual average concentration of uranium in Scarboro (pCi/m^3)

Annual average release rate of uranium (pCi/s)

The mathematical quantity, "empirical chi over Q" (or χ/Q) is based on two physical quantities: Greek letter chi (χ) represents the measured air uranium concentrations in Scarboro and Q represents annual uranium release rates from Y-12 to the air.

Task 2 designed a "custom" distribution from 20 discrete χ/Q values using uranium data from 1986 through 1995 (ten χ/Q values for uranium-238 and ten values for uranium-234/235).[33] The consistency of the ratios is good for uranium-234/235 (linear regression analysis, $r^2 = 0.97$) and not as good for uranium-238 ($r^2 = 0.64$). The data are only from years with relatively low uranium releases because we do not have data from years with high releases. Among the data, the highest estimated annual uranium release (210 kg in 1986) was nearly 30 times smaller than the estimated amount of uranium released in 1959—the year with the highest estimated annual air uranium release (6,200 kg). The linearity and predictive value of the model is unknown for the

[32] The χ/Q model was developed for the Task 6 (Y-12 uranium) report. Additional information is provided in the Task 6 report (ChemRisk 1999b).

[33] The Task 2 report does not describe how it designed the "custom" distribution from the uranium data or what is "custom" about the distribution.

years with high uranium releases (1953 through the middle 1960s). The validity of the model is also unknown for the years when mercury releases to air were highest (10,260 kg in 1955).

The primary assumption of this model is that mercury releases to the air from the Y-12 plant behave the same as uranium air releases from Y-12. The Task 2 report provides the following discussion points:

Both uranium and mercury were released to the air from a variety of locations spread over the Y-12 site, in many cases from the same buildings. Uranium was released from short stacks on top of buildings more often than mercury, which in turn was released more often from windows and other ventilation sources. Therefore, uranium was generally released from greater heights than mercury. This might have resulted in more uranium crossing over Pine Ridge than mercury. However, uranium was released as solid particles and would likely have experienced a higher wet and dry deposition rate than mercury. All the mercury releases were assumed to be elemental vapor and would be expected to travel higher and further than uranium. Therefore, more mercury could have traveled over Pine Ridge than uranium. The Task 2 report suggests that the differences between the physical behavior of uranium and mercury were not likely large enough to have had a significant impact on relative atmospheric mercury concentrations in Scarboro, but there are no data that support or refute this assumption.

Mercury released into the air from the Y-12 plant might behave like uranium from Y-12 if the particle sizes of mercury and uranium released were similar. Data do not support this presumption. As a vapor, the average mercury droplet size (i.e., the geometric mean aerodynamic diameter) would be in the vicinity of 1 micrometer (µm) or smaller. In a 1975 study of uranium operations at the Y-12 plant, the measured median airborne uranium particle diameters, for different types of uranium operations, were between 1.1 µm and 3.3 µm (mean = 2.3 µm). If mercury quickly became attached to other particulate matter in the air, the similarity between the behavior of mercury and uranium in air might be stronger. However, ATSDR found no studies that described the immediate fate and transport of mercury releases coming from the Y-12 facilities.

Task 2 applied the custom χ/Q distribution to the annual estimated airborne mercury release rates from the Y-12 plant for the years 1953 through 1962. Annual uranium and mercury release estimates from Y-12 were assumed to be evenly distributed over the years in question. This calculation produced the estimated annual average mercury concentrations in air from 1953 through 1962 for the Scarboro community (see Table E-1).

The Task 2 team included the estimated air mercury concentrations for Scarboro, however the data were not presented numerically (ChemRisk 1999a).[34] Therefore, ATSDR calculated annual average air mercury concentrations using the minimum, mean, and maximum χ/Q values from the Task 2 report. Uncertainties in the estimated mean air mercury concentrations are bounded by the estimated minimum and maximum concentrations (see Table E-1).

[34].Data were presented in a difficult-to-read bar chart (ChemRisk 1999a; Figure 7-2).

Table E-1. Estimated Annual Average Air Mercury Concentrations in Scarboro

Year	*Y-12 Mercury Release Rates*		*Mercury Concentrations*		
			Minimum χ/Q (3.50E-08 sec/m³)	*Mean χ/Q (2.20E-07 sec/m³)*	*Maximum χ/Q (6.80E-07 sec/m³)*
	lbs y^{-1}	mg/sec	mg/m^3	mg/m^3	mg/m^3
1953	1496	2.15E+01	7.53E-07	4.73E-06	1.46E-05
1954	3438	4.94E+01	1.73E-06	1.09E-05	3.36E-05
1955	**22606**	**3.25E+02**	**1.14E-05**	**7.15E-05**	**2.21E-04**
1956	13831	1.99E+02	6.96E-06	4.37E-05	1.35E-04
1957	5902	8.48E+01	2.97E-06	1.87E-05	5.77E-05
1958	9243	1.33E+02	4.65E-06	2.92E-05	9.03E-05
1959	7803	1.12E+02	3.93E-06	2.47E-05	7.63E-05
1960	3714	5.34E+01	1.87E-06	1.17E-05	3.63E-05
1961	2475	3.56E+01	1.25E-06	7.83E-06	2.42E-05
1962	2456	3.53E+01	1.24E-06	7.77E-06	2.40E-05

Source: ChemRisk 1999a
Values in mg/m^3 are calculated from lbs/y.
Bold indicates the year with the highest annual average mercury concentrations in Scarboro.

The highest Y-12 air mercury releases, and therefore the highest annual average mercury concentrations in Scarboro, were in 1955. But the annual average air mercury concentrations in Scarboro include mercury from both the Y-12 releases and from EFPC.

We do not know whether air releases of mercury behaved like those of uranium. We do not know whether the χ/Q "custom distribution" is an accurate depiction of the relationship between the mercury quantities released and the air mercury concentrations in Scarboro. ATSDR has no basis for reliably evaluating the air mercury concentrations generated from this model.

Mercury Concentrations in Air Due to Volatilization from EFPC

The Task 2 team recognized that Pine Ridge partially limits the air exchange between the Y-12 plant and Oak Ridge communities, including Scarboro. Still, analyses of mercury in red cedar core samples collected near East Tulsa Road in the EFPC floodplain in 1993 showed that air mercury concentrations had been elevated in neighborhoods beyond Scarboro during the years of peak mercury releases from Y-12 (see Table E-2).

Table E-2. Mercury Concentrations Detected in Tree Rings from the EFPC Floodplain

Year	*Y-12 E1*	*Y-12 E2*	*Y-12 W*	*EFPC-2*	*EFPC-3*	*EFPC-4*	*EFPC-5*	*EFPC-6*
1950	0.47	0.20001	0.48	5.3	1.8	ND	ND	1.2
1951	0.40	0.34	0.45	5.3	1.8	ND	ND	0.61
1952	0.36	0.34	0.66	5.3	1.8	ND	ND	0.37
1953	0.36	0.52	0.75	7.2	1.8	ND	ND	0.31
1954	0.36	0.47	1.1	7.2	2.7	ND	4.6	0.29
1955	0.25	0.46	0.67	7.2	2.7	ND	4.6	0.33
1956	0.16	0.46	0.98	7.2	2.7	ND	4.6	0.25
1957	0.16	0.32	1.1	7.2	2.7	ND	5.1	0.29
1958	0.11	0.14	1.2	1.5	2.7	ND	5.1	0.26
1959	0.11	0.10	1.2	1.5	3.0	0.22	0.63	0.17
1960	0.077	0.10	0.76	1.5	3.0	0.22	0.63	0.17
1961	0.077	0.068	0.76	1.5	3.0	0.22	0.63	0.17
1962	0.077	0.068	0.95	1.5	3.0	0.22	0.63	0.17
1963	0.042	0.043	0.95	1.5	3.0	0.22	0.63	0.17
1964	0.042	0.043	1.5	1.5	0.49	0.050	0.29	0.098
1965	0.042	0.043	1.5	0.14	0.49	0.050	0.29	0.098
1966	0.035	0.043	1.6	0.14	0.49	0.050	0.29	0.098
1967	0.033	0.043	1.6	0.14	0.49	0.050	0.29	0.098
1968	0.029	0.043	1.0	0.14	0.49	0.050	0.29	0.098
1969	0.030	0.032	1.0	0.14	1.7	0.016	0.32	0.036
1970	0.021	0.032	0.47	0.14	1.7	0.016	0.32	0.036
1971	0.019	0.032	0.47	0.14	1.7	0.016	0.32	0.036
1972	0.016	0.018	0.23	0.050	1.7	0.016	0.32	0.036
1973	0.016	0.018	0.23	0.050	1.7	0.016	0.32	0.036
1974	0.016	0.018	0.13	0.050	0.632	0.058	0.16	0.014
1975	0.016	0.018	0.13	0.050	0.63	0.058	0.16	0.014
1976	0.016	0.018	0.085	0.050	0.63	0.058	0.16	0.014
1977	0.016	0.0097	0.085	0.050	0.63	0.058	0.16	0.014
1978	0.014	0.0097	0.058	0.050	0.63	0.058	0.16	0.014
1979	0.014	0.0097	0.058	0.343	0.093	0.0040	0.092	0.011
1980	0.014	0.0097	0.048	0.343	0.093	0.0040	0.092	0.011
1981	0.014	0.0097	0.048	0.343	0.093	0.0040	0.092	0.011
1982	0.014	0.0012	0.058	0.343	0.093	0.0040	0.092	0.011
1983	0.015	0.0012	0.058	0.343	0.093	0.0040	0.092	0.011
1984	0.016	0.0012	0.060	0.343	0.059	0.0057	0.13	0.0055
1985	0.016	0.0012	0.031	0.343	0.059	0.0057	0.13	0.0055
1986	0.0078	0.0012	0.019	0.070	0.059	0.0057	0.13	0.0055
1987	0.0067	0.0012	0.023	0.070	0.059	0.0057	0.13	0.0055

Year	Y-12 E1	Y-12 E2	Y-12 W	EFPC-2	EFPC-3	EFPC-4	EFPC-5	EFPC-6
1988	0.0039	0.0082	0.030	0.070	0.059	0.0057	0.13	0.0055
1989	0.0035	0.0049	0.050	0.070	0.12	0.0074	0.074	0.0014
1990	0.0044	0.0043	0.018	0.070	0.12	0.0074	0.074	0.0014
1991	0.0022	0.0043	0.016	0.070	0.12	0.0074	0.074	0.0014
1992	0.0020	0.0027	0.010	0.070	0.12	0.0074	0.074	0.0014
1993	0.0020	0.0027	0.012	0.070	0.12	0.0074	0.074	0.0014

Source: ChemRisk 1999a
Units are in parts per million (ppm)

Plants take up and release mercury through their leaves and stems—uptake of mercury through plant roots is minimal. The Task 2 team studied mercury in tree rings in hopes of using the quantity of mercury found in tree rings to estimate annual average air mercury concentrations for the years represented by each ring. The Task 2 team, however, determined that the tree ring data could not reliably predict air mercury concentrations for several reasons:

- Mercury concentrations in rings did not correlate well with mercury release quantities in different years.
- Mercury concentrations in specific rings, corresponding to particular years, were not similar in trees that were close together.
- Analyses of the ratios of tree ring concentrations were not consistent between different trees.
- Mercury concentrations in rings in some trees corresponding to years before the lithium separation process was in full production were higher in some cases than in subsequent years.[35]

The Task 2 report suggested that the mercury did not remain in individual rings; it may have migrated across rings inside the tree. Therefore, the Task 2 team could not reliably assign the measured mercury concentrations to specific years. As a result, the Task 2 team abandoned its effort to estimate historic air mercury concentrations from tree core samples. Therefore, the Task 2 report modeled air mercury concentrations from the volatilization of mercury from the floodplain.

The Task 2 team looked at EFPC floodplain soil emissions. A 1993 study in the EFPC floodplain indicated that mercury concentrations in the air directly over mercury-contaminated soil were 340 times lower than air mercury concentrations directly over EFPC water.[36] Task 2 also reviewed studies in the scientific literature and concluded that mercury emissions from EFPC soils were insignificant compared with mercury emissions from EFPC water. Therefore, the Task 2 team modeled mercury in air originating from EFPC surface water only.

The Task 2 team modeled air mercury concentrations from the volatilization of mercury from EFPC to the following five potentially exposed communities:

[35] The Task 2 team indicated that mercury concentrations in the tree ring corresponding to 1938—before the Manhattan Project began—was higher than in subsequent years in a tree on the west end of Y-12 property (ChemRisk 1999a).

[36] Concentrations of mercury in air over water were modeled; concentrations in air over soil were measured. These data were from separate studies.

- Scarboro community
- Robertsville School
- Oak Ridge community population #1
- Oak Ridge community population #2
- EFPC floodplain farm family

The Task 2 team estimated the amount of mercury that volatilized from EFPC by dividing the entire length of EFPC into 403 theoretical rectangular segments, each with a width of 15 meters and a length between 15 and 140 meters (see Figure E-1) (ChemRisk 1999a). The Task 2 team assumed the volatilization rate was constant throughout EFPC. But the starting mass of mercury at each segment was the amount released from the Y-12 plant less the amount of mercury lost from the water from each of the preceding upstream segments. Therefore, the amount of mercury that volatilized from each segment was a function of its distance from Y-12. No adjustments in the volatilization fraction were made for the variations in the creek flow.

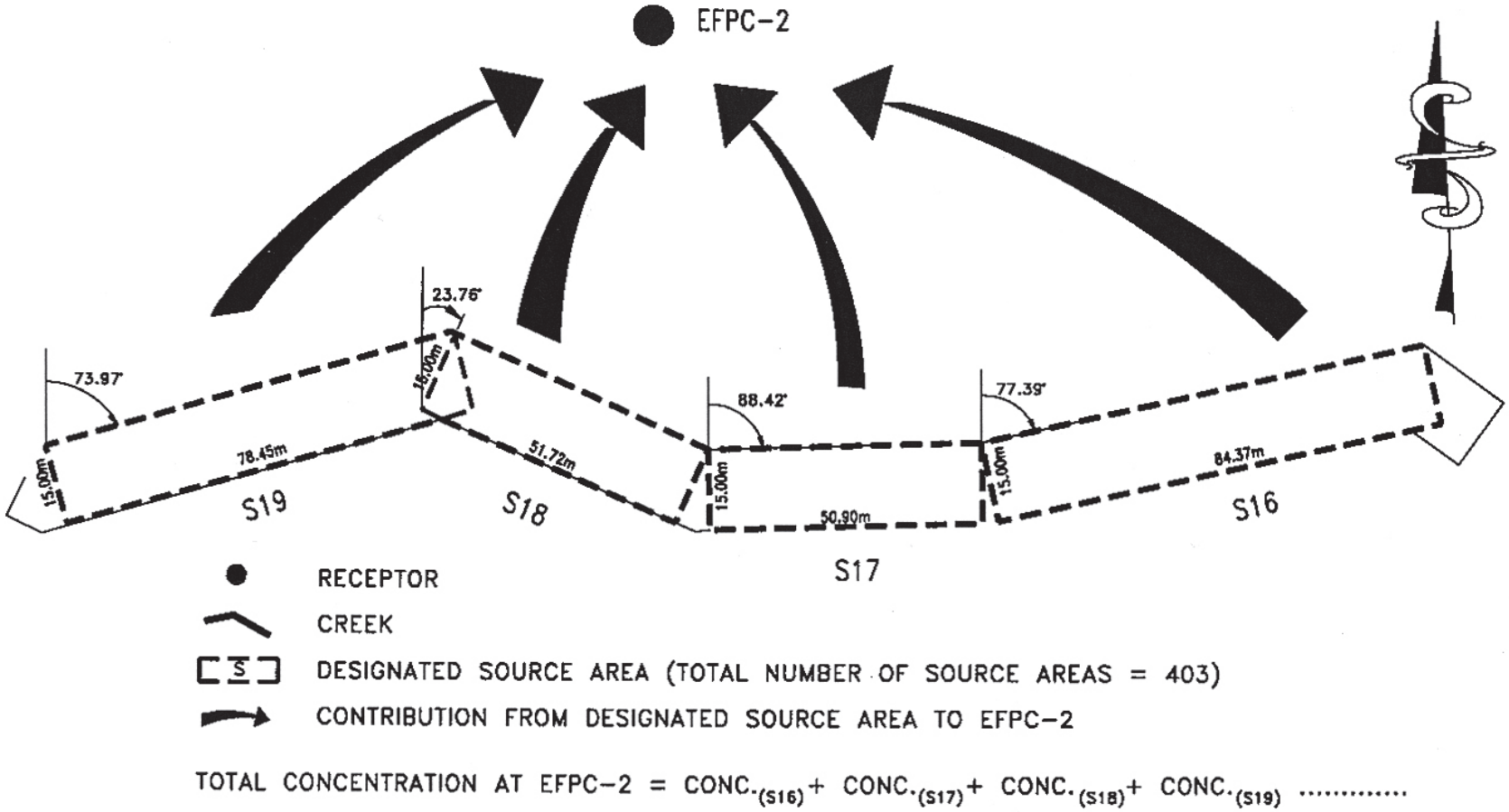
The estimated mass of mercury lost from each water segment (in grams of mercury discharged to air per year [g/y]) was used as a line source term in the U.S.EPA ISCST3 dispersion model (Version 96113, 1995). The dispersion model calculated air mercury concentrations at the various potentially exposed communities. In the dispersion model the Task 2 team used 1987 meteorological data from the Y-12 East Meteorological station. The Task 2 team included an uncertainty factor to account for uncertainty in the air dispersion model, but did not include a factor for the uncertainty or variability in the meteorological data. The amount of mercury that was released into EFPC at the Y-12 plant is provided by the annual source terms for Y-12 mercury releases to water.

The fraction of mercury that will volatilize from EFPC depends on the amount of dissolved gaseous mercury (DGM) in the water, as well as the physical conditions of the water and the adjacent air. DGM is dissolved elemental mercury; it is the only mercury species in water that will significantly volatilize from water. Elemental mercury is only slightly soluble in water (56 µg/L at 25° C), but supersaturation (the build-up of DGM beyond its equilibrium concentration) has often been documented in environmental water systems. Conditions in the water, such as the water temperature, pH, stream flow, and mixing of the water column may favor either the loss of, or the formation of, DGM. Higher temperatures and higher wind currents at the water surface, for example, will increase the volatilization of DGM from the water to air. Water agitation and air flow at the water's surface may significantly affect the propensity of DGM to overcome surface energy barriers to volatilization (Saouter et al. 1995). Higher pH will favor the reduction (chemical conversion) of mercuric forms of mercury to elemental mercury, while lower pH will favor the oxidation (chemical conversion) of elemental mercury to mercurous and mercuric species. The presence of minerals and organic matter in the water favor the oxidation of elemental mercury and the removal of DGM from the water. Finally, DGM may be formed either biotically (mediated by microscopic organisms) or abiotically (occurring chemically without microscopic organisms) in the water.

Measurements of DGM in EFPC during the 1950s are not available. The only data that characterize stream conditions, available from the 1950s, are some pH and flow measurements. The pH values and the flow volumes during the 1950s, as well as the many curves in the EFPC bed, would generally favor the formation and volatilization of mercury. But these data are

insufficient to estimate with any precision or known accuracy the amount of mercury that volatilized. The magnitude of their effects or those of competing processes occurring in the creek are not known.

Figure E-1. Conceptual Model for Mercury Releases from EFPC



Source: ChemRisk 1999a

For the volatilization fraction, the Task 2 team assumed a distribution of values: a minimum, a best estimate, and a maximum value equal to 1, 5, and 30 percent, respectively, of the total mercury mass released annually to the creek. The Task 2 team derived these percentages from a 1995 published study of Reality Lake—a settling pond within EFPC on the Y-12 property. But the Task 2 report did not present the derivation of these numbers, and the study does not clearly support the range of values the Task 2 team selected (Saouter et al. 1995).

Although the Task 2 team also assumed the minimum, best estimate, and maximum fractions from a logtriangle distribution, it provided no justification for that choice. A logtriangle distribution provides greater weight to the lower concentration estimates and less weight to the higher ones. ATSDR has seen no evidence to favor one portion of the distribution of the volatilization fractions over any other portion. For example, we do not know the time-average distribution of wind patterns at the water surface, or the pattern of variability of DGM concentrations in EFPC during a typical year during the 1950s. Mercury may have volatilized less frequently in the high-lying volatilization fractions than in the low-lying fractions, but no evidence supports such an assumption.

Recently, George R. Southworth, affiliated with the Oak Ridge National Laboratory, estimated that the EFPC mercury evasion rate may be about 3 percent of the total mercury flux over the length of EFPC (Southworth GR, personal communication, February 14, 2005). Southworth based his calculation on the amount of DGM measured in EFPC in 1997 as well as estimates of the total mercury in the water and the surface area of EFPC. Southworth's calculations appear in the text box to the right:

EFPC Mercury Evasion Rate Calculations

Mean dissolved gaseous mercury in EFPC (summer, 1997) = 1.1 ng/L = 0.0011 ng/cm^3.

Mass transfer coefficient = 10 cm/h.

Evasion flux = 0.0011 ng/cm^3 × 10 cm/h^1 = 0.011 ng/cm^2/h = 110 ng/m^2/h.

EFPC surface area = length × width = 25,000 m × 10 m = 250,000 m^2.

Total surface flux = creek area × evasion flux = 27.5 mg/h = 660 mg/d.

Hg flux through the creek = 22 g/d.

Therefore, 660 mg/d ÷ 22 g/d = 0.03 or 3 percent.

Southworth emphasized that the volatilization fraction he calculated (3 percent) is imprecise. It depends on many variables that can vary widely and are not well determined.

The Task 2 team's best estimate value of 5 percent is similar to Southworth's estimate of 3 percent. Still, they are both based on 1990s data. Between the 1950s and 1990s, many changes occurred at the Y-12 facilities that affected what was released into EFPC. To determine whether either value accurately predicts mercury volatilization from EFPC during the 1950s is impossible. Similarly, no evidence supports the assumption that the fraction of total mercury in the creek that volatilized was similar in both decades.

The minimum best estimate and maximum volatilization fractions generated three source terms for each segment of EFPC for each year and produced three air mercury concentrations at each potentially exposed community for each year.

The highest estimated mercury releases from the Y-12 plant to EFPC, and consequently the highest air mercury emissions from EFPC, occurred in 1957.[37] The Task 2 team estimated air

[37] The highest air mercury concentration in the Scarboro community occurred in 1955, due to a significant component from the χ/Q model for that year.

mercury concentrations for each of the five potentially exposed communities using the 5 percent mercury volatilization fraction (see Table E-3; ChemRisk 1999a). The mercury concentrations in Table E-3 for the Scarboro community do not include the contribution from the χ/Q model. Table E-4 presents the combined air mercury concentrations for the Scarboro community.

Table E-3. Estimated Air Mercury Concentrations (mg/m^3)[1]

Year	*EFPC Floodplain Farm Family*	*Scarboro Community*	*Robertsville School*	*Oak Ridge Location 1*	*Oak Ridge Location 2*
1953	6.4E-05	6.5E-06	4.3E-06	2.2E-06	1.1E-06
1954	3.8E-05	3.9E-06	2.6E-06	1.3E-06	6.3E-07
1955	1.9E-04	2.0E-05	1.3E-05	6.6E-06	3.2E-06
1956	1.6E-04	1.6E-05	1.1E-05	5.4E-06	2.6E-06
1957	3.9E-04	4.0E-05	2.6E-05	1.3E-05	6.5E-06
1958	3.5E-04	3.5E-05	2.3E-05	1.2E-05	5.8E-06
1959	1.0E-04	1.0E-05	6.9E-06	3.5E-06	1.7E-06
1960	3.8E-05	3.8E-06	2.5E-06	1.3E-06	6.3E-07
1961	3.6E-05	3.6E-06	2.4E-06	1.2E-06	5.9E-07
1962	2.5E-05	2.5E-06	1.7E-06	8.4E-07	4.1E-07
1963	1.7E-05	1.7E-06	1.1E-06	5.6E-07	2.8E-07

[1] Estimates are based on the volatilization of mercury at five receptor locations from EFPC.

Table E-4. Combined Estimated Air Mercury Concentrations for Scarboro (mg/m^3)[1]

Year	*EFPC (5% vf)*	*χ/Q (mean)*	*Sum*	*% due to χ/Q*
1953	6.5E-06	4.7E-06	1.1E-05	42%
1954	3.9E-06	1.1E-05	1.5E-05	74%
1955	2.0E-05	7.2E-05	9.1E-05	78%
1956	1.6E-05	4.4E-05	6.0E-05	73%
1957	4.0E-05	1.9E-05	5.8E-05	32%
1958	3.5E-05	2.9E-05	6.4E-05	45%
1959	1.0E-05	2.5E-05	3.5E-05	70%
1960	3.8E-06	1.2E-05	1.6E-05	75%
1961	3.6E-06	7.8E-06	1.1E-05	68%
1962	2.5E-06	7.8E-06	1.0E-05	76%
1963	1.7E-06		1.7E-06	

[1] Estimated concentrations are from both the χ/Q model and the volatilization of mercury from EFPC.

EFPC = the Task 2 air mercury concentration from the volatilization of EFPC using a volatilization fraction of 5 percent
χ/Q = the Task 2 air mercury concentration from Y-12 air mercury releases using the Task 2 χ/Q model and the mean χ/Q value
Sum = EFPC + χ/Q columns
% = the percentage which the χ/Q-derived concentration is of the whole (sum)

The Task 2 Water Model for Mercury Concentrations in EFPC

The Task 2 team developed a model to estimate water mercury concentrations at different locations along EFPC from 1950 through 1990. The Task 2 team did not estimate exposures to mercury in surface water downstream from EFPC—the water mercury concentrations below EFPC were considered insignificant.

Task 2 selected the following potentially exposed communities for exposures to surface water:

- Scarboro community
- Robertsville School students
- EFPC floodplain farm family[38]

The Task 2 team estimated mercury concentrations in water for each of the three populations by selecting areas along EFPC corresponding to the closest populations. The Task 2 EFPC mile marker locations corresponding to the Scarboro community, Robertsville School students, and the EFPC floodplain farm family are EFPC Mile 14, Mile 12, and Mile 10, respectively[39] (see Figure 13).

The basis of the Task 2 model was the average annual water mercury release estimates and additional specific water mercury concentration data generated or compiled by the Task 2 team. The annual release estimates were calculated from data available in ORR weekly, monthly, and quarterly environmental reports. The reported data include mercury concentrations in weekly composite water samples collected in EFPC on the Y-12 property and weekly average flow volumes of EFPC on Y-12 property. The reported monthly and quarterly data are averages calculated from the weekly data. Not all the data are available for all the time periods. In addition to measurements at Y-12, Oak Ridge personnel collected water samples on or close to a weekly basis between 1955 and 1961, just upstream of the confluence of EFPC with Poplar Creek. The samples from EFPC near the Poplar Creek confluence contained between 1 and 60 percent (average = 11 percent) of the estimated mercury concentrations in EFPC directly below the discharge point at the Y-12 plant during the same time period.

Task 2 Equations for Calculating EFPC Mercury Concentrations at each Reference Location

C_{ref} (mg/L) = $C_{Y\text{-}12}$ (mg/L) x Water Concentration Ratio

Where:

C_{ref} = Mercury concentration in water at a population reference location

$C_{Y\text{-}12}$ = Mercury concentration in water at Y-12

Water Concentration Ratio = Dilution Ratio × (1 - fraction lost to other compartments)

The Dilution Ratio, estimated from the size of the drainage basin at C_{ref}, is:

Dilution Ratio = Y-12 discharge volume (in cubic feet per second, cfs)

Y-12 discharge volume (cfs) + EFPC inflow volume (cfs)

Larger volumes of runoff to EFPC result in a smaller dilution ratio. The smaller the dilution ratio, the smaller the water concentration ratio and the more the water mercury concentration is reduced downstream at reference locations (C_{ref}) compared with the concentration at Y-12 ($C_{Y\text{-}12}$).

[38] Despite that EFPC does not run through the Scarboro community, the Task 2 team thought children from Scarboro might have played in or near EFPC.

[39] Mile marker numbers increase from the juncture of EFPC with Poplar Creek (EFPC Mile 0) up to the source of EFPC at the Y-12 plant (EFPC Mile 14.4).

The Task 2 team assumed some of the difference in the mercury concentrations in water at each end of EFPC was due to dilution, and some was due to the loss of mercury to soil, sediment, and air. Task 2 first estimated the portion of the difference that was due to dilution and attributed the remainder of the difference to the loss of mercury to soil, sediment, and air.

The Task 2 team obtained information about the area of the drainage basin and the percent of precipitation runoff to EFPC from a 1985 study by the Tennessee Valley Authority (TVA). TVA divided the drainage basin into sections along EFPC according to the location of tributaries that feed surface water runoff into the creek. The Task 2 team calculated drainage basin areas for each potentially exposed community by interpolating between the nearest drainage areas in the TVA study for each potentially exposed community along EFPC. Task 2 obtained annual precipitation data from a 1967 U.S. Geological Survey (USGS) report. With the precipitation information, Task 2 calculated inflow volumes at each of the three potentially exposed communities for each year from 1950 to 1990. Task 2 used these data to estimate the effect of dilution on mercury concentrations at the potentially exposed communities along EFPC and for the creek as a whole.

The Task 2 team used average Y-12 release volumes[40] for the 24 calendar quarters from 1956 through 1961, the drainage basin data, and the precipitation data. The Task 2 team estimated that the volume flow at the EFPC-Poplar Creek junction increased approximately 3.6 times over the volume flow at the Y-12 plant. This is an average dilution ratio of 0.26 (range: 0.15–0.42) over the expanse of EFPC.

The Task 2 team estimated that on average, EFPC lost about 58 percent (range: -160 to 97) of mercury from water to sediment and air for each of the 24 calendar quarters. The -160 percent and two other negative values occurred during 1956 and the first quarter of 1957. Negative values indicate no losses of mercury to sediment and air, and surface water runoff had less effect than proposed. Or that less surface water runoff occurred than estimated. But this is counterintuitive—it indicates that the validity and, therefore, the results of the model are in question for those quarters. The average mercury loss estimates for the remainder of 1957 through 1961 (ignoring the earlier, inconsistent data), over the expanse of the creek, was 79 percent.

In 1984, TVA collected 141 soil core samples from 30 transects across EFPC. From the core data, TVA estimated that the total mass of mercury in the EFPC floodplain was 157,000 pounds. This mass is approximately 56 percent of the estimated 279,000 pounds of mercury that the Task 2 team estimated the Y-12 plant had released to EFPC from 1953 through 1984. This result is roughly the same as the 79 percent mercury mass the Task 2 team estimated using the water model above. Both estimates suggest a large fraction of the mass of mercury released from the Y-12 plant was lost to sediments, with only a small fraction of mercury lost to air. The Task 2 team also referenced a study that showed more than 99 percent of mercury transported in surface water was associated with the solid phase (particulate matter or sediment).

From these analyses, Task 2 assumed that EFPC water lost 70 ± 30 percent of its mercury mass to other environmental compartments (soil, sediment, and air) over the full length of the creek. This number is not an exact numerical derivation—it includes a relatively large degree of uncertainty.

[40] Water released to EFPC in cubic feet per second (cfs)

EFPC Mercury Concentrations at the Potentially Exposed Communities

At the potentially exposed communities, average dilution ratios over the 41-year period were 0.54, 0.67, and 0.90 at EFPC Miles 10 (EFPC floodplain farm family), 12 (Robertsville School), and 14 (Scarboro), respectively. These are reductions in water mercury concentrations of 46, 33, and 10 percent, respectively, from the initial water mercury concentrations at the Y-12 plant (ChemRisk 1999a).

To estimate the percent of mercury lost to the sediment and air at the potentially exposed communities, the Task 2 team interpolated linearly between EFPC Mile 14.7 at the Y-12 plant and EFPC Mile 0 at Poplar Creek. The annual average fractions of mercury lost to soil, sediment, and air, based on an overall loss of 70 percent and the distance of the potentially exposed community from Y-12, were 22, 13, and 3 percent for the EFPC floodplain farm family, Robertsville School, and Scarboro communities, respectively (see Table E-5). At all three locations, therefore, dilution had a greater effect on the mercury concentrations than did loss of mercury to soil, sediment, and air.

Table E-5. Percent Reduction in Mercury Concentrations at Potentially Exposed Communities[1]

Potentially Exposed Community	*Mile Marker Location (EFPC Mile #)*	*Reduction from Dilution (%)*	*Reduction from Loss to Sediment and Air (%)*	*Total Reduction (%)*
EFPC Floodplain Farm Family	10	46	22	68
Robertsville School	12	33	13	46
Scarboro	14	10	3	13

[1] Compared with initial mercury concentrations at the Y-12 plant

The water concentration ratios for each potentially exposed community multiplied times the annual average mercury concentrations in surface water discharged at Y-12 for the same years yielded the average annual mercury concentrations in EFPC surface water at the potentially exposed communities (see Table E-6).

Table E-6. Estimated Average Annual Mercury Concentrations for the Potentially Exposed Communities

Year	*Y-12 Plant EFPC Mile 14.7 (mg/L)*	*Scarboro EFPC Mile 14 (mg/L)*	*Robertsville School EFPC Mile 12 (mg/L)*	*EFPC Floodplain EFPC Mile 10 (mg/L)*
1950[1]	0.003	0.003	0.002	0.001
1951[1]	0.003	0.003	0.002	0.001
1952[1]	0.003	0.003	0.002	0.001
1953	0.470	0.417	0.305	0.226
1954	0.220	0.194	0.131	0.094
1955	1.060	0.931	0.653	0.476
1956	0.850	0.737	0.496	0.359
1957	2.220	1.940	1.288	0.936
1958	2.330	2.037	1.505	1.092
1959	0.680	0.601	0.418	0.304
1960	0.240	0.213	0.139	0.101
1961	0.200	0.175	0.122	0.086
1962	0.120	0.107	0.075	0.055
1963	0.086	0.078	0.057	0.044
1964	0.044	0.039	0.026	0.019
1965	0.095	0.083	0.057	0.041
1966	0.043	0.039	0.028	0.020
1967	0.031	0.026	0.017	0.012
1968	0.005	0.005	0.003	0.002
1969	0.006	0.005	0.004	0.003
1970	0.026	0.022	0.016	0.011
1971	0.006	0.005	0.004	0.003
1972	0.001	0.001	0.001	0.000
1973	0.065	0.054	0.033	0.023
1974	0.015	0.013	0.075	0.005
1975	0.001	0.001	0.001	0.000
1976	0.001	0.001	0.001	0.000
1977	0.002	0.002	0.001	0.001
1978	0.001	0.001	0.001	0.000
1979	0.002	0.002	0.001	0.001
1980	0.002	0.002	0.001	0.001
1981	0.002	0.002	0.001	0.001
1982	0.002	0.003	0.002	0.001
1983	0.002	0.002	0.001	0.001
1984	0.002	0.001	0.001	0.001

Year	*Y-12 Plant EFPC Mile 14.7 (mg/L)*	*Scarboro EFPC Mile 14 (mg/L)*	*Robertsville School EFPC Mile 12 (mg/L)*	*EFPC Floodplain EFPC Mile 10 (mg/L)*
1985	0.003	0.002	0.001	0.001
1986	0.000	0.002	0.001	0.001
1987	0.008	0.003	0.002	0.001
1988	0.002	0.002	0.001	0.001
1989	0.002	0.001	0.001	0.001
1990	0.002	0.001	0.001	0.001

[1] Concentrations for 1950, 1951, and 1952 were calculated using the percentages in Table E-5. Task 2 did not calculate "dilution only" concentrations for those years.

The Task 2 team did not provide its estimates of the EFPC mercury concentrations at the three potentially exposed communities. Instead, the Task 2 report provided the average annual mercury concentrations reduced by dilution alone (ChemRisk 1999a, Appendix M). ATSDR, then, calculated the average annual mercury concentrations for each location by reducing the "dilution only" concentrations by the relative "fraction lost to other compartments" for each location. The highest estimated annual average mercury concentrations in EFPC at all potentially exposed communities are for the year 1958.[41]

The Task 2 team calculated mercury doses for each potentially exposed community, assuming young children (6 months to 3 years; 12 kg average body weight) ingested on average 25 milliliters (mL) of water per hour, 8 hours per day for 16 days during the year. Using the above water mercury concentrations in Table E-6, the Task 2 team determined that none of the mercury doses for any potentially exposed community exceeded U.S.EPA's reference dose (RfD) for inorganic mercury.

The Task 2 team provided the following uncertainties (see Table E-7) associated with the variables contributing to the estimates of EFPC water mercury concentrations (ChemRisk 1999a). The Task 2 report did not provide a value for the overall uncertainty in the EFPC water mercury concentrations.

[41] Total estimated mercury releases were higher during 1957 than in 1958, but water flow rates were smaller during 1958, so average water mercury concentrations in 1958 were higher than in 1957.

Table E-7: Task 2 Uncertainty Bounds for Characterization of Surface Water Concentrations Downstream from the Y-12 Plant

Year	*Y-12 Conc. (%)*	*Y-12 Flow Rate (%)*	*Annual Average Precip. (%)*	*Annual Average Runoff (%)*	*Drainage Basin Area (%)*	*Loss to Other Compartments (%)*
1953–56	±50	±15	±10	±10	±10	±30
1957–59	±15	±15	±10	±10	±10	±30
1960–61	±30	±15	±10	±10	±10	±30
1962–67	±40	±15	±10	±10	±10	±30
1968–82	±20	±10	±10	±10	±10	±30
1983–93	±20	±10	±10	±10	±10	±30

The uncertainties in the initial mercury concentrations at Y-12 (e.g., ± 50 percent for the period 1953–1956) are the uncertainties associated with the different analytical methods that were used to measure mercury in the samples. The Task 2 report does not include the uncertainties due to the assumptions made to fill the data gaps in the initial mercury concentrations before 1955, or due to the water collection methods including the absence of acidification of the samples before 1977.

Before 1977, to minimize volatilization of mercury vapor from the sample containers, samples were not acidified at the time of collection. An acidic pH favors dissolved ionic mercury and a basic pH favors undissolved, elemental mercury. Once mercury is in the elemental form, at ambient temperatures it may evaporate or volatilize from water. Due to the nitric acid in the liquid wastes, little risk of mercury loss arose from the samples. That said, however, not all of the liquid waste streams were acidic.

Discussion of the Task 2 Water Model

The Task 2 team developed the water model as a method of estimating average annual water mercury concentrations. The estimated water mercury concentrations were then used to calculate average annual mercury exposure doses. These dose estimates, however, should be used with caution: predicted concentrations of mercury in water are not always reliable and the model is not sufficiently precise to evaluate the more important short-term exposures.

The Task 2 model includes three assumptions: 1) Over the length of EFPC, mercury concentrations decrease due to dilution and due to mercury loss from water to soil, sediment, and air; 2) Between 40 and 90 percent of the mercury mass released from the Y-12 plant to EFPC was lost from the water to soil, sediment, and air over the full length of EFPC, and 3) the loss of mercury to other environmental compartments is linear with the distance from the Y-12 plant. But the data suggest more is going on than just dilution and linear loss of mercury mass.

Task 2 derived the mercury mass partition value (70 ± 30 percent of the mass of mercury lost to sediment and air over the length of EFPC) using mercury concentration data from both ends of EFPC. This partition range is very broad and has limited interpretive value. The two water mercury concentration data sets are minimally correlated, even when they are adjusted for changes in water volume (correlation coefficient [r] = 0.37). The mercury concentrations at the Poplar Creek end of EFPC are inconsistent relative to the concentrations at the Y-12 plant, probably because of many significant chemical and physical processes affecting the dissolved mercury mass during its transport through the creek. The exchange of mercury between water

and other compartments (sediment and air, for example) is complex and may depend on many variables such as water temperature, flow rates, turbulence, amount of precipitation, surface runoff, amount and types of mercury in "storage depots" in the floodplain soils and sediments, and the quantity and physical properties of organic and particulate matter present. These processes are not quantitatively characterized in the scientific literature. The low correlation of the data means the model is not predictive. The lack of accuracy of the model was demonstrated by its failure to predict sizeable mercury losses for three calendar quarters in 1956 and 1957.

The Task 2 model-estimated mercury concentrations are also limited—they are annual averages. ATSDR notes that the longer the duration over which periodic data are averaged, the lower the peak values. Thus, the average annual water mercury concentrations are lower than some of the quarterly concentrations for the same period. The average quarterly concentrations are lower than some of the monthly concentrations, and the average monthly concentrations are lower than some of the weekly concentrations.

ATSDR believes that some of the assumptions used by the Task 2 team may not be representative of actual exposure conditions. Many of the exposures to EFPC water occurred over periods of time shorter than 1 year. Children did not typically play in EFPC over the winter months, and if they did, they were not likely to have ingested much water. And notwithstanding Task 2's assumption, a child 3 years of age and younger playing in the creek is unlikely. Older children may have played in the creek over several (or many) years, but each year they likely took time off from playing in the creek. In any event, the Task 2 average annual mercury doses provide only an estimate of exposures averaged over a full year—an exposure that is least likely to be a public health concern.

To estimate the short-term reduction of mercury mass in EFPC, ATSDR considered comparing *on a weekly basis* (rather than quarterly) the concentration data from the water samples collected from each end of EFPC in the 1950s. But no evidence supports the assumption that the predictability or linearity of the Task 2 model increases with shorter periods. Any quantitative evaluation based on such an exercise would thus suffer from a lack of confidence.

The Task 2 Model for Mercury Concentrations in Soil and Sediment

The Task 2 team estimated doses and risks associated with direct exposures to contaminated soil and sediment for the following populations:

- EFPC floodplain farm family
- Robertsville School students
- Scarboro community

The direct exposure pathways are 1) ingestion of mercury-contaminated soil or sediment, and 2) dermal absorption of mercury from skin contact with mercury-contaminated soil or sediment. For each selected group, the Task 2 team identified samples collected from areas of the floodplain or creek likely to have been contacted by people.

The Task 2 team used soil samples from two studies to estimate past mercury concentrations in both soil and sediment in the EFPC floodplain and Scarboro (see Table E-8). The two studies are the Science Applications International Corporation (SAIC) EFPC Floodplain Remedial Investigation (RI) from 1990–1992 and the Oak Ridge Associated University (ORAU) study in

1984. The EFPC RI study included more than 2,800 core (16-inch long) soil samples, with many of the samples from the EFPC floodplain, but it did not include any soil samples from Scarboro. The ORAU study included more than 3,000 soil samples from the EFPC floodplain and properties throughout Oak Ridge (including Scarboro), but they were only surface samples (0 to 3 inches below the surface) (ChemRisk 1999a).

Table E-8. Data Sources for Past Soil and Sediment Mercury Concentrations

Environmental Pathway	*EFPC Farm Family*	*Robertsville School*	*Scarboro Community*
Soil	EFPC RI	EFPC RI	ORAU
Sediment	EFPC RI	EFPC RI	EFPC RI

The EFPC RI included soil samples from throughout the EFPC floodplain. The samples were plotted on transects, imaginary lines that cross the EFPC floodplain at right angles to the creek. The RI included 159 transects that crossed the full length (23.2 kilometers or 14.4 miles) of the creek. Each was separated by approximately 100-meter (330-foot) intervals. Samples were taken at the edge of the water and every 20 meters (65 feet) away from the creek, up to the elevation of the 100-year floodplain (see Figure 16).

The RI core samples had already been collected, mixed together (i.e., composited), and analyzed before the dose reconstruction project began. Thus the mercury concentrations at various depths in those samples could not be determined. But other studies could provide data that allowed the Task 2 team to estimate the possible vertical mercury distribution. One 1993 study indicated that most of the mercury in the EFPC floodplain was contained within the first 16 inches of soil. This was attributed to the tendency for elemental and mercuric mercury to stay bound to soil and to the fact that elemental mercury is not very soluble in water. With time, cleaner soil and sediment accumulates on top of the more highly contaminated soil and sediment.

In 1992, SAIC conducted a study called the Vertical Integration Study (VIS). SAIC took five 16-inch EFPC soil cores and analyzed each 1-inch depth separately. The cores were taken at four locations:

- EFPC confluence with Poplar Creek
- Grand Cove Subdivision
- Bruner's Center site (two core samples)
- National Oceanic and Atmospheric Administration (NOAA) property

Key findings included the observation that the highest mercury concentrations were deep in the core, and the lowest concentrations were found near the top of the core sample. And when composited, the mercury concentration of the top 16 inches of soil was approximately equal to the average mercury concentration from the individual 16 inches analyzed separately. Task 2 used this observation and the average stratification of mercury in the VIS core samples to construct a table of soil concentration adjustment factors (see Table E-9).

Table E-9. Task 2 Soil Concentration Adjustment Factors

Year	*Adjustment Factor (%)*
1950–1954	100–400
1955–1958	200–500
1959–1962	50–300
1963–1966	50–300
1967–1970	40–200
1971–1974	10–100
1975–1978	5–100
1979–1982	3–50
1983–1986	1–50
1987–1990	2–50
1991–1994	1–30

Source: ChemRisk 1999a

The Task 2 team assumed that the highest mercury concentrations in the VIS core samples were attributable to the period of the highest mercury releases (from 1955–1959), and that the rate of soil deposition in all samples was a constant ¼ inch per year. The Task 2 team assigned specific years to the vertical distribution of mercury concentrations in the VIS samples. The concentrations for different years were then converted to percentages of the average composited concentration. These percentages are the concentration adjustment factors. They are presented as ranges to account for the uncertainty in the actual value of the soil or sediment mercury concentration. The adjustment factors were multiplied by the average soil mercury concentrations in the composited core samples (the top 16 inches of soil) from the EFPC RI to estimate annual average soil and sediment mercury concentrations for the years 1950–1990.

Historic soil and sediment mercury concentrations for the EFPC floodplain farm family and the Robertsville School students were calculated from the RI samples collected near Mile 10 (± 0.5 mile) and near Mile 12 (± 0.5 mile) in the EFPC floodplain, respectively. The historic sediment samples for Scarboro residents were calculated from EFPC RI samples collected near the floodplain's Mile 14 (± 1 mile).

During the RI, samples were defined as either soil or sediment on the basis of where they were collected in proximity to EFPC. Samples collected at the edge of EFPC were considered sediment. But samples used for evaluating soil exposure pathways (the EFPC floodplain farm family and Robertsville School children, for example) included the full set of samples collected from just beyond the edge of the creek, to the elevation of the 100-year floodplain.

For the Scarboro community, mercury concentrations in sediment were calculated from the RI core samples, and mercury concentrations in soil were calculated from the 1984 ORAU study data. The ORAU study included a total of 57 samples from Scarboro—16 samples from Hampton Road and 41 samples near the intersection of Tulsa and Tuskegee Roads. All of the samples were surface samples (0 to 3 inches deep). The Task 2 report does not indicate how historic soil mercury concentrations in the Scarboro community were estimated.

Task 2 used the VIS samples to calculate annual mercury concentrations from the many composited RI core samples. The range of mercury concentrations as a percentage of the average concentration within some of the VIS core samples is wide, varying from less than 1 to 380 percent of the average mercury concentration in the composite sample. The location where the minimum and maximum mercury concentrations are found in the VIS samples often varies

between the samples (the overall pattern of mercury concentrations measured at different depths in the two samples collected from the same location [Bruner's Center] for example, are not similar). To compensate, the Task 2 team extended the ranges of the adjustment factors beyond the measured range for the years with the highest mercury releases to EFPC. Thus in the composite samples, Task 2 increased the upper range of the adjustment factors for the years of the highest mercury releases from 380 percent to 500 percent of the mercury concentration.

Task 2 Results

Task 2 used the soil and sediment mercury concentrations—estimated from its model—to calculate average annual mercury doses for the three potentially exposed communities. None of the Task 2 estimated doses from soil or sediment ingestion for 1950 through 1990 exceeded U.S.EPA's RfD or ATSDR's minimal risk level (MRL) for inorganic mercury. For 1950 through 1966 (except 1962), however, Task 2 estimated upper-end doses to EFPC floodplain farm children could have exceeded the inorganic mercury RfD (though not the MRL) from dermal contact with soil.[42] Also, for 1958 only, Task 2 estimated upper-end doses Robertsville School children could have exceeded the inorganic mercury RfD (though not the MRL) from dermal contact with soil. Still, none of the dermal mercury doses calculated at the 50 percentile exceeded either agency's health guideline value, and none of the calculated doses from sediment exposures exceeded either agency's health guideline value.

Doses exceeding the RfD or MRL do not necessarily presuppose adverse health effects.

Discussion

ATSDR reviewed ORAU soil data. ATSDR identified 43 surface (0–3 inches below surface) soil samples collected in the Scarboro area in 1984.[43] The highest soil mercury concentration among the 43 samples was 3.8 ppm, below ATSDR's comparison value of 20 ppm. ATSDR does not, however, consider the mercury concentrations in ORAU samples collected in the top 3 inches of soil in 1984 as representative of past mercury concentrations in Scarboro soils. Core data from a 1992 study indicate that the floodplain soil layers with the highest mercury concentrations are buried beneath as much as 10 inches of soil and sediment (ChemRisk 1999a). The near-surface soil data collected in Scarboro would not likely reflect historical mercury concentrations in soil and sediment.

The overall weighted-average adjustment factor for the years 1950 through 1990 is nearly 130 percent. This ensures that overall, none of the mercury measured in the top 16-inch cores is "lost" through modeling. The Task 2 team assumed, however, that mercury deposition occurred at a constant rate over the floodplain and that mercury does not migrate significantly in the soil. No studies demonstrate how well these assumptions hold. The model might increase the mercury levels for some years and decrease them in other years, relative to the true concentration values. This averaging effect could underestimate exposures in years with high mercury releases or in

[42] The "upper-end" doses are the 97.5 percentile doses, which, according to the Task 2 report, are the 97.5 percentile confidence levels of the probability density functions (PDFs). The PDFs, which characterize the distribution of doses for each specific pathway, were calculated by Task 2 using Monte Carlo simulations. The 97.5 percentile doses are less likely to occur than doses at lower probability levels; they are calculated with the most extreme exposure assumptions. Task 2, however, considers the highest doses are possible because the full range of assumptions used in its calculations was considered possible.

[43] Some additional samples may have been collected in Scarboro, but ATSDR only identified 43 samples.

areas with high mercury deposits, even considering the wide range of adjustment factors that the Task 2 team adopted for those years. The very small number of samples in the VIS and the poor consistency between mercury concentrations at similar depths suggest that the model is not reliable. Given the small number of samples on which the adjustment factors are based and given the nonuniformity of concentrations within each of the vertical layers, considerable uncertainty surrounds whether the extended adjustment factors adequately reflect the true pattern of mercury distribution in the core samples since 1950.

Additionally, the Task 2 model may not sufficiently account for the mass of mercury in EFPC. The Task 2 team only applied the adjustment factors to the uppermost core data. In some areas of the floodplain, multiple core samples were collected from a single location (maximum of five core samples deep). Historical soil or sediment mercury concentrations could be underestimated if significant mercury were present below 16 inches. SAIC estimated that 18 percent of the soil volume contaminated with mercury at levels greater than or equal to 50 ppm lay in the second core "horizon" (16–32 inches below ground surface), and 29 percent of the soil volume contaminated with mercury at levels greater than or equal to 200 ppm lay in the second core horizon. These analyses indicate that for the highest contaminated regions of the floodplain, the Task 2 efforts to assign soil mercury concentrations to individual years are not reliable.

Given the uncertainties described above, in this public health assessment ATSDR decided to evaluate the soil data without considering the Task 2 team's method of assigning an estimated timeframe of mercury deposition.

The Task 2 Model for Mercury Concentrations in Fish

Before 1970, fish downstream from the Y-12 plant were not collected and analyzed for mercury. But the largest releases of mercury from the Y-12 plant to EFPC occurred during the 1950s and early 1960s. For the years 1950–1990, the Task 2 team estimated average annual mercury concentrations in fish from three bodies of water:

- EFPC
- Poplar Creek (downstream of EFPC) and the Clinch River (downstream of Poplar Creek)
- Tennessee River/Watts Bar Reservoir (downstream of the Clinch River)

The Task 2 team estimated mercury doses from eating fish from EFPC for residents of the Scarboro community and the EFPC floodplain farm family. The Task 2 team also estimated mercury doses for people who ate fish from Poplar Creek/Clinch River and the Tennessee River/Watts Bar Reservoir. Where the latter fish-eating populations lived was not identified; people who fish in these waters come from all around the area.

The Task 2 team considered that if mercury concentrations in fish were proportional to mercury concentrations reported in sediments, historic sediment data could be used to estimate past mercury concentrations in fish. Task 2 therefore studied the relationship between mercury concentrations in fish and mercury concentrations in surface sediment samples collected during the 1970s and 1980s in EFPC, Poplar Creek, the Clinch River, and the Tennessee River (to Watts Bar Dam). Fish data were compared with sediment data from samples collected near one another in the water. Linear, semi-log, and log-log regression analyses were conducted of mercury concentrations in bluegill sunfish and largemouth bass and compared to mercury concentrations in sediment. The database for other fish species was too small to analyze and both bluegill

sunfish, and largemouth bass are resident sport species anglers commonly catch for eating. Mercury concentrations in bluegill sunfish and largemouth bass correlated well with surface sediment mercury concentrations using linear regression analysis.[44] The mercury concentrations in sediments that were co-located with fish samples ranged from 0.18 to 99 ppm (bluegill sunfish) and 0.18 to 46 ppm (largemouth bass).

The general approach was to apply the regression equations for bluegill sunfish and largemouth bass (developed from 1970s and 1980s fish and sediment data) to mercury concentrations in sediment for the years 1950–1990, to estimate fish mercury concentrations for those years. Some characteristics of the model the Task 2 team used to estimate mercury in fish are described below.

The sediment mercury concentrations used for these calculations were estimated from six sediment core samples taken in the 1980s from EFPC, Poplar Creek, the Clinch River, and the Tennessee River. The team assigned different years to different core depths based on an analysis of mercury and cesium-137 in the sediment samples and estimates of the annual quantities of mercury and cesium-137 released from the Y-12 plant. Concentrations of both mercury and cesium-137 in sediment layers were assumed to be proportional to the annual quantities of mercury and cesium-137 released from the Y-12 plant.

To estimate the fish mercury concentrations, the Task 2 team used one core sample and one surface sediment sample for fish from EFPC, three core samples from Poplar Creek and the Clinch River, and two core samples from the Watts Bar Reservoir. The six sediment cores analyzed to estimate past mercury concentrations in fish were collected from the following six locations:

1. New Hope Pond, in EFPC immediately downstream from the Y-12 plant,
2. Poplar Creek near the confluence with EFPC,
3. The Clinch River approximately midway between the confluence of Poplar Creek and the confluence of the Clinch River with the Tennessee River,
4. One mile up from the confluence of the Clinch River,
5. Just past the confluence of the Clinch River in the Tennessee River, and
6. Eight miles upstream of Watts Bar Dam in the Tennessee River (Watts Bar Reservoir).

Having generated the regression model, Task 2 dispensed with it when the sediment mercury concentrations in core samples exceeded the regression limits. Task 2 did not assume that the correlation between fish and sediment mercury concentrations was linear beyond the range of the data used in the regression analysis. The Task 2 team, then, did not apply the regression equations to sediment mercury concentrations above 99 ppm. For years corresponding to sediment layers whose mercury concentrations exceeded

During 1969, a chloralkali plant on the St. Clair River discharged approximately 30 pounds of elemental mercury per day to the river.

In 1970, sediment mercury concentrations of up to 1,700 ppm were measured in the river. In 1971, mercury was analyzed in fish collected in the river and further downstream in Lake St. Clair.

From this study, the Task 2 team selected mercury concentrations for past years (during years of peak releases from the Y-12 plant) from fish that were comparable species and sizes to those in Poplar Creek and the Clinch River.

[44] The squared correlation coefficients (r^2) for bluegill sunfish and largemouth bass were 0.69 and 0.66, respectively, indicating a good correlation.

those in the linear regression model (99 ppm), Task 2 used default fish mercury concentrations from a fish study in 1971 from the St. Clair River and Lake St. Clair in the Great Lakes region. This was the case for some layers of sediment in EFPC and Poplar Creek.

Task 2 Evaluation of EFPC Fish Concentrations

For EFPC, the Task 2 team examined a 1982 sediment core sample collected from the upper end of EFPC in New Hope Pond, downstream of Y-12 buildings. For the lower end of EFPC, before EFPC feeds into Poplar Creek, no core samples were taken, but a surface sediment sample was collected in 1982. The Task 2 report noted that the surface sediment mercury concentration at the lower end of EFPC was approximately 20 percent of the surface sediment mercury concentration at New Hope Pond. The Task 2 team assumed that the historic sediment mercury concentrations at the lower end of EFPC were 20 percent of those for the same years at New Hope Pond.

But the New Hope pond was dredged in 1973. The sediment core only included sediment as old as 1973; any preexisting sediment was removed at that time. All the New Hope Pond mercury concentrations in sediment between 1973 and 1982 exceeded the upper end of the sediment concentrations used to generate the regression equations. And all of the fish concentrations at New Hope Pond, including those before 1973, were default values from the St. Clair River/Lake St. Clair study. The lower limit, mean, and upper limit fish concentrations that the Task 2 team selected for fish in EFPC from the St. Clair River/Lake St. Clair study were 1, 1.7, and 4 ppm for bluegill sunfish, and 2, 3.2, and 4.5 ppm for largemouth bass.

At the lower end of EFPC, the same default fish mercury concentrations from the St. Clair River/Lake St. Clair study were used for the years between 1950 and 1964. The Task 2 team assumed that sediment mercury concentrations exceeded the sediment regression limit values for those years. Beginning in 1965, the Task 2 team reported that it applied the regression equations to the estimated sediment concentrations to calculate fish mercury concentrations for the lower end of EFPC. The Task 2 report, however, does not present the sediment mercury concentrations it used with the regression equations for those calculations. Information gaps mean data gaps in certain periods.[45] After 1982 (after the date of the New Hope Pond core sample, for example), the Task 2 team presumably used analytical data from fish collected in EFPC. But the report does not describe what data it used or how it calculated fish mercury concentrations for those later years.

The highest Task 2 estimated annual fish mercury concentrations in EFPC were for the years from 1950 to 1964. The minimum, mean, and maximum average annual fish mercury concentrations for those years were 1.5, 2.5, and 4.3 ppm, respectively. These values are the averages of the default fish mercury concentrations from the St. Clair River/Lake St. Clair study for bluegill sunfish and largemouth bass; they were not calculated using the regression equations.

[45] For example, if the sediment mercury concentrations at the lower end of EFPC were assumed to be 20 percent of those in New Hope Pond, but the oldest sediment in New Hope Pond was from 1973, what sediment data were used between 1965 and 1972?

Task 2 Evaluation of Poplar Creek/Clinch River and Tennessee River/Watts Bar Reservoir Fish Concentrations

For the sediment core sample collected at the Poplar Creek location below the confluence of EFPC, mercury concentrations in core sample layers corresponding to the years from 1956 to 1961 exceeded the maximum surface sediment mercury concentrations used to generate the correlation equations.[46] Again, Task 2 took default mean and maximum fish mercury concentrations (3.3 and 7 ppm, respectively) from the St. Clair study. The same values were used for both bluegill sunfish and largemouth bass.[47] In other years and at sediment core sample locations farther downstream, Task 2 used the regression equations to calculate fish mercury concentrations.

The Task 2 team averaged together the estimated fish mercury concentrations at the locations of the sediment core samples in each water segment. It also averaged together the estimated mercury concentrations of the bluegill sunfish and largemouth bass.

The Task 2 team calculated 95 percent confidence intervals around the predicted mean fish concentrations associated with sediment core mercury concentrations, using the regression model's estimated standard error. The averaging of mercury concentrations in fish from different locations in a water segment, from two fish species, and the use of confidence intervals based on the regression model resulted in three mercury concentrations (a minimum, a mean, and a maximum) for each year (1950–1990) for each water segment.

Generally, the sediment mercury concentrations (and correlated fish mercury concentrations) the Task 2 team used were higher closer to the Y-12 plant and decreased with distance downstream. Table E-10 contains the mean fish mercury concentrations for each surface water segment for the years 1950–1970.

[46] The upper Poplar Creek sediment mercury concentrations from 1956–1961 ranged between 156 and 460 ppm.
[47] The Task 2 team used different values than those used for fish from EFPC.

Table E-10. Estimated Annual Average Mercury Concentrations in Fish (1950–1970)

Year	*EFPC (ppm)*	*Poplar Creek/Clinch River (ppm)*	*Watts Bar Reservoir (ppm)*
1950	2.5	1.1	0.13
1951	2.5	1.1	0.13
1952	2.5	1.1	0.16
1953	2.5	1.4	0.17
1954	2.5	1.2	0.19
1955	2.5	0.9	0.34
1956	2.5	2.2	0.52
1957	2.5	2.6	0.66
1958	2.5	2.5	0.74
1959	2.5	2.4	0.74
1960	2.5	2.2	0.52
1961	2.5	2.0	0.29
1962	2.5	1.9	0.29
1963	2.5	1.2	0.27
1964	2.5	0.97	0.25
1965	2.5	0.82	0.25
1966	2.5	0.73	0.23
1967	2.5	0.63	0.22
1968	2.4	0.52	0.22
1969	2.4	0.55	0.20
1970	2.4	0.58	0.19

Concentrations are based on fresh weight samples.
ppm: parts per million

Task 2 Mercury Doses to Humans

The Task 2 team used the estimated fish mercury concentrations to calculate mercury doses for past fish consumption.[48] Table E-11 contains the mean fish ingestion rates that the Task 2 team used in its dose calculations. The Task 2 team generated unspecified "custom" distributions of childhood ingestion rates from the adult rates.

The Task 2 team calculated doses using a Monte Carlo simulation. This produces a central dose value and lower and upper bound values corresponding to the 95 percent confidence interval around the central value. The Task 2 team compared its estimated mercury doses to U.S.EPA RfDs for ingestion of methylmercury.

[48] Most of the mercury found in fish is methylmercury.

Table E-11. Task 2 Average Fish Mercury Dose Ingestion Rates

Population	*Location*	*Body Size*	*Ingestion Rate (g/d)*	*Ingestion Rate (m/y)*
Scarboro	EFPC	adult	1.2	2.6
Scarboro	EFPC	child	0.27	0.58
EFPC Floodplain Farm Family	EFPC	adult	1.2	2.6
EFPC Floodplain Farm Family	EFPC	child	0.27	0.58
Commercial Angler	Poplar Creek/Clinch River	adult	2.2	4.7
Commercial Angler	Poplar Creek/Clinch River	child	0.49	1.1
Recreational Angler	Poplar Creek/Clinch River	adult	18	39
Recreational Angler	Poplar Creek/Clinch River	child	4.0	8.6
Commercial Angler	Watts Bar Reservoir	adult	24	52
Commercial Angler	Watts Bar Reservoir	child	5.4	12
Recreational Angler	Watts Bar Reservoir	adult	30	64
Recreational Angler	Watts Bar Reservoir	child	6.7	14

Source: ChemRisk 1999a
g/d: grams per day
m/y: meals per year
The adult ingestion rates are arithmetic means of lognormal distributions.
A fish meal is assumed to be approximately 6 ounces or 170 grams.

Using the ingestion rates presented in Table E-11, the Task 2 team determined that none of the estimated methylmercury central dose values for Scarboro residents and the EFPC floodplain farm family (adults or children) who ate fish from EFPC exceeded the RfD for methylmercury. But at the upper bound end of the estimated dose range, all of the estimated doses for the same two populations exceeded the RfD for all the years from 1950 through 1990.

For people who fished in Poplar Creek or the Clinch River, the central doses of recreational fishers exceeded the RfD for methylmercury for the years from 1950 through 1964. For Watts Bar Reservoir (Tennessee River) fishers, the central dose value for methylmercury exceeded the RfD for 1957, 1958, and 1959 only.

At the high end of the dose range (the 97.5 percentile doses), all the Task 2 report estimated doses to recreational anglers who fished in Poplar Creek/Clinch River and both recreational and commercial anglers who fished in Watts Bar Reservoir exceeded the RfD. The upper bound estimated doses to commercial anglers who fished in Poplar Creek/Clinch River exceeded the RfD from 1950 through 1967.

Discussion

The sediment core samples were used to estimate mercury concentrations in fish. These values were generally spread out across the upper and lower ends of each water segment between EFPC and Watts Bar Dam. The small sample size, however, may not adequately represent the past sediment mercury concentrations (and correlated fish tissue concentrations) in the surface water segments downstream from the Y-12 plant: only three core samples were used in the Task 2 model to represent nearly 12 miles of Poplar Creek and the Clinch River. Only two core samples were used to represent approximately 30 miles of the Tennessee River.

Mercury in the EFPC floodplain soil is not distributed evenly. Nor is it simply deposited in quantities inversely proportional to distance from the Y-12 plant. Sediment is often mobile in these surface stream beds. Numerous regions of the stream beds have no apparent sediment accumulation at all. Even in places where sediment accumulates, it may be subject to significant agitation and dispersion. No co-located sediment core samples with surface sediment samples were found that to examine the consistency of the mercury measurements. In addition, no independent means were available to judge how representative the core sample layers are of surface sediment mercury concentrations across the miles of creeks and rivers in past years.

The Task 2 team used default mercury concentrations for fish in EFPC and Poplar Creek in some years; published studies suggested limits to the amounts of mercury that fish can bioaccumulate. The Task 2 team listed three laboratory studies that indicate mercury body burdens ranging between 10 and 20 ppm are lethal to rainbow trout. Yet the relevance of those studies to fish in EFPC in the 1950s is questionable.[49]

The St. Clair River and Lake St. Clair studies of mercury in fish suggest limits to the amounts of mercury that bluegill sunfish and largemouth bass accumulate. The water environments in those studies, however, may have been dissimilar to EFPC in ways that affected available fish diets, methylmercury production, and the fish accumulation of mercury. Many hazardous substances (such as industrial cleaning chemicals) were released in large quantities to EFPC during the earlier decades of the Y-12 plant operations. These releases likely contributed to poor aquatic health and to smaller numbers of fish and smaller sized fish in EFPC than in later years. The St. Clair studies included similar sizes and species of fish (bluegill sunfish and largemouth bass) as those analyzed in EFPC. But different conditions may have obtained (more aquatic tropic layers, for example) in the St. Clair studies that affected the bioaccumulation of mercury differently than in EFPC. Moreover, the maximum mercury concentrations in sediments reported from the St. Clair studies (up to 1,700 ppm) were about one-half the maximum mercury concentrations measured in the EFPC floodplain soils (3,420 ppm). ATSDR does not have sufficient information to determine whether the St. Clair mercury concentrations in fish are good surrogates for those in EFPC and Poplar Creek during the 1950s and 1960s. Consequently, ATSDR thinks the fish mercury concentrations, which the Task 2 team adopted for the mercury dose reconstruction, do not reflect adequately the level of uncertainty associated with these data.

In summary, ATSDR believes the Task 2 team relied on fewer sediment core samples than needed to estimate adequately past mercury concentrations in sediment, And consequently, to provide reliable estimates of fish tissue concentrations from these water bodies. The applicability of the St. Clair data is unknown and need to be explored further before data from this study can be used with confidence.

Task 2 Vegetation Model for Mercury Concentrations

The Task 2 team calculated deposition of mercury from the air to above-ground vegetation. Total deposition was calculated by adding the amount deposited during dry conditions to the amount deposited during wet conditions.

The dry deposition component of the equation takes the total dry deposition velocity and accounts for the amount retained by the vegetation in relation to the mass of the vegetation.

[49] For example, in the trout studies, mercuric chloride was put into the water, where as elemental mercury and mercuric nitrate were released from the Y-12 plant into EFPC.

The wet deposition component of the equation takes into account climatological conditions. This component requires additional parameters to calculate wet deposition velocity, specifically the washout ratio and the average annual precipitation rate.

The dry and wet deposition components are then added together to calculate the total deposition from the air onto vegetation.

ATSDR's Technical Review

ATSDR's technical reviewers commented that the Task 2 report's assumptions in estimating air to plant mercury transfer appeared reasonable. One reviewer, however, criticized the report for combining the distinct issues of mercury deposition on plants and mercury absorption by plants. Another reviewer commented that the report had probably slightly overestimated the deposition of mercury on fruits and fruiting vegetables. He pointed out the following:

- The analysis treats mercury deposition as a function of mass, rather than surface area. Because fruits and fruiting vegetables (peppers, tomatoes, squash, for example) have lower surface area-to-mass ratios, the report's analysis probably exaggerated the degree of mercury accumulation.
- Estimating mercury in plant fruits and stems based on deposition is likely an overestimate; mercury is unlikely to be translocated within the plant.
- The analysis assumes that airborne Hg° deposited on plant surfaces is completely oxidized to Hg^{+2}. Because this process is gradual, however, a portion of the Hg° deposited onto plant surfaces is lost due to revolatilization.
- The analysis assumes that the mercury ingested in aboveground fruits and vegetables is Hg^{+2}, however a portion of this is Hg°, which has a low absorption rate in the gastrointestinal tract.
- The use of mass interception factors for small aerosols, mists, and gases may overestimate the accumulation of mercury in vegetation depending on the aerosols/mists/gases used to determine the factors. Hg° is relatively insoluble, and will likely stay near the air (that is, the surface).

A third technical reviewer commented on the huge uncertainty in the calculations of mercury transfer to vegetation. Still, he noted that the estimates are probably adequate to assess their contribution to the overall exposure of persons. The fourth technical reviewer noted several uncertain components in the calculation of air concentrations and deposition to vegetation. To remove some of the uncertainty, he suggested the required data could be obtained by a field study or a wind-tunnel (environmental chamber) study.

Discussion

Task 2's approach seems reasonable. It might even be the best estimate available. But how accurately this model represents actual exposures from 50 years ago is unclear. The key parameters with the greatest apparent influence on the estimated concentration (air concentration, weathering rate of vegetables, fraction of mercury remaining after washing, and the bioavailability factor, for example) are either 1) highly uncertain, 2) taken from literature relating to radionuclides in plants, or 3) based on professional judgment. Given these observations, to determine what the estimated numbers truly mean is difficult. Using past ATSDR modeling

experience, estimating historical air concentrations is a challenge. And estimating plant tissue concentrations that result from air concentrations adds an entire level of complexity, as well as uncertainty.

Appendix F. Evaluation of Mercury Emissions from Selected Electricity Generating Facilities

- M E M O R A N D U M -

DATE: June 15, 2005

TO: Jack Hanley and Bill Taylor, ATSDR

FROM: John Wilhelmi, ERG

RE: **Oak Ridge Reservation: Evaluation of Mercury Emissions from Selected Electricity Generating Facilities**

This memo presents ERG's evaluation of past air emissions of mercury from electricity generating facilities near the Oak Ridge Reservation, such that ATSDR has context for evaluating past inhalation exposures to mercury in the vicinity of Oak Ridge. ERG used two different analyses to comment on this matter. First, for *qualitative* insights on air quality impacts from electricity generating facilities, this memo presents a brief review of EPA's 1997 "Mercury Study Report to Congress" (EPA 1997). Second, the memo presents *quantitative* estimates of air quality impacts from an electricity generating facility operated by the Tennessee Valley Authority (TVA). The memo concludes with summary statements based on the two different types of analyses. Citations for all references are presented at the end of the memo.

Review of EPA's 1997 "Mercury Study Report to Congress." For general insights into potential mercury air quality impacts from power plants, ERG first reviewed EPA's 1997 "Mercury Study Report to Congress" (EPA 1997)—an extensive overview of the environmental and health impacts associated with environmental releases of mercury. The following paragraphs summarize key statements from this report, specifically those that pertain to coal-fired power plants. No references are provided in this section, as all information was taken from the EPA report (EPA 1997).

- *Emissions.* The EPA report includes a detailed inventory of anthropogenic emissions sources of mercury for a 1994-1995 baseline. The report acknowledges that significant amounts of mercury are also released from non-anthropogenic sources, including natural sources (e.g., volcanoes) and sources that "re-emit" mercury to the environment after it deposits from the air (e.g., volatilization from oceans, soils, and other media).

  The inventory of anthropogenic sources considers more than 30 different source categories, including electricity generating facilities, incinerators, chlor-alkali facilities, mobile sources, and numerous others. Emissions from coal-fired boilers, which ranked highest of all these source categories, were estimated to account for 33 percent of the total nationwide mercury air emissions from anthropogenic sources. Emissions estimates for these power plants were computed from multiple input parameters, including coal throughput, average concentration of mercury in coal, and mercury reductions attributed to coal cleaning and air pollution controls.

Mercury emitted from these sources can be found in different chemical forms (elemental and compounds) and different physical forms (vapor phase and particle-bound), and the speciation of mercury emissions significantly affects fate and transport properties, as described below. Mercury species emitted from coal-fired power plants reportedly vary with coal type, boiler design, and operating conditions. The EPA report presents limited data on speciation for these sources, but suggests the following mercury speciation for air emissions from coal-fired power plants: 50 percent as elemental mercury vapor, 30 percent as divalent mercury vapor, and 20 percent as particle-bound mercury.

- *Fate and transport.* Though the EPA report includes an extensive multi-media fate and transport analysis of local, regional, and global mercury cycling, this memo focuses on conclusions that pertain to atmospheric transport on local scales (i.e., less than 50 km from the emissions source). On these local scales, the report repeatedly emphasizes that fate and transport behavior of mercury depends largely on its chemical and physical state.

  On the one hand, *elemental mercury vapor* can remain airborne for roughly 1 year and transport thousands of miles from emissions sources. The primary removal mechanisms for the mercury vapor are deposition, chemical conversion to mercury compounds, and uptake and retention by plants. However, such mechanisms appear to have fairly slow kinetics, as EPA modeling results suggest that only a small percentage (<5 percent) of mercury vapor emissions deposits to the surface within 50 km of a coal-fired plant. Because of this, elemental mercury vapor typically accounts for the majority of total airborne mercury (see next section).

  On the other hand, *airborne mercury compounds* (divalent mercury) and *particle-bound mercury* have estimated residence times in the atmosphere of a few days or less. These forms of mercury are more readily removed from the atmosphere by both dry and wet deposition processes. Therefore, these forms of mercury account for smaller percentages of total airborne mercury.

- *Ambient air concentrations.* According to several environmental monitoring studies, elevated mercury concentrations in multiple environmental media have been measured around large mercury emissions sources. However, no comprehensive monitoring data are available to quantify the exact extent to which various emissions sources contribute to measured air concentrations. Qualitatively, ambient air concentrations of mercury at any given location will depend on the locations of nearby sources, the amounts and species of mercury emitted, and local meteorological conditions.

  EPA's report includes a brief review of several ambient air monitoring studies published in the 1990s. In all studies and monitoring locations considered, average concentrations of total airborne mercury were less than 50 ng/m^3—EPA's Reference Concentration (RfC) for mercury. Moreover, the monitoring results clearly showed that most airborne mercury is in the form of mercury vapor: average air concentrations of mercury vapor were consistently at least 20 times greater than corresponding average concentrations of particulate-bound mercury.

  EPA's report also presents monitoring data from a single study designed to characterize mercury air quality impacts from a coal-fired power plant. That study reported no significant differences between particulate-bound mercury concentrations measured 5 km upwind and 5 km downwind from the source of concern; no information was provided on whether the study considered vapor phase concentrations.

In addition to summarizing measured concentrations, EPA's report presents estimated concentrations based on dispersion modeling analysis. Of particular interest, EPA evaluated air quality impacts from a generic "large coal-fired power plant" (i.e., a plant with 975 Megawatt capacity that emits 230 kg of mercury to the air per year). Using typical stack parameters and mercury speciation data, the modeling predicted that ground-level ambient air concentrations of mercury at distances 2.5 km, 10 km, and 25 km from the generic power plant would be less than 1.7 ng/m^3—the background concentration attributed to natural sources and re-emitted mercury. Thus, the incremental air quality impacts from large coal-fired power plants were estimated to be essentially negligible in comparison to EPA's RfC.

- *Exposure and risk.* The EPA report repeatedly emphasizes that, nationwide, exposure to mercury is dominated by the fish ingestion pathway. This conclusion was based on estimated exposures for numerous scenarios, including evaluations of exposures in the vicinity of coal-fired power plants. Chlor-alkali plants were the only industrial source category predicted to cause notable exposures via the inhalation pathway. Although EPA's report does not provide quantitative risk or hazard estimates, the modeling results clearly show that the estimated air quality impacts from the generic coal-fired power plant were below appropriate health benchmarks.

Screening Modeling Analysis. To supplement the general information available from EPA's "Mercury Study Report to Congress," ERG conducted a screening dispersion modeling analysis to examine potential air quality impacts from the Tennessee Valley Authority (TVA) Kingston Fossil Plant.[50] Construction of this facility was completed in 1955 and operations continue today. The facility currently consumes approximately 14,000 tons of coal per day and has a winter net generating capacity of 1,456 Megawatts (TVA 2005). Thus, current operations appear to be slightly larger than those considered in EPA's modeling efforts of a "large coal-fired power plant." Information on coal usage data for earlier years is not available.

The purpose of the screening analysis was to estimate coal usage rates at the Kingston Fossil Plant that might be expected to cause elevated air quality impacts in the immediate vicinity of the Y-12 Plant, located more than 25 km away. ERG used a screening model (SCREEN3) to estimate air quality impacts based on the following release parameters:

- Stack height = 100 feet (30.5 meters)
- Stack diameter = 15 feet (4.6 meters)
- Stack exit velocity = 70 feet/second (21.3 meters/second)
- Stack exit temperature = 270 degrees Fahrenheit (405 degrees Kelvin)

With one exception, these release parameters were estimated from recent data that the Department of Energy compiled on electricity generating facilities across the country.[51] As the exception, the stack height was set artificially low to reflect the approximate stack heights at the

[50] ERG did not evaluate air quality impacts from the Bull Run Plant, because construction of that facility was not completed until 1967, which is several years after the time frame of interest for ATSDR's evaluation of mercury issues.

[51] ERG ran sensitivity analyses on the model to assess the impacts of uncertainty in the input parameters. Lower stack heights, lower exit velocities, and lower exit temperatures would all lead to higher estimates of air quality impacts, but the modeling analysis was not unusually sensitive to any of these parameters. For instance, a 10% decrease in stack height resulted in only a 5% increase in estimated air concentrations at the receptors of interest.

Kingston Fossil Plant during the time when the Y-12 facility released considerable quantities of mercury. Several additional assumptions were programmed into the model:

- ERG assumed that all mercury in the coal burned at the Kingston Fossil Plant became airborne, with none collected by pollution controls, removed in coal cleaning processes, or sequestered in ash. This assumption should serve to overstate actual air quality impacts.
- ERG assumed that all mercury is released as elemental vapor and remains airborne throughout the modeling domain. By not considering deposition, this assumption causes the model to overstate the amounts of mercury in air and available for human exposure.
- ERG assumed that annual average concentrations of mercury near Y-12 are 8 percent of the maximum hourly average concentrations. This factor is documented in EPA guidance for screening analyses (EPA 1992) and is used to extrapolate the 1-hour maximum levels in the SCREEN3 outputs to longer averaging times. According to EPA, "a degree of conservatism is incorporated in the factor to provide reasonable assurance that maximum concentrations…will not be underestimated" (EPA 1992). ERG further notes that the factor will tend to overstate long-term air quality impacts with increased distance from the emissions source. Thus, ERG has reason to believe that using this factor could considerably overstate air quality impacts.
- ERG assumed no complex terrain separates the Kingston Fossil Plant and the Y-12 Plant. In reality, several small ridges separate these two areas, and these ridges would likely inhibit atmospheric transport of the Kingston Fossil Plant's emissions toward the Y-12 area. By not considering these terrain features, the screening analysis likely overstates the potential air quality impacts in the vicinity of Y-12.
- ERG used data from a recent EPA guidance document on estimating air emissions from electricity generating facilities (EPA 2000) for a default concentration of mercury in coal. That document lists typical mercury concentrations for coal mined in different states across the country. ERG used the highest mercury composition in the entire document (0.42 ppm by weight) in the calculations of air quality impacts. While using the highest mercury composition figure is likely another conservative assumption, ERG acknowledges that the mercury content of coal in specific mining areas might exceed the highest statewide average used in this analysis. The screening analysis can be further refined if TVA were to provide composition data for the coal that was previously used at the Kingston Fossil Plant.

Based on the aforementioned input parameters and assumptions, the SCREEN3 model outputs predict that ambient air concentrations of mercury near Y-12 likely would not have exceeded the RfC (0.05 $\mu g/m^3$) unless the Kingston Fossil Plant was burning nearly 275,000 tons of coal *per day*. For reference, this coal throughput is approximately 20 times greater than the current coal usage rates and almost undoubtedly exceeds the processing capacity of the facility. In other words, even when considering the combination of multiple assumptions that likely overstate air quality impacts, it seems exceedingly unlikely that air emissions from the Kingston Fossil Plant could have caused ambient air concentrations near the Y-12 Plant to approach health benchmarks.

ERG acknowledges that this screening analysis has inherent limitations and uncertainties. Most notably, the analysis only estimates air quality impacts, which may not adequately represent actual conditions. However, the approach of including multiple conservative assumptions (i.e., assigning highly uncertain inputs values that are known to overstate air quality impacts) provides

some confidence that this analysis does not underestimate actual air concentrations. Additionally, the sensitivity analysis provides further confidence that the modeling outputs are not strongly dependent on the stack parameters that were chosen as model inputs. There are several opportunities for reducing model uncertainty. These include, but are not limited to, obtaining site-specific data on actual coal usage for the time frame of interest, obtaining data on the typical mercury content of the coal that was burned, or using a refined dispersion model. However, the results of this screening analysis suggest that additional modeling for this issue might not be necessary.

Conclusions and Recommendations. The following summary statements are supported by the analyses presented earlier in this memo:

- EPA's "Mercury Study Report to Congress" suggests that emissions from coal-fired power plants have extremely limited incremental effects on ground-level air quality. The modeling analyses EPA conducted on a hypothetical coal-fired power plant found essentially no ground-level impacts at locations 2.5 km, 10 km, and 25 km downwind.
- Consistent with these general findings, ERG's screening modeling analysis showed that past mercury emissions from the TVA Kingston Fossil Plant almost certainly did not have substantial air quality impacts (i.e., concentrations approaching the RfC) near the Y-12 Plant, even when considering a series of health-protective assumptions.

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Appendix G. Past Exposure Pathway Parameters

Surface Water Ingestion

As far as ATSDR has been able to determine, East Fork Poplar Creek (EFPC) water has not been used as a primary source of drinking water since the time the Y-12 plant was built in the early 1940s. ATSDR's exposure pathway evaluation of mercury in EFPC water thus includes only incidental ingestion and dermal contact with the water.

ATSDR has sufficient anecdotal information that children played and swam in EFPC. For example, several people told ATSDR that they did so as children, or they knew children who did. ATSDR also knows of adults who waded through the creek for various reasons and on occasion possibly fell into the creek. Some people washed their horses in EFPC. ATSDR knows, with less certainty, how many children and adults played or swam in the creek, how often they did, how much the children weighed, who played in the creek, and how much water they swallowed when they played in the creek. These exposure parameters are based on a series of assumptions, as described below.

Body Weight (BW): The mean age of an 8-year-old child is 28.1 kg (EPA 1997). The body weight could have been lower, but ATSDR thought the chances were less likely that such a small child would be playing in EFPC.

Ingestion Rate (IR): ATSDR knows that children get water in their mouths when they swim. ATSDR assumed that children who swam inadvertently swallowed 0.15 liters of water each day they were in the creek (EPA 1997). ATSDR surmises that children old enough to play in the creek knew not to swallow the water intentionally, but that children inadvertently do swallow water is well known.

Exposure Frequency (EF): ATSDR assumed a child could have played in the water for up to 2 weeks (for acute exposures) or intermittently for 75 days over the course of a year (for intermediate-duration exposures). ATSDR selected 75 days for intermittent exposures as follows: first, Oak Ridge receives an average of 60 inches of rain or snow (combined) per year. Therefore, ATSDR estimated that children did not play outside for approximately 3 months during the year because of wet weather. ATSDR also assumed that another 3 months were too cold or too hot to play outside in the creek. In the remaining 6 months, during 3 of those months children might have played outside 15 days per month, and for the remaining 3 months they might have played outside 10 days per month. In this estimate, the total number of days a child played outside, and in EFPC, was 75 days. This means that a child played in EFPC 20 percent of the days of the year (75 days ÷ 365 days = 0.2), which ATSDR considers a conservative estimate.

For the longer-duration exposures, the dose is calculated from an average of mercury concentrations over a calendar quarter. For acute exposures, the dose is calculated from (higher) average weekly water mercury concentrations.

Summary of Assumptions Implemented for Analysis of the Water Exposure Pathway

To determine how much of the mercury released to EFPC was elemental mercury was not possible. No reliable information provides the dates or quantities of elemental mercury disposed of in EFPC. On suggestion is that the amount of elemental mercury increased after mercury spills occurred. Elemental mercury is measurable in water, but it has a very low solubility (0.056 mg/L at 25° C). Elemental mercury is also very bio-unavailable. Thus ATSDR's calculations assumed that 100 percent of the inorganic mercury in water behaved like the ionic forms of inorganic mercury, such as mercuric nitrate. This was a conservative assumption—mercuric nitrate is one of the most bioavailable forms of mercury.

ATSDR's Human and Environmental Exposure Assumptions for the Surface Water Ingestion Pathway

A child weighing 28.1 kg swam or played in EFPC for as many as 75 days a year, and accidentally swallowed 0.15 liters of water from the creek each day he or she played in the creek.

The child played in the creek daily, for up to two weeks, on some occasions (for acute exposures); and intermittently for 75 days during a year at other times (for longer-duration exposures).

The mercury in the water was 100 percent inorganic mercury when inorganic mercury doses were calculated.

100 percent of the methylmercury in the water is bioavailable and 60 percent of the inorganic mercury in the water is bioavailable.

Weekly water mercury concentrations were used to evaluate acute exposures.

Quarterly water mercury concentrations were used to evaluate longer-duration exposures.

The portion of methylmercury in EFPC during the 1950s and 1960s was less than 1 percent of the total mercury. For the purposes of calculating doses to methylmercury, ATSDR assumed that the portion of methylmercury was equal to 0.3 percent of the total mercury concentration. This percent was the highest measured concentration of methylmercury found in the scientific literature. For the purposes of calculating exposure doses to inorganic mercury in water, ATSDR assumed that 100 percent of the mercury in the water samples was inorganic mercury. These were conservative assumptions; the methylmercury portion was likely less than 0.3 percent.

ATSDR hypothesized that there was a loss of mercury to sediment and air between its source at the Y-12 plant and the nearest property off site where children could have played. How much mercury was lost to sediment and air is not known, but because that distance is relatively short, we assumed the amount of mercury lost was insignificant. The values of the reported mercury concentrations due to loss of mercury from the water thus were not reduced. This was a conservative assumption—some mercury was in fact lost to sediment and air.

ATSDR surmised that some mercury in the water remained dissolved. And that some mercury precipitated and was bound to other inorganic or organic species. Mercuric sulfide for example was present in the soils. To assume that mercuric sulfide formed in the water was reasonable. But how much inorganic mercury was fully dissolved and how much was not dissolved was not known. Thus we made no specific assumption concerning the proportion of dissolved and undissolved inorganic mercury in water; it doesn't help to identify the amount of mercury that was bioavailable. We did not suggest that the distribution of bioavailable and biounavailable inorganic mercury necessarily was in the same proportion as the distribution of dissolved and undissolved mercury in water. We knew that fully dissolved mercuric chloride was not 100 percent bioavailable. At the same time, precipitated or bound mercury could become dissolved and bioavailable in the stomach.

ATSDR assumed that the relative bioavailability of inorganic mercury in EFPC in the 1950s was 60 percent. This value was calculated from the reported bioavailability of mercuric nitrate (15 percent) divided by the reported upper range of the bioavailability of mercuric chloride in adult mice (25 percent). This assumption is equivalent to assuming that the mercury in the water in EFPC is absorbed into the bloodstream to the same extent as mercuric nitrate. This is likely a conservative assumption—it does not consider that some of the mercury was lost from the water and some might have been less bioavailable than was mercuric nitrate.

No sufficient data are available to estimate the bioavailability of inorganic mercury in EFPC during the 1950s.

Although the relative bioavailability factor is highly uncertain and variable, ATSDR's conclusion is not strongly dependent on the choice of bioavailability factors. A higher relative bioavailability factor means more data (more weeks) are available when the mercury concentrations exceeded the acute oral inorganic mercury MRL; a lower relative bioavailability factor means fewer weeks when the data exceeded the MRL. Using a relative bioavailability factor of 60 percent (ATSDR's choice), weekly concentrations that exceed the MRL are available during the years 1956, 1957, and 1958. If the relative bioavailability factor is lowered to 40 percent, only weekly data during 1957 and 1958 exceed the MRL. Only at a relative bioavailability below 11 percent would all of the weekly mercury concentrations fall below the acute oral MRL. But no compelling evidence suggests reducing the relative bioavailability below 11 percent, which is an absolute bioavailability for inorganic mercury of less than 3 percent.

Mercury Water Exposure Pathway Data Assessment Limitations

- Missing data prior to 1956
- Analytical methods for measuring mercury were no better than ± 40percent
- Not known how much mercury was lost to sediment and air
- No real good sense of the relative bioavailability of mercury in EFPC water

Results

Using all of the above-mentioned assumptions, ATSDR calculated mercury doses and made the following observations:

- The calculated short-term inorganic mercury doses from ingestion of water from EFPC between May and September were ***above*** the ATSDR acute oral inorganic mercury MRL in 1956, 1957, and 1958, but not in other years.
- The calculated longer-duration inorganic mercury doses were ***below*** the ATSDR intermediate oral inorganic mercury MRL for all years.
- The calculated methylmercury doses were ***below*** the ATSDR chronic oral methylmercury MRL for all years.

Soil-Sediment Ingestion

ATSDR considered two types of mercury in the soil—inorganic mercury and methylmercury. The mercury in EFPC floodplain soil and sediment is primarily inorganic mercury, but a small amount is methylmercury. Methylmercury is slowly formed in sediment and soils by bacteria or fungi which attach methyl groups to inorganic mercury. Conditions which favor the conversion of inorganic mercury to methylmercury are not well understood. Measurements of methylmercury in soil from the EFPC floodplain range from 0.0008 to 0.0044 percent of the total mercury in the soil (SAIC 1994). When considering the inorganic mercury exposures, ATSDR

assumed that the data (representing total mercury) is 100 percent inorganic mercury; and when considering methylmercury exposures, ATSDR assumed that 0.0044 percent of the total mercury is methylmercury.

The EFPC RI data are presented as composite samples using the average mercury concentrations in 12-inch, 16-inch, or 24-inch cores. If the mercury in a 16-inch core sample (for example) is entirely localized in a 3-inch layer and the remainder of the core soil is clean, then the average mercury concentration in that 3-inch layer before being composited (i.e., mixed and blended together) will theoretically be 5.3 times higher than the mercury concentration in the entire core after being mixed and reported as a composite (i.e., 16 inches ÷ 3 inches = 5.3). Multiplying the average core concentration times the multiplier (5.3) results in the theoretical maximum mercury concentration for a 3-inch layer. ATSDR calculated the theoretical maximum mercury concentrations for 3-inch layers for all the EFPC RI soil core data in this way.[52] The results of these calculations are referred to as the "adjusted" RI data.

Specific mercury concentrations that ATSDR used in the calculations are discussed below:

Intake Rate (IR): Experimental studies have reported soil ingestion rates for children range from approximately 40 to 270 milligrams per day (mg/day) with 100 mg/day representing the best estimate of the average intake rate. There are very few data on soil ingestion by adults, but limited experimental studies suggest a soil ingestion rate in adults of up to 100 mg/day, with an average intake of 50 mg/day (EPA 1997). ATSDR used soil ingestion rates of 100 mg/day for adults and 200 mg/day for children.

Soil Ingestion Exposure Dose Equation

$D = (C \times IR \times AF \times EF \times CF) / BW$

Where,

D = exposure dose (mg/kg/day)
C = mercury concentration (mg/kg/day)
IR = intake rate of contaminated soil (mg/day)
AF = bioavailability factor (unitless)
EF = exposure factor (unitless)
CF = conversion factor (10^{-6} kg/mg)
BW = body weight (kg)

Dermal Contact with Soil Exposure Dose Equation

$D = (C \times A \times AF \times EF \times CF) / BW$

Where,

D = exposure dose (mg/kg/day)
C = mercury concentration (mg/kg)
A = soil adhered (mg/day)
AF = bioavailability factor (unitless)
EF = exposure factor (unitless)
CF = conversion factor (10^{-6} kg/mg)
BW = body weight (kg)

Young children (6 years old and younger) occasionally exhibit soil-pica behavior which is typically characterized by soil ingestion rates between 1,000 and 5,000 mg/day. These children intentionally eat soil and ingestion in these cases is not accidental. Occurrence of soil-pica behavior is rare (less than 1 percent of young children in the U.S. population) but rates vary widely. Soil-pica behavior is influenced by the child's nutritional status and the quality of child care and supervision. ATSDR does not know whether soil-pica behavior occurred among children living near the EFPC floodplain. However, if it did occur, it represents a worst-case ingestion rate. Pica behavior is considered under acute exposures. ATSDR assumed an intake rate of 5,000 mg/day for children who exhibit soil-pica behavior. This rate is 25 times higher than our default intake rate for children and may lead to adverse health effects at soil mercury concentrations 25 times lower than those concentrations which cause effects in children who ingest soil incidentally. ATSDR did not consider pica-soil behavior further in this report.

[52] Different core lengths have different multipliers: 3.3 for 10-inch cores, 4 for 1-foot cores, 8 for 2-foot cores, and 5.3 for 16-inch cores.

Soil Adhered (A): There are few studies available which provide consistent and reliable information regarding the amount of soil that adheres to the skin. ATSDR used U.S.EPA default values for the total amount of soil that adheres to the skin. These values are based on estimates of the exposed body surface area for people in different age groups. For children the value is 525 milligrams (mg) and for adults the value is 326 mg of soil (ATSDR 2005; EPA 1997, 2001).

Bioavailability (AF): When a person swallows mercury-contaminated soil or gets it on his or her skin, not all of the mercury is absorbed into the body. Some mercury remains with the soil and passes through the gastrointestinal tract and is eliminated in the feces. Similarly, when mercury-contaminated soil adheres to the skin, not all the mercury in the soil is absorbed through the skin. The fraction or percent of mercury in the soil absorbed into the blood is called the mercury bioavailability.

Revis et al. (1989) reported that EFPC floodplain soils contain 84–98 percent mercuric sulfide, an insoluble salt. Although mercuric sulfide is very insoluble in water,[53] studies comparing it with mercuric chloride show that its bioavailability is greater than is predicted from water solubility alone. In one mouse study, the kidney deposition of mercury was approximately 30–60 times lower in mice exposed to mercuric sulfide as compared with mice exposed to mercuric chloride. This study does not provide a measure of bioavailability, but it does show that mercuric sulfide is absorbed from the gastrointestinal tract at a measurable extent (Schoof and Nielsen 1997). From this and other studies, the bioavailability of mercuric sulfide is known to be considerably lower than mercuric chloride, although studies to measure its specific bioavailability have not been identified in the scientific literature (ATSDR 1999).

In the early 1990s, Shepard et al. studied heavy metals in soils and reported that the bioavailability of mercury in soil-amended diets in laboratory mice was approximately 40 percent of that in diets consisting of feed alone (Paustenbach et al. 1997). This means that independent of other factors, the soil matrix by itself will decrease the bioavailability of ingested inorganic mercury. ATSDR used this figure (0.4) in the dose estimates to reflect the fact that we are considering ingestion of mercury-contaminated soil and not mercury dissolved in water, as given to laboratory animals in the studies used to derive the MRLs, for example.

The highest oral bioavailability reported in the scientific literature for any inorganic mercury species is 38 percent for mercuric chloride administered in water to week-old suckling laboratory mice; for adult mice the figure is 25 percent (Kostial et al. 1978). Due to the soil matrix, ATSDR assumed the oral bioavailability of inorganic mercury in soil was 40 percent of these figures, or 15 percent and 10 percent for children and adults, respectively. ATSDR recognizes that these oral bioavailability factors are very likely conservative because they do not necessarily account for the diversity of mercury species in EFPC floodplain soil, most of which may be less bioavailable than mercuric chloride. But no sufficient evidence establishes a lower bioavailability factor.

In contrast to inorganic mercury, methylmercury seems to be nearly completely absorbed (95 percent) following ingestion (Miettinen 1973). There is no evidence that a soil matrix inhibits the absorption of methylmercury from the gut; therefore, ATSDR assumed that methylmercury is 95 percent bioavailable, if ingested.

[53] The solubility product constant (K_{sp}) for HgS at 25 °C is 2E-53.

In contrast to oral bioavailability of mercury in soil, no quantitative data describe the dermal bioavailability of mercury in soil. ATSDR thus assumed the dermal bioavailabilities of inorganic mercury and organic mercury in soil are the same as the oral bioavailabilities.

Exposure Factor (EF): ATSDR considered both acute exposure (1–14 days) and intermediate duration exposure (15–364 days in a year). For acute exposure, only exposures to soil or sediment with very high mercury concentrations were considered because humans can eliminate mercury before harm occurs, if the exposures are not too high or too frequent. Exposures of intermediate duration may involve soil from a variety of locations and with a range of mercury concentrations. ATSDR calculations for intermediate exposures included average soil mercury concentrations from multiple groupings of data.

The exposure factor expresses how often or how long a person is exposed to a contaminated medium. For a short-term or acute exposure, the exposure factor is 1. This indicates that for the duration of the exposure, a person is exposed continuously or daily. For intermediate- and long-term exposures, however, ATSDR calculates an average exposure over the duration that exposures occur. In the case of ingesting soil or sediment, exposures might have occurred over several years, but not necessarily in consecutive days. ATSDR assumed that exposure to soil or sediment does not occur every day of the year, but rather is largely dependent on season and weather conditions. An exposure factor of 90 days a year (or one-quarter year) was used as the maximum number of days in a year a person was exposed to mercury-contaminated soil from the EFPC floodplain.

Body Weight (BW): ATSDR assumed a body weight of 70 kg (154 pounds) for adults and 28.1 kg (62 pounds) for children. Sometimes, ATSDR and U.S.EPA assume higher weights than these values, but these are more conservative. Smaller body weights in the exposure dose equations result in higher mercury doses when all other parameters are the same.

Results

Table G-1 contains the soil and sediment dose calculations for acute, intermediate, and chronic exposure. The lowest concentration that results in doses above ATSDR's oral mercury MRL is 2,400 ppm.

Table G-1. Soil and Sediment Exposure Dose Calculations

Oral Exposure Route	*Inorganic*				*Organic*				*Units*
MRL	***0.002***		***0.007***		***0.0003***				***mg/kg/day***
D = C x IR x AF x EF / BW	Intermediate		Acute		Chronic				
	Child	Adult	Child	Adult	Child	Adult	Child	Adult	
C = contaminant concentration	2,400	2,400	2,400	2,400	0.11	0.11	0.11	0.11	mg/kg
IR = intake rate	0.0002	0.0001	0.0002	0.0001	0.0004	0.0001	0.0002	0.0001	kg/day
AF = bioavailability factor	0.15	0.1	0.15	0.1	0.95	0.95	0.95	0.95	unitless
EF = exposure factor	0.25	0.25	1	1	0.25	0.25	1	1	unitless
BW = body weight	28.1	70	28.1	70	28.1	70	28.1	70	kg
D = exposure dose	6.4×10^{-4}	8.6×10^{-5}	2.6×10^{-3}	3.4×10^{-4}	1.8×10^{-7}	3.6×10^{-8}	7.1×10^{-7}	1.4×10^{-7}	mg/kg/day
ratio dose to MRL	3.2×10^{-1}	4.3×10^{-2}	3.7×10^{-1}	4.9×10^{-2}	6.0×10^{-4}	1.2×10^{-4}	2.4×10^{-3}	4.8×10^{-4}	unitless
Dermal Exposure Route	***Inorganic***				***Organic***				***Units***
D = C x A x AF x EF / BW	Intermediate		Acute		Chronic				
	Child	Adult	Child	Adult	Child	Adult	Child	Adult	
C = contaminant concentration	2,400	2,400	2,400	2,400	0.11	0.11	0.11	0.11	mg/kg
A = soil adhered	0.00053	0.00033	0.00053	0.00033	0.00053	0.00033	0.00053	0.00033	kg/day
AF = bioavailability factor	0.15	0.1	0.15	0.1	0.95	0.95	0.95	0.95	unitless
EF = exposure factor	0.25	0.25	1	1	0.25	0.25	1	1	unitless
BW = body weight	28.1	70	28.1	70	28.1	70	28.1	70	kg
D = exposure dose	1.7×10^{-3}	2.8×10^{-4}	6.7×10^{-3}	1.1×10^{-3}	4.7×10^{-7}	1.2×10^{-7}	1.9×10^{-6}	4.7×10^{-7}	mg/kg/day
ratio dose to MRL	8.4×10^{-1}	1.4×10^{-1}	9.6×10^{-1}	1.6×10^{-1}	1.6×10^{-3}	3.9×10^{-4}	6.2×10^{-3}	1.6×10^{-3}	unitless
ratio dermal dose to oral dose	2.6	3.3	2.6	3.3	2.6	3.3	2.6	3.3	unitless

Consumption of Fish

The only significant human exposure pathway to methylmercury in fish is ingestion of fish. Estimates of mercury exposure are based on a series of assumptions that account for how much mercury is in the fish, how much fish people eat, and how much mercury that is swallowed is absorbed into the bloodstream.

Fish Ingestion Exposure Dose Equation

D = (C x IR x AF x CF) / BW

Where,

D = exposure dose (mg/kg/d)
C = mercury concentration (mg/kg)
IR = intake rate of contaminated fish (mg/d)
AF = bioavailability factor (unitless)
CF = conversion factor (10-6 kg/mg)
BW = body weight (kg)

The exposure factor (EF) which is used in several other exposure dose equations is figured into the intake rate and does not appear separately in the equation.

Mercury Concentrations (C): ATSDR calculated human methylmercury doses from the fish data presented in Table 12. For chronic exposures, ATSDR considered the highest average (i.e., mean) mercury concentrations in fish samples collected from each sampling location (EFPC, Poplar Creek, Clinch River, and Watts Bar Reservoir). For acute exposures, ATSDR considered the maximum reported mercury concentration in fish collected from each sampling location.

Intake Rate (IR): Ingestion rates vary widely between individuals and are highly uncertain for each population group. For chronic exposures, ATSDR used the mean and maximum adult fish ingestion rates developed by Task 2 (except the maximum ingestion rate ATSDR used for EFPC was the U.S.EPA rate for average daily fish consumption for recreational anglers in small ponds or streams[54]). Each of the child ingestion rates are one-half of the adult rates rather than the 20 percent that Task 2 used because, in our model, ATSDR used an older child who would eat more fish than Task 2 used in its model. For acute exposures, ATSDR assumed a person would eat one or two whole fish meals consisting of 170 grams (6 ounces) or 340 grams (12 ounces) of fish, respectively. Refer to Table G-2 (ingestion—kg/day) and Table G-3 (ingestion—meals/year) for location-specific chronic consumption rates.

The Task 2 fish consumption rates were discussed in meetings with the Oak Ridge Health Agreement Steering Panel (ORHASP), which oversaw the Oak Ridge Dose Reconstruction efforts. ORHASP members expressed limited confidence concerning the consumption rates. However, the maximum Task 2 rates for the Watts Bar Reservoir are only slightly higher than the highest fish consumption rates that ATSDR staff recorded during interviews with anglers around the Watts Bar Reservoir during the 1997 exposure investigation (ATSDR 1998).

[54] Task 2 did not present a maximum fish ingestion rate for EFPC fishers.

Table G-2. Chronic Fish Ingestion Rates (kg/day)

	Average Consumption Rates (kg/day)		*Maximum Consumption Rates (kg/day)*	
	Recreational		*Recreational*	
	child	*adult*	*child*	*adult*
EFPC	0.0006	0.0012	0.002	0.004
Poplar Creek/Clinch River[1]	0.009	0.018	0.033	0.065
Watts Bar Reservoir	0.015	0.03	0.055	0.11

EFPC: East Fork Poplar Creek
kg/day: kilograms per day
[1] Poplar Creek and Clinch River are presented together because the Task 2 investigation does not separate these two locations, and therefore, ingestion rates can only be calculated as one combined location.

Table G-3. Chronic Fish Ingestion Rates (meals/year)

	Average Consumption Rates (meals/year)		*Maximum Consumption Rates (meals/year)*	
	Recreational		*Recreational*	
	child	*adult*	*child*	*adult*
EFPC	1.3	2.6	4.3	8.6
Poplar Creek/Clinch River[1]	19	39	70	140
Watts Bar Reservoir	32	64	120	240

EFPC: East Fork Poplar Creek
One fish meal = 6 ounces
[1] Poplar Creek and Clinch River are presented together because the Task 2 investigation does not separate these two locations, and therefore, ingestion rates can only be calculated as one combined location.

Bioavailability (AF): ATSDR assumed that the mercury measured in fish is 100 percent methylmercury and that the methylmercury is completely bioavailable (i.e., bioavailability = 1) for both children and adults.

Body Weight (BW): ATSDR assumed a body weight of 70 kg (154 pounds) for adults and 28.1 kg (62 pounds) for children.

Consumption of Fruits and Vegetables

The only significant exposure pathway to mercury in garden vegetation is ingestion of fruits and vegetables. Estimates of mercury exposure are based on a series of assumptions that account for how much mercury is in the produce, how much produce people eat, and how much ingested mercury is absorbed into the bloodstream (ATSDR 2005):

Mercury Concentration (C): ATSDR assumed that the total mercury measured in fruits and vegetables is inorganic mercury. Mercury speciation studies of plants grown in soil with inorganic mercury contamination indicate that the mercury taken into plants is taken up as inorganic mercury (i.e., mercuric ions) (ChemRisk 1999a).

Intake Rate (IR): ATSDR used an intake rate from the *U.S.EPA Exposure Factors Handbook* (EPA 1997) for people living in the South. Adults and children were reported to eat 2.27 grams of homegrown vegetables per kilogram of body weight per day (g/kg/day) (EPA 1997). Note that a body weight factor is already incorporated into the ingestion rate.

Bioavailability (AF): In contrast to oral bioavailability of mercury in soil, there is limited quantitative data describing the oral bioavailability of mercury in produce. Therefore, ATSDR assumed that the oral bioavailability of inorganic mercury in produce is the same as the oral bioavailability in soil. ATSDR assumed the oral bioavailabilities of inorganic mercury in produce are 15 percent and 10 percent for children and adults, respectively.

Exposure Factor (EF): ATSDR assumed the same exposure factor as for soil exposures; that is, people will eat home-grown fruits and vegetables during 25 percent of the days in a year for intermediate exposures (EF = 0.25) and everyday for acute exposures (EF = 1).

Edible Vegetation Ingestion Exposure Dose Equation

D = (C x IR x AF x EF x CF)

Where,

D = exposure dose (mg/kg/d)

C = mercury concentration (mg/kg)

IR = intake rate of contaminated produce (g/kg/day)

AF = bioavailability factor (unitless)

EF = exposure factor (unitless)

CF = conversion factor (10^{-3} g/kg)

Results

Using the average mercury concentration of 1.6 ppm from leafy vegetables from the ORAU and SAIC data sets, the intermediate exposure doses to both children and adults are well below the ATSDR inorganic mercury intermediate oral MRL (0.002 mg/kg/day). Using the highest mercury concentration measured in edible fruits and vegetables among the ORAU and SAIC data sets (3.2 ppm for kale leaf), the resulting acute exposure doses (for children and adults) are below the ATSDR inorganic mercury acute oral MRL (0.007 mg/kg/day). Table G-4 presents the exposure dose calculations for acute and intermediate ingestion of fruits and vegetables.

Table G-4. Fruit and Vegetable Exposure Dose Calculations

Oral Exposure Route	***Inorganic***				***Units***
MRL	***0.002***		***0.007***		***mg/kg/day***
D = C x IR x AF x EF	intermediate		Acute		
	child	Adult	child	adult	
C = contaminant concentration	1.6	1.6	3.2	3.2	mg/kg
IR = intake rate	2.27	2.27	2.27	2.27	g/kg/day
AF = bioavailability factor	0.15	0.1	0.15	0.1	unitless
EF = exposure factor	0.25	0.25	1	1	unitless
CF = conversion factor	10^{-3}	10^{-3}	10^{-3}	10^{-3}	g/kg
D = exposure dose	0.0001	0.00009	0.001	0.0007	mg/kg/day
ratio dose to MRL	0.07	0.04	0.14	0.1	unitless

Appendix H.
What You Need to Know About Mercury in Fish and Shellfish

The Facts

Fish and shellfish are an important part of a healthy diet. Fish and shellfish contain high-quality protein and other essential nutrients, are low in saturated fat, and contain omega-3 fatty acids. A well-balanced diet that includes a variety of fish and shellfish can contribute to heart health and children's proper growth and development. So, women and young children in particular should include fish or shellfish in their diets due to the many nutritional benefits.

However, nearly all fish and shellfish contain traces of mercury. For most people, the risk from mercury by eating fish and shellfish is not a health concern. Yet, some fish and shellfish contain higher levels of mercury that may harm an unborn baby or young child's developing nervous system. The risks from mercury in fish and shellfish depend on the amount of fish and shellfish eaten and the levels of mercury in the fish and shellfish. Therefore, the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) are advising women who may become pregnant, pregnant women, nursing mothers, and young children to avoid some types of fish and eat fish and shellfish that are lower in mercury.

For further information about the risks of mercury in fish and shellfish call the U.S. Food and Drug Administration's food information line toll-free at **1-888-SAFEFOOD** or visit FDA's Food Safety website **www.cfsan.fda.gov/seafood1.html**.

For further information about the safety of locally caught fish and shellfish, visit the Environmental Protection Agency's Fish Advisory website **www.epa.gov/ost/fish** or contact your State or Local Health Department. A list of state or local health department contacts is available at **www.epa.gov/ost/fish**. Click on Federal, State, and Tribal Contacts. For information on EPA's actions to control mercury, visit EPA's mercury website at **www.epa.gov/mercury**.

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What You Need to Know About Mercury in Fish and Shellfish

Advice for

Women Who Might Become Pregnant
Women Who are Pregnant
Nursing Mothers
Young Children

from the
U.S. Food and Drug Administration
U.S. Environmental Protection Agency

3 Safety Tips

By following these 3 recommendations for selecting and eating fish or shellfish, women and young children will receive the benefits of eating fish and shellfish and be confident that they have reduced their exposure to the harmful effects of mercury.

1. Do not eat:

- **Shark**
- **Swordfish**
- **King Mackerel**
- **Tilefish**

They contain high levels of mercury.

2. Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury.

- Five of the most commonly eaten fish that are low in mercury are shrimp, canned light tuna, salmon, pollock, and catfish.
- Another commonly eaten fish, albacore ("white") tuna has more mercury than canned light tuna. So, when choosing your two meals of fish and shellfish, you may eat up to 6 ounces (one average meal) of albacore tuna per week.

3. Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers, and coastal areas.

If no advice is available, eat up to 6 ounces (one average meal) per week of fish you catch from local waters, but don't consume any other fish during that week.

Follow these same recommendations when feeding fish and shellfish to your young child, but serve smaller portions.

Visit the Food and Drug Administration's Food Safety Website www.cfsan.fda.gov or the Environmental Protection Agency's Fish Advisory Website www.epa.gov/ost/fish for a listing of mercury levels in fish.

Frequently Asked Questions *about Mercury in Fish and Shellfish:*

What is mercury?

Mercury occurs naturally in the environment and can also be released into the air through industrial pollution. Mercury falls from the air and can accumulate in streams and oceans and is turned into methylmercury in the water. It is this type of mercury that can be harmful to your unborn baby and young child. Fish absorb the methylmercury as they feed in these waters and so it builds up in them. It builds up more in some types of fish and shellfish than others, depending on what the fish eat, which is why the levels vary.

I'm a woman who could have children but I'm not pregnant - so why should I be concerned about methylmercury?

If you regularly eat types of fish that are high in methylmercury, it can accumulate in your blood stream over time. Methylmercury is removed from the body naturally, but it may take over a year for the levels to drop significantly. Thus, it may be present in a woman even before she becomes pregnant. This is the reason why women who are trying to become pregnant should also avoid eating certain types of fish.

Is there methylmercury in all fish and shellfish?

Nearly all fish and shellfish contain traces of methylmercury. However, larger fish that have lived longer have the highest levels of methylmercury because they've had more time to accumulate it. These large fish (swordfish, shark, king mackerel and tilefish) pose the greatest risk. Other types of fish and shellfish may be eaten in the amounts recommended by FDA and EPA.

Note:
If you have questions or think you've been exposed to large amounts of methylmercury, see your doctor or health care provider immediately.

I don't see the fish I eat in the advisory. What should I do?

If you want more information about the levels in the various types of fish you eat, see the FDA food safety website www.cfsan.fda.gov/~frf/sea-mehg.html or the EPA website at www.epa.gov/ost/fish.

What about fish sticks and fast food sandwiches?

Fish sticks and "fast-food" sandwiches are commonly made from fish that are low in mercury.

The advice about canned tuna is in the advisory, but what's the advice about tuna steaks?

Because tuna steak generally contains higher levels of mercury than canned light tuna, when choosing your two meals of fish and shellfish, you may eat up to 6 ounces (one average meal) of tuna steak per week.

What if I eat more than the recommended amount of fish and shellfish in a week?

One week's consumption of fish does not change the level of methylmercury in the body much at all. If you eat a lot of fish one week, you can cut back for the next week or two. Just make sure you average the recommended amount per week.

Where do I get information about the safety of fish caught recreationally by family or friends?

Before you go fishing, check your Fishing Regulations Booklet for information about recreationally caught fish. You can also contact your local health department for information about local advisories. You need to check local advisories because some kinds of fish and shellfish caught in your local waters may have higher or much lower than average levels of mercury. This depends on the levels of mercury in the water in which the fish are caught. Those fish with much lower levels may be eaten more frequently and in larger amounts.