Appendix D. Summary Briefs

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

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 This involved interviewing both active and retired DOE staff members about past operations, as well as reviewing historical documents (such as purchase orders, laboratory records, and published operational reports).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. This 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), was 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 offsite 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	Ingestion
		Soil/sediment	Ingestion
		Soil/sediment to vegetables; livestock/game (beef); dairy cattle milk	Ingestion
Mercury	Y-12 Lithium separation and enrichment operations (1955-1963)	Air	Inhalation
		Air to vegetables; Livestock/game (beef); dairy cattle milk	Ingestion
		Surface water to fish	Ingestion
		Soil/sediment to livestock/game (beef); vegetables	Ingestion
Polychlorinated biphenyls	K-25 and Y-12 Transformers and machining	Surface water to fish	Ingestion

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Reports of the Oak Ridge Dose Reconstruction, *Radionuclide Releases to the Clinch River from White Oak Creek on the Oak Ridge Reservation—an Assessment of Historical Quantities Released, Off-Site Radiation Doses, and Health Risks (referred to as the Task 4)*

Site: Oak Ridge Reservation

Conducted by: ChemRisk/ORHASP for the Tennessee Department of Health

Time period: 1999

Location: Oak Ridge, Tennessee

Purpose

The purposes of Task 4 of the Oak Ridge Dose Reconstruction were (1) to estimate the historical radiological releases from the X-10 facility to the Clinch River, (2) to evaluate the potential pathways by which members of the public could have been exposed to radioactive effluents in the Clinch River between 1944 and 1991, and (3) to calculate radiation doses and risks to reference individuals who were potentially exposed to radioactivity released to the Clinch River from the X-10 facility. Direct measurement of the amounts of radionuclides taken up by the organs of specific individuals since 1944 was no longer feasible because most of these radionuclides do not stay in the human body for long periods of time. Therefore, a dose reconstruction was necessary to determine the magnitude and extent of past exposure and to interpret the health consequences of these exposures. This dose reconstruction relies upon independent evaluation of the amounts of radionuclides released, reported environmental measurements, and mathematical models to estimate the magnitude and extent of past exposures, doses, and health risks.

Background

Construction of the Oak Ridge National Laboratory (ORNL, which is also known as the "Clinton Laboratory" or "X-10 facility") began on February 10, 1943. The laboratory was built as a pilot plant for demonstrating the production and separation of plutonium. In 1944, the first radioactive effluents from the X-10 site entered White Oak Creek and flowed into White Oak Lake. White Oak Lake served as a settling basin for contaminants released to White Oak Creek. Radionuclides remaining in the water column were released from the X-10 site with the flow of water over White Oak Dam into the White Oak Creek Embayment, and then entered the Clinch River. The radionuclides in the surface water and sediments that traveled through the Clinch River eventually flowed into the Lower Watts Bar Reservoir.

During the early years of X-10 operations, the graphite reactor and the "hot pilot plant" (a chemical separation plant) were the major sources of radioactive wastes. Wastes from the "hot pilot plant" were placed into open waste pits; in 1959, high levels of ruthenium 106 (Ru 106) began seeping from the pits into White Oak Lake. Amounts of Ru 106 as high as 2,000 curies (7.4 x 10^{13} Bequerel [Bq])per year were released from White Oak Dam between 1959 and 1963. From 1944 to 1991, approximately 200,000 curies of radioactivity were released over White Oak Dam to the Clinch River; of this amount, 91% was tritium and the rest was mixed fission and activation products.

Evidence suggests that a secondary source of radionuclides released to the Clinch River was the scouring of contaminated sediment from White Oak Creek Embayment. After White Oak Lake was drained in 1955, heavy rainfall scoured the bottom sediment of White Oak Lake, resulting in the deposition of particle reactive radionuclides (primarily Cs 137) in White Oak Creek Embayment. The peaking discharges from Melton Hill Dam, which was completed in 1963, resulted in the backflow of water up White Oak Creek Embayment and the scouring of radionuclide-containing sediments into the Clinch River. A coffer cell dam was constructed at the mouth of White Oak Creek in the early 1990s to prevent the backflow of water up White Oak Creek Embayment, and scouring of embayment sediment ceased at that time.

Methods

The dose reconstruction relies on estimates and reported measurements of radionuclides released from White Oak Dam from 1944–1991. A detailed investigation was performed for (1) the methods used for measurements of radioactive releases from White Oak Dam, (2) the methods used for estimation of flow rates at White Oak Dam, and (3) the uncertainties associated with these measurements. Estimates that measured the amount of radionuclides historically released from White Oak Dam were based on laboratory documents, available log books, and interviews with personnel who were either responsible for or involved in the sampling and monitoring of radioactive releases at White Oak Dam. Direct measurements of the radionuclides released from White Oak Dam were available, except for the years 1944 to 1949. For these years, estimates were based on the fraction that each radionuclide contributed to a measurement or estimate of gross beta activity.

The Task 4 team conducted a screening analysis to select the radionuclides released to White Oak Creek and potential exposure pathways of most importance. Based on its screening, the Task 4 team concluded that 16 out of 24 radionuclides released to White Oak Creek did not need further evaluation because the estimated screening indices were below the minimal level of concern. Detailed source terms (annual release amounts) were developed for the following eight radionuclides deemed more likely to carry significant risks: Co 60, Sr 90, Nb 95, Zr 95, Ru 106, I 131, Cs 137, and Ce 144. The uncertainty of the amount released each year varied over time because of various changes in sampling and analytical methods as well as changes in waste disposal or treatment events.

Measured concentrations of radionuclides in water were available for many years for several locations downstream from the confluence of White Oak Creek and the Clinch River (Clinch River Mile [CRM] 20.8). These measurements were not entirely consistent as to location or method of measurement and did not include all of the radionuclides of concern. Therefore, a modeling effort was conducted to estimate the historical annual average concentrations of radionuclides in water at specific locations downstream of White Oak Creek.

Estimated shoreline concentrations of radionuclides in sediment were obtained to track the sediment inventory in various reaches of the Clinch River. Monitoring data collected in the 1990s were used to calibrate the shoreline sediment estimates.

Study Subjects

References individuals, or hypothetically exposed individuals, in this study were identified with respect to the pathways involved and the specific characteristics of the each of the five pathways. For the fish consumption pathway, reference individuals were defined in terms of fish consumption rate as Category I (1 to 2.5 meals per week), Category II (0.25 to 1.3 meals per week), or Category III (0.04 to 0.33 meals per week).

The evaluation also considered potential exposures for hypothetical individuals within five reference areas along the Clinch River.

These locations are CRM 21 to CRM 17 (Jones Island), CRM 17 to CRM 14 (Grassy Creek), CRM 14 to CRM 5 (K-25), CRM 5 to CRM 2 (Kingston Steam Plant), and CRM 2 to CRM 0 (city of Kingston).

Exposures

The following potential exposure pathways were evaluated: consumption of drinking water from the Clinch River, consumption of milk and beef, ingestion of fish caught from the Clinch River, and exposure to sediments along the shore of the Clinch River. Other pathways, such as swimming in the Clinch River, exposure to irrigation water from the Clinch River, and eating produce, were eliminated through the screening process because their estimated screening indices was below the level of minimal concern.

Outcome measure

Health outcomes were not studied.

Results

Ingestion of Fish: The estimated organ doses to individuals consuming fish exceeded the dose estimates for all other pathways. The organ doses depended on how often they ate fish and the area of the Clinch River where the fish were taken. The highest doses were for the maximum exposure scenario (Category I fish consumers) in which an individual ate 1 to 2.5 fish meals a week of fish caught at CRM 20.5 (just below the confluence of White Oak Creek and the Clinch River). Central values of the cumulative doses for 1944 to 1991 for specific organs ranged from 0.31 (skin) to 0.81 centisievert (cSv)(bone) for males and from 0.23 (skin) to 0.60 cSv (bone) for females. Estimated organ doses were lower for individuals who ate fewer fish (Category II and III fish consumers) or fished further downstream.

For Category I fish consumers near Jones Island (CRM 20.5), the 95% subjective confidence interval of the total excess lifetime risk of cancer incidence for all radionuclides and organs was 3.6×10^{-5} to 3.5×10^{-3} (central value, 2.8×10^{-4}) for males and 2.9×10^{-5} to 2.8×10^{-3} (central value, 2.3×10^{-4}) for females.

Other Exposure Pathways: Organ-specific doses from external exposure were about a factor of 1.1 to 3.5 lower than the doses to a Category I fish consumer at CRM 14, with the largest doses to skin, bone, and thyroid. For most organs, doses from drinking water at CRM 14 and CRM 3.5 were lower than the doses from external exposure at the same location. Estimated doses from ingestion of meat and milk were lower than those for ingestion of drinking water by 1 to 3 orders of magnitude. The highest doses were to the large intestine, bone, red bone marrow, and (for the ingestion of milk) the thyroid.

For the combined pathways at CRM 20.5, the upper bounds on the total excess lifetime risk were 3.6×10^{-3} for male consumers of fish in Category I.

Estimates of Thyroid Dose to a Child from the Drinking Water and Milk Ingestion Pathways: The 95% subjective confidence intervals for the estimated dose to a child 0 to 14 years of age drinking home-produced milk at CRM 14 or CRM 3.5 from 1946-1960 were 0.00058 to 0.054 cSv (0.0062 central value) and 0.00055 to 0.042 cSv (0.0044 central value), respectively.

The highest excess lifetime risk of thyroid cancer occurred for a female child ingesting milk obtained from an area near CRM 14 between 1946 and 1960 (95% confidence interval, 1.1×10^{-7} to 2.5×10^{-5}; central value, 1.8×10^{-6}).

Conclusions

The radiological doses and excess lifetime cancer risks estimated in this report were incremental increases above those resulting from exposure to background sources of radiation in the East Tennessee region. Nevertheless, for the exposure pathways considered in this task, the doses and risks were not large enough for a commensurate increase in health effects in the population to be detectable, even by the most thorough of epidemiological investigations. In most cases, the estimated organ doses were clearly below the limits of epidemiological detection (1 to 30 cSv) for radiation-induced health outcomes that were observed following irradiation of large cohorts of individuals exposed either *in utero,* as children, or as adults. Even in the case of Category I fish consumers, the upper confidence limits on the highest estimated organ-specific doses were below 10 cSv, and the central values were below 1 cSv. The lower confidence limits on these doses were well below limits considered for epidemiological detection in studies of cohorts of other exposed populations.

Even though this present dose reconstruction study identified increased individual risks up to 1×10^{-3} resulting from these exposures, it is unlikely that any observed trends in the incidence of disease in populations that used the Clinch River and Lower Watts Bar Reservoir after 1944 could be conclusively attributed to exposure to radionuclides released from the X-10 site.

ORRHES Brief
Oak Ridge Reservation Health Effects Subcommittee

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Screening-Level Evaluation of Additional Potential Materials of Concern, July 1999—Task 7

Site: Oak Ridge Reservation
Study area: Oak Ridge Area
Time period: 1942–1990
Conducted by: Tennessee Department of Health and the Oak Ridge Health Agreement Steering Panel

Purpose

The purpose of this screening-level evaluation was to determine whether additional contaminants that existed at Oak Ridge Reservation (ORR), other than the five already identified in the Oak Ridge Dose Reconstruction Feasibility Study (iodine, mercury, polychlorinated biphenyls [PCBs], radionuclides, and uranium), warrant further evaluation of their potential for causing health effects in off-site populations.

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 ORR. The Oak Ridge Dose Reconstruction Feasibility Study was conducted from 1992 to 1993 to identify those operations and materials that warranted detailed evaluation based on the risks posed to off-site populations. The feasibility study recommended that dose reconstructions be conducted for radioactive iodine releases from X-10 radioactive lanthanum processing (Task 1), mercury releases from Y-12 lithium enrichment (Task 2), PCBs in the environment near Oak Ridge (Task 3), and radionuclides released from White Oak Creek to the Clinch River (Task 4). In addition, the study called for a systematic search of historical records (Task 5), an evaluation of the quality of historical uranium effluent monitoring data (Task 6), and additional screening of materials that could not be evaluated during the feasibility study (Task 7).

The Oak Ridge Health Agreement Steering Panel (ORRHES) was established to direct and oversee the Oak Ridge Health Studies and to facilitate interaction and cooperation with the community. This group is comprised of local citizens and nationally recognized scientists.

Methods

During the Task 7 Screening-Level Evaluation, three different methods (qualitative screening, the threshold quantity approach, and quantitative screening) were used to evaluate the importance of materials with respect to their potential for causing off-site health effects. Twenty-five materials or groups of materials were evaluated. Please see Table 1 for a summary of the methods used to evaluate each material/group of materials.

- Qualitative Screening—All materials used on ORR were qualitatively screened for quantities used, forms used, and/or manners of use. If it was unlikely that off-site releases were sufficient to pose an off-site health hazard, then these materials were not evaluated quantitatively. If off-site exposures were likely to have occurred at harmful levels, then the materials were evaluated quantitatively.

- Threshold Quantity Approach—When information was insufficient to conduct quantitative screening, inventories of materials used at ORR were estimated based on historical records and interviews of workers. These estimated inventories of materials were determined to be either above or below a conservatively calculated health-based threshold quantity. If the estimates for a material were below the calculated threshold quantity, then it was determined to be highly unlikely to have posed a risk to human health through off-site releases.

- Quantitative Screening—The quantitative screening used a two-level screening approach to identify those materials that could produce health risks (i.e., doses) to exposed people that are clearly below minimum levels of health concern (Level I Screen) and above minimum levels of health concern (Refined Level I Screen). Health-based decision guides were established by the Oak Ridge Health Agreement Steering Panel and represent minimum levels of health concern.

  — The Level I Screening calculates a screening index for a maximally exposed reference individual who would have received the highest exposure. This conservative (protective) screening index is not expected to underestimate exposure to any real person in the population of interest. If the estimated Level I screening index was below the ORRHES decision guide, then the hazard to essentially all members of the population, including the maximally exposed individual, would be below the minimum level of health concern. In addition, the Level I screening index would be so low that further detailed study of exposures is not warranted because the screening index is below the threshold for consideration of more extensive health effects studies. However, if during the Level I Screening, the screening index was above the ORRHES decision guide, then the contaminant was further evaluated using Refined Level I Screening.

  — The Refined Level I Screen calculates a less conservative, more realistic screening index by using more reasonable exposure parameters than the Level I Screen. In addition, depending upon the contaminant, a less conservative environmental concentration was sometimes used. However, the transfer factors and toxicity values remained the same for both screening levels. The Refined Level I Screening maintains considerable conservatism because of these conservative transfer factors and toxicity values.

  If the Refined Level I screening index was below the ORRHES decision guide, then the hazard to most members of the population would be below minimum levels of health concern. In addition, the Refined Level I screening index would be so low that further detail study of exposure is not warranted because the screening index is below the threshold for consideration of more extensive health effects studies and was given a low priority for further study. However, if during the Refined Level I Screening, the screening index was above the ORRHES decision guide, then the contaminant was determined to be of high priority for a detail evaluation.

Study Group

The screening evaluation focuses on the potential for health effects to occur in off-site residents. The Level I Screen estimates a dose for the hypothetical maximally exposed individual who would have received the highest exposure and would have been the most at-risk. The Refined Level I Screen estimates a dose for a more typically exposed individual in the targeted population. The study group for exposure from lead were children because they are particularly sensitive to the neurological effects of lead.

Exposures

Quantitative screening used mathematical equations to calculate a screening index (theoretical estimates of risk or hazard) from multiple exposure pathways, including inhalation; ground exposure (for radionuclides); ingestion of soil or sediment; and ingestion of vegetables, meat, milk, and/or fish.

Outcome Measures

No outcome measures were studied.

Results

Screening-level analyses were performed for seven carcinogens. They were evaluated according to source, resulting in 10 separate analyses. Three of the Level I Screen analyses (Np-237 from K-25, Np-237 from Y-12, and tritium from Y-12) yielded results that were below the decision guides. Refined Level I Screens were performed on the other seven carcinogenic assessments. The results of five separate analyses (beryllium from Y-12, chromium VI from ORR, nickel from K-25, technetium-99 from K-25, and technetium-99 from Y-12) were below the decision guides, and two analyses (arsenic from K-25 and arsenic from Y-12) were above the decision guides.

Arsenic was released into the air from the burning of coal at several coal-fired steam plants located on the Oak Ridge Reservation and into the soil, sediment, and surface water from coal piles and disposal of fly ash from the steam plants. Lead was likely released into soil, sediment, and surface water from the disposal of liquid waste into the Y-12 storm sewers and may have been released into the air from process stacks and the plant ventilation system.

Screening-level analyses were performed for seven noncarcinogens. These, too, were evaluated according to source, resulting in eight separate analyses. One Level I Screen analysis (beryllium from Y-12) yielded results that were below the decision guide. Refined Level I Screens were performed on the other seven noncarcinogenic assessments. Four analyses (chromium VI from ORR, copper from K-25, lithium from Y-12, and nickel from K-25) were below the decision guides and three analyses (arsenic from K-25, arsenic from Y-12, and lead from Y-12) were above the decision guides.

Three materials (niobium, zirconium, and tetramethylammoniumborohydride [TMAB]) were evaluated using the threshold quantity approach because information was insufficient to perform quantitative screening. None of the three was determined to be present in high enough quantities at the Y-12 Plant to have posed off-site health hazards.

Conclusions

Based on the qualitative and quantitative screening, the materials were separated into three classes in terms of potential off-site health hazards: not candidates for further study, potential candidates for further study, and high priority candidates for further study. (as shown in Table 2).

- Not Candidates—Five materials at the K-25 and 14 materials used at the Y-12 Plant were determined to not warrant further study. All of these chemicals were eliminated because either (1) quantitatively, they fell below Level I Screening decision guides; (2) not enough material was present to have posed an off-site health hazard according to the threshold quantity approach; or (3) qualitatively, the quantities used, forms used, and/or manners of usage were such that off-site releases would not have been sufficient to cause off-site health hazards.

- Potential Candidates—Three materials at the K-25 (copper powder, nickel, and technetium-99), three materials used at the Y-12 Plant (beryllium compounds, lithium compounds, and technetium-99), and one material used at ORR (chromium VI) were determined to be potential candidates for further study. These materials were identified as potential candidates because (1) their Level I Screening indices exceeded the decision guides and (2) their Refined Level I Screening indices did not exceed the decision guides.

- High Priority Candidates—One material used at the K-25 (arsenic) and two at the Y-12 Plant (arsenic and lead) were determined to be high priority candidates for further study. They were chosen as high priority materials because their Refined Level I Screening indices exceeded the decision guides.

Two issues remaining from the Dose Reconstruction Feasibility Study were evaluated during Task 7: the possible off-site health risks associated with asbestos and the composition of plutonium formed and released to the environment.

- Asbestos—Asbestos could not be fully evaluated during the feasibility study; therefore, it was qualitatively evaluated during this task for the potential for off-site releases and community exposure. Available information on the use and disposal of asbestos, as well as, off-site asbestos monitoring was summarized. None of the investigations performed to date have identified any asbestos-related exposure events or activities associated with community exposure, making it very unlikely that asbestos from ORR has caused any significant off-site health risks.

- Plutonium—The records that documented the rate of plutonium release did not specify the isotopic composition of the product formed. As a result, during the feasibility study, the project team made the assumption that the plutonium that was formed and released was plutonium-239. If incorrect, this assumption could have significant ramifications on the screening of past airborne plutonium releases. Therefore, the composition of the plutonium formed and released was evaluated further during this task. Plutonium inventory from X-10 was calculated, and plutonium-239 was found to comprise at least 99.9% of the plutonium present in Clinton Pile fuel slugs. This result confirmed that the assumptions made in the feasibility study did not introduce significant inaccuracy into the screening evaluation that was conducted.

TABLE 1

Summary of Screening Methods Used for Each Material

Qualitative Screening			
Material	**Source**	**Notes**	
Boron carbide, boron nitride, yttrium boride, titanium boride, rubidium nitrate, triplex coating, carbon fibers, glass fibers, and four-ring polyphenyl ether	ORR	Evaluated based on quantities used, forms used, and manners of usage.	
Tellurium	Y-12	Evaluated based on quantities used, forms used, and manners of usage.	
Threshold Quantity Approach			
Material	**Source**	**Media**	**Threshold Values**
Niobium	Y-12 Used in production of two alloys, mulberry and binary	Air Surface Water	Evaluated using a reference dose derived from an LD50, an empirically derived dispersion factor for airborne releases from Y-12 to Scarboro, and estimated average East Fork Poplar Creek (EFPC) flow rates.
Tetramethylammoniumboro-hydride (TMAB)	Y-12 Use classified	Air Surface Water	Inventory quantities and specific applications remain classified.
Zirconium	Y-12 Used in production of an alloy, mulberry	Air Surface Water	Evaluated using a reference dose derived from an ACGIH Threshold Limit Value for occupational exposure, an empirically derived dispersion factor for air released from Y-12 to Scarboro, and estimated average EFPC flow rates.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening			
Material	**Source**	**Media**	**Exposure Values**
Arsenic Level I Screen and Refined Level I Screen	K-25 Y-12 Released as a naturally occurring product in coal, which was used in coal–fired steam plants	Air	Based on coal use and dispersion modeling to Union/Lawnville (K-25) and Scarboro (Y-12).
		Surface Water	Used maximum in Poplar Creek (K-25) and the 95% upper confidence limit (UCL) on the mean concentration in McCoy Branch (Y-12).
		Soil/Sediment	Used sediment core concentration detected in Poplar Creek to represent the early 1960s (K-25) and the 95% UCL on the mean concentration in McCoy Branch (Y-12).
		Food Items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Beryllium compounds Level I Screen and Refined Level I Screen	Y-12 Used in production	Air	Used Y-12 stack monitoring data and an empirical dispersion factor for releases to Scarboro.
		Surface Water	Used maximum concentration measured in EFPC.
		Soil	Used maximum concentration measured in EFPC.
		Food Items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Copper Level I Screen and Refined Level I Screen	K-25 Use of copper powder is classified	Air	Based on airborne concentrations measured at the most-affected on-site air sampler that were adjusted according to the ratio of dispersion model results at that sampler to those at Union/Lawnville.
		Surface Water	Used maximum concentration measured during the Clinch River Remedial Investigation.
		Soil/Sediment	Used highest mean concentration in Clinch River.
		Food Items	Based on concentrations in air, soil, and water and NCRP biotransfer factor and an ATSDR bioconcentration factor.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening (continued)			
Material	**Source**	**Media**	**Exposure Values**
Hexavalent chromium (Chromium VI) Level I Screen and Refined Level I Screen	ORR Used in cooling towers to control corrosion	Air	Based on modeling of emission and drift from K-25 cooling towers to Union/Lawnville.
		Surface Water	Used maximum concentration measured in Poplar Creek before 1970.
		Soil	Used average concentration of total chromium measured during the EFPC Remedial Investigation; assumed to be 1/6 (16.7%) chromium VI.
		Food Items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Lead EPA's Integrated Exposure Uptake Biokinetic model	Y-12 Used in production of components, in paints, and as radiation shielding	Air	Estimated from background concentrations of lead prior to mid-1970s.
		Surface Water	Used maximum concentration measured in EFPC (a higher concentration was detected near Y-12; however it was considered to be anomalous).
		Soil/Sediment	Used maximum concentration measured in the EFPC Remedial Investigation, the 95% UCL, and the 95% UCL multiplied by 3.5 for a higher past concentration.
		Food Items	Based on concentrations in air, soil, and water and biotransfer and bio-concentration factors from literature.
Lithium Level I Screen and Refined Level I Screen	Y-12 Used in lithium isotope separation, chemical, and component fabrication	Air	Used stack sampling data from two lithium processing buildings and an empirical dispersion factor for releases to Scarboro.
		Surface Water	Used highest quarterly average measured in EFPC.
		Soil/Sediment	Used maximum concentration measured in the EFPC floodplain.
		Food Items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Material	Source	Media	Exposure Values
Quantitative Screening (continued)			
Neptunium-237 Level I Screen	K-25 Y-12 Found in recycled uranium	Air	Based on levels in recycled uranium, an estimated release fraction, and dispersion modeling to Union/Lawnville (K-25) and Scarboro (Y-12).
		Surface Water	Based on reported releases to Clinch River (K-25) and EFPC (Y-12), corrected for dilution.
		Soil/Sediment	Used maximum concentrations detected in Clinch River (K-25) and EFPC (Y-12).
		Food Items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Nickel Level I Screen and Refined Level I Screen	K-25 Used in the production of barrier material for the gaseous diffusion process	Air	Based on the 95% UCL for the year of the highest measured concentrations in on-site air samplers and dispersion modeling to Union/Lawnville.
		Surface Water	Used 95% UCL for the year of the highest concentrations in Clinch River.
		Soil/Sediment	Used highest mean concentration in Clinch River.
		Food Items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Technetium-99 Level I Screen and Refined Level I Screen	K-25 Y-12 Product of fission of uranium atoms and from neutron activation of stable molybdenum-98	Air	Used an average of concentrations modeled to Union/Lawnville (K-25) and Scarboro (Y-12).
		Surface Water	Used maximum concentration detected in Clinch River (K-25) and EFPC (Y-12).
		Soil/Sediment	Used maximum concentration from the K-25 perimeter and EFPC (Y-12).
		Food Items	Based on concentrations in air, soil, and water and biotransfer and bioconcentration factors from literature.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening (continued)			
Material	**Source**	**Media**	**Exposure Values**
Tritium Level I Screen	Y-12 Used in deuterium gas production and lithium deuteride recovery operations	Surface Water	Evaluated based on deuterium inventory differences and the peak tritium concentration in the deuterium that was processed at Y-12; the release estimate was used with the International Atomic Energy Agency method for tritium dose assessment, assuming all the tritium that escaped was released to EFPC.

TABLE 2
Categorization of Materials Based on Screening Results

Contaminant Source	Not Candidates for Further Study (Level I result was below the decision guide)	Potential Candidates for Further Study (Refined Level I result was below the decision guide)	High Priority Candidates for Further Study (Refined Level I result was above the decision guide)
K-25	Neptunium-237 (cancer) <u>Evaluated qualitatively</u> (quantities, forms, and manner of use were not sufficient): • Carbon fibers • Four-ring polyphenyl ether • Glass fibers • Triplex coating	• Copper powder (noncancer) • Nickel (cancer) • Nickel (noncancer) • Technetium-99 (cancer)	• Arsenic (cancer) • Arsenic (noncancer)
Y-12 Plant	• Beryllium compounds (noncancer) • Neptunium-237 (cancer) • Tritium (cancer) <u>Evaluated using Threshold Quantity Approach</u> (not enough material was present): • Niobium (noncancer) • TMAB • Zirconium (noncancer) <u>Evaluated qualitatively</u> (quantities, forms, and manner of use were not sufficient): • Boron carbide • Boron nitride • Rubidium nitrate • Rubidium bromide • Tellurium • Titanium boride • Yttrium boride • Zirconium	• Beryllium compounds (cancer) • Lithium compounds (noncancer) • Technetium-99 (cancer)	• Arsenic (cancer) • Arsenic (noncancer) • Lead (noncancer) Arsenic was released into the air from the burning of coal at several coal-fired steam plants located on the Oak Ridge Reservation and into the soil, sediment, and surface water from coal piles and disposal of fly ash from the steam plants. Lead was likely released into soil, sediment, and surface water from the disposal of liquid waste into the Y-12 storm sewers and may have been released into the air from process stacks and the plant ventilation system.
ORR (all complexes)		• Chromium VI (cancer) • Chromium VI (noncancer)	

Health Consultation, U.S. DOE Oak Ridge Reservation, Lower Watts Bar Operable Unit, February 1996

Site: Oak Ridge Reservation
Study authors: Agency for Toxic Substances and Disease Registry
Time period: 1980s and 1990s
Target population: Lower Watts Bar Reservoir Area

Purpose

This health consultation was conducted to evaluate the public health implications of chemical and radiological contaminants in the Watts Bar Reservoir and the effectiveness of the Department of Energy's proposed remedial action plan for protecting public health.

Background

In March 1995, the Department of Energy (DOE) released a proposed plan for addressing contaminants in the Lower Watts Bar Reservoir. The plan presented the potential risk posed by contaminants and DOE's preferred remedial action alternative. DOE's risk assessment indicated that consumption of certain species of fish from the Lower Watts Bar Reservoir and the transfer of sediment from deeper areas of the reservoir to areas on land where crops were grown could result in unacceptable risk to human health.

The September 1995 Record of Decision for the Lower Watts Bar Reservoir presented DOE's remedial action plan for the reservoir. This remedial action included maintaining the fish consumption advisories of the Tennessee Department of Environment and Conservation (TDEC), continuing environmental monitoring, and implementing institutional controls to prevent disturbance, resuspension, removal, or disposal of contaminated sediment. The U.S. Environmental Protection Agency (EPA) and TDEC concurred with the remedial action plan.

Concerned about the sufficiency of DOE's plan, local residents asked the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate the health risk related to contaminants in the Lower Watts Bar Reservoir. These residents asked ATSDR to provide an independent opinion on whether DOE's selected remedial actions would adequately protect public health.

Methods

ATSDR agreed to provide a health consultation. A health consultation is conducted in response to a specific request for information about health risks related to a specific site, a specific chemical release, or the presence of other hazardous material. The response from ATSDR may be verbal or written.

To assess the current and recent past health hazards from the Lower Watts Bar Reservoir contamination, ATSDR evaluated environmental sampling data. ATSDR evaluated reservoir studies conducted by DOE and the Tennessee Valley Authority during the 1980s and 1990s. ATSDR also evaluated TVA's 1993 and 1994 Annual Radiological Environmental Reports for the Watts Bar nuclear plant. ATSDR first screened the voluminous environmental data to determine whether any contaminants were present at levels above health–based comparison values. ATSDR next estimated exposure doses for any contaminants exceeding comparison values. It is important to note that the fact that a contaminant exceeds comparison values does not necessarily mean that the contaminant will cause adverse health effects. Comparison values simply help ATSDR determine which contaminants to evaluate more closely.

ATSDR estimated exposure doses, using both worst case and realistic exposure scenarios, to determine if current chemical and radiological contaminant levels could pose a health risk to area residents. The worst case scenarios assumed that the most sensitive population (young children) would be exposed to the highest concentration of each contaminant in each media by the most probable exposure routes.

Target population

Individuals living along the Watts Bar Reservoir and individuals visiting the area.

Exposures

The exposures investigated were those to metals, radionuclides, volatile organic compounds, polychlorinated biphenyls (PCBs), and pesticides in surface water, sediment, and fish.

Outcome measure

ATSDR did not review health outcome data.

Results

Reservoir Fish and Other Wildlife: Using a realistic exposure scenario for fish consumption that assumed an adult weighing 70 kilogram (kg) consumed one 8-ounce sport fish meal per week, or per month, for 30 years, ATSDR determined that PCB levels in reservoir fish were at levels of health concern. ATSDR estimated ranges of PCB exposure doses from 0.099 to 0.24 micrograms of PCBs per kilogram of human body weight every day (µg/kg/day) for the one fish meal a week scenario and 0.023 to 0.055 µg/kg/day for the one fish per month scenario.

At these exposure doses, ATSDR estimates that approximately one additional cancer case might develop in 1,000 people eating one fish meal a week for 30 years and three additional cancer cases might develop in 10,000 people eating one fish meal a month for 30 years.

At these exposure doses, ATSDR also determined that ingestion of reservoir fish by pregnant women and nursing mothers might cause adverse neurobehavioral effects in infants. Although the evidence that PCBs cause developmental defects in infants is difficult to evaluate and inconclusive, ATSDR's determination was made on the basis of the special vulnerability of developing fetuses and infants.

Using a worst case scenario that assumed adults and children consumed two 8-ounce fish meals a week, containing the maximum concentration of each radioactive contaminant, ATSDR determined that the potential level of radiological exposure, which was less than 6 millirem per year (mrem/yr), was not a public health hazard.

Reservoir Surface Water: Using a worst case exposure scenario that assumed a child would daily ingest a liter of unfiltered reservoir water containing the maximum level of contaminants, ATSDR determined that the levels of chemicals in the reservoir surface water were not a public health hazard.

Levels of radionuclides in surface water were well below the levels of the current and proposed EPA drinking water standards. In addition, the total radiation dose to children from waterborne radioactive contaminants would be less that 1 mrem/yr, which is well below background levels. The radiation dose was estimated using the conservative assumption that a 10-year-old child would drink and shower with unfiltered reservoir water and swim in the reservoir daily.

Reservoir Sediment: ATSDR determined that the maximum chemical and radioactive contaminant concentrations reported in the recent surface sediments data (mercury, Co-60, Sr–89/90, and Cs-137) would not present a public health hazard. The estimated dose from radioactive contaminants was less than 15 mrem/yr, which is below background levels.

ATSDR also evaluated the potential exposure a child might receive if the subsurface sediments were removed from the deep reservoir channels and used as surface soil in residential properties. Using a worst case exposure scenario that included ingestion, inhalation, external, and dermal contact exposure routes, ATSDR determined that the potential radiation dose to individuals living on these properties (less than 20 mrem/yr) would not pose a public health hazard.

Conclusions

ATSDR found that only PCBs in the reservoir fish were of potential public health concern. Other contaminants in the surface water, sediment, and fish were not found to be a public health hazard.

On the basis of current levels of contaminants in the water, sediment, and wildlife, ATSDR concluded the following.

- The levels of PCBs in the Lower Watts Bar Reservoir fish posed a public health concern. Frequent and long-term ingestion of fish from the reservoir posed a moderately increased risk of cancer in adults and increased the possibility of developmental effects in infants whose mothers consumed fish regularly during gestation and while nursing. Turtles in the reservoir might also contain PCBs at levels of public health concern.

- Current levels of contaminants in the reservoir surface water and sediment were not a public health hazard. The reservoir was safe for swimming, skiing, boating, and other recreational purposes. It is safe to drink water from the municipal water systems, which draw surface water from tributary embayments in the Lower Watts Bar Reservoir and the Tennessee River upstream from the Clinch River and Lower Watts Bar Reservoir.

- DOE's selected remedial action was protective of public health.

ATSDR made the following recommendations.

- The Lower Watts Bar Reservoir fish advisory should remain in effect to minimize exposure to PCBs.

- ATSDR should work with the state of Tennessee to implement a community health education program on the Lower Watts Bar fish advisory and the health effects of PCB exposure.

- The health risk from consumption of turtles in the Lower Watts Bar Reservoir should be evaluated. The evaluation should investigate turtle consumption patterns and PCB levels in edible portions of turtles.

- Surface and subsurface sediments should not be disturbed, removed, or disposed of without careful review by the interagency working group.

- Sampling of municipal drinking water at regular intervals should be continued. In addition, at any time a significant release of contaminants from the Oak Ridge Reservation is discharged into the Clinch River, DOE should notify municipal water systems and monitor surface water intakes.

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

Report on Turtle Sampling in Watts Bar Reservoir and Clinch River, May 1997

Site: Oak Ridge Reservation

Conducted by: Tennessee Department of Environment and Conservation

Time period: 1996

Study area: Watts Bar Reservoir and Clinch River

Purpose

The purpose of this study was to investigate levels of contaminants—especially polychlorinated biphenyls (PCBs)—in snapping turtles in the Watts Bar Reservoir and Clinch River/Poplar Creek water systems. The results of this study were used to assess exposure levels of people who might use the turtles for food.

Background

For more than 50 years, the U.S. Department of Energy's (DOE) Oak Ridge Reservation released radionuclides, metals, and other hazardous substances into the Clinch River and its tributaries. Subsequent studies conducted by DOE and the Tennessee Valley Authority (TVA) documented elevated levels of PCBs in certain species of fish in the Watts Bar Reservoir and Clinch River. As a result, the Tennessee Department of Environment and Conservation (TDEC) issued several consumption advisories on fish. Although noncommercial fishermen are known to harvest turtles, as well as fish, from the Watts Bar Reservoir, TDEC did not issue any consumption advisories on turtles. Since little information was available on contaminant levels in turtles and previous studies from other states indicated that snapping turtles have a tendency to accumulate PCBs (for example, in their fat tissue), the Agency for Toxic Substances and Disease Registry's (ATSDR) health consultation on the Lower Watts Bar Reservoir recommended sampling of turtles for PCBs.

Study Design and Methods

To evaluate levels of contaminants in turtles, TDEC collected 25 snapping turtles from 10 sampling stations in the Watts Bar Reservoir and Clinch River between April and June 1996. As recommended by the U.S. Environmental Protection Agency (EPA), the turtles were euthanized by freezing. Fat tissue and muscle tissue were analyzed separately, as were eggs when present. The samples were processed according to EPA guidelines.

Muscle tissue, fat tissue, and eggs were analyzed for PCBs using EPA methods. TDEC also conducted a PCB-congener[1] -specific analysis on the muscle tissue of two large turtles.To compare contaminant levels in turtles to contaminant levels previously detected in fish, TDEC analyzed turtle muscle tissue for metals and pesticides. Mercury analysis was performed on 13 turtles according to EPA method 245.6, and the remaining metals were analyzed using EPA method 200.1.

Specific pesticides and organic compounds analyzed for included chlordane, DDE, DDT, endrin, hexachlorobenzene, lindane, methoxychlor, and nonachlor. Specific metals analyzed for included arsenic, cadmium, chromium, copper, lead, and mercury.

[1] PCBs are mixtures of up to 209 individual chlorinated compounds referred to as congeners. For more information, see ATSDR's toxicological profile for PCBs at *http://www.atsdr.cdc.gov/toxprofiles/tp17.html.*

Study Group

Levels of contaminants were measured in turtles only. Human exposure levels were not investigated.

Exposures

No human exposure was assessed in this study.

Outcome Measure

Health outcomes were not evaluated.

Results

PCB concentrations were highest in the fat tissue of snapping turtles. Levels in fat tissue, muscle tissue, and eggs ranged from 0.274 parts per million (ppm) to 516 ppm, 0.032 ppm to 3.38 ppm, and 0.354 ppm to 3.56 ppm, respectively. Mean values for fat and muscle tissue were 64.8 ppm and 0.5 ppm, respectively.

Ten PCB congeners considered of highest concern by EPA were identified in the two turtles analyzed for congeners. The distribution of congeners in the two turtles was similar, but the concentrations varied considerably. The turtle with the higher concentrations of PCB congeners was caught from Poplar Creek.

Mercury and copper were the only metals detected in muscle tissue. Mercury concentrations were below the U.S. Food and Drug Administration (FDA) guidance level of 1.0 ppm, and ranged from 0.1 ppm to 0.35 ppm. Copper concentrations ranged from 0.2 ppm to 2.6 ppm.

Of the pesticides studied, *cis*-nonachlor, *trans*-nonachlor, and endrin were detected. They were detected at low levels: 0.001 ppm to 0.036 ppm for *cis*-nonachlor, 0.003 ppm to 0.045 ppm for *trans*-nonachlor, and 0.043 ppm to 0.93 ppm for endrin.

Conclusions

Turtle consumption practices should be further investigated before conducting quantitative assessments to evaluate risks to human health. In particular, it is important to determine which parts of the turtle are most commonly consumed (for example, fat or muscle tissue), as well as the frequency of consumption.

While it appears that PCBs concentrate at higher levels in turtles than in fish, caution is advised in comparing fish results to turtles. Unlike the turtle studies, previous fish studies did not analyze muscle tissue and fat tissue separately.

When assessing potential human health risks related to PCBs, it is important to consider the uncertainty in the toxicity values for PCBs. Because there are no toxicity values for individual PCB congeners, uncertainty in the toxicity of PCB mixtures remains.

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Uranium Releases from the Oak Ridge Reservation—a Review of the Quality of Historical Effluent Monitoring Data and a Screening Evaluation of Potential Off-Site Exposures, Report of the Oak Ridge Dose Reconstruction, Vol. 5 The Report of Project Task 6

Site: Oak Ridge Reservation

Conducted by: ChemRisk/ORHASP for the Tennessee Department of Health

Time Period: 1999

Location: Oak Ridge, Tennessee

Purpose

The purpose of the Task 6 study was to further evaluate the quality of historical uranium operations and effluent monitoring records, to confirm or modify previous uranium release estimates for the period from 1944 to 1995 for all three complexes on the Oak Ridge Reservation (ORR), and to determine if uranium releases from the ORR likely resulted in off-site doses that warrant further study. The main results of the study are revised uranium release estimates from the Y-12 plant, K-25 gaseous diffusion plant, and the S-50 liquid thermal diffusion plant and screening-level estimates of potential health effects to people living near the ORR. These results, which are called "screening indices," are conservative estimates of potential exposures and health impacts and are intended to be used with the decision guide established by Oak Ridge Health Agreement Steering Panel (ORHASP) to determine if further work is warranted to estimate the human health risks from past uranium releases.

Background

The 1993 Oak Ridge Health Studies, Phase I Dose Reconstruction Feasibility Study by the Tennessee Department of Health indicated that uranium was not among the list of contaminants that warranted highest priority for detailed dose reconstruction investigation of off-site health effects. After receiving comments from several long-term employees at the ORR uranium facilities, a number of ORHASP members recommended that past uranium emissions and potential resulting exposures receive closer examination. In 1994, the Task 6 uranium screening evaluation was included in the Oak Ridge Dose Reconstruction project.

The Oak Ridge 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 complex 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 Y-12 plant housed many operations involving uranium, including the preparation, forming, machining, and recycling of uranium for Weapon Component Operations.

Construction of the K-25 uranium enrichment facility began in 1943, and the facility was operational by January 1945. The K-25 site is located near the western end of the ORR, along Poplar Creek near where it meets the Clinch River. The primary mission of K-25 was to enrich uranium by the gaseous diffusion process.

Located along the Clinch River near the K-25 site was a liquid thermal diffusion plant (the S-50 site) that operated from October 1944 to September 1945. Because of their close proximity, the K-25 and S-50 complexes were generally discussed together in the Task 6 report.

The X-10 facility, which conducted chemical processing of reactor fuel and other nuclear materials, was not a primary focus of the Task 6 study.

Methods

An extensive information gathering and review effort was undertaken by the project team in searching for information related to historical uranium operations at the Y-12, K-25, and S-50 sites. Thousands of documents were searched and many active and retired workers were interviewed.

The Task 6 investigation followed these basic steps:

- Information that described uranium uses and releases on the ORR was collected.
- Effluent monitoring data were evaluated for quality and consistency with previous U.S. Department of Energy (DOE) historical uranium release reports.
- Updated estimates of airborne uranium releases over time were generated using the more complete data available to the project team.
- Air dispersion models were used to estimate uranium air concentrations at selected reference locations near each ORR facility. The reference locations were:

  — the Scarboro community (for Y-12),

  — the Union/Lawnville community (for K-25/S-50), and

  — Jones Island area along the Clinch River (for X-10).

  Because the terrain surrounding the Y-12 facility has complex topography, air dispersion modeling techniques were not employed. Instead, an empirical relative concentration (chi/Q) relationship was established between measured releases of uranium from Y-12 and measured airborne concentrations of uranium at Scarboro. The chi/Q relationship was then used to extrapolate airborne uranium concentrations for times in which it was not directly measured.

- The screening evaluation of potential off-site exposures to waterborne uranium was based on environmental measurements of uranium at local surface waters. The sampling sites were: White Oak Dam, downstream of New Hope Pond, and the confluence of Poplar Creek and the Clinch River.
- A screening-level evaluation of the potential for health effects was performed by calculating intakes and associated radiation doses. A two-tiered exposure assessment methodology was employed, which provided both upper bound and more typical results. Because of the scarcity of information regarding estimates of uranium concentrations in the environment over the period of interest, some conservatism was maintained in the uranium concentrations used in the Level II screening.
- Annual radiation doses from uranium intake and external exposure were calculated for the adult age group for each screening assessment and then converted to screening indices using a dose-to-risk coefficient of 7.3% Sv^{-1}.
- Estimates of annual-average intakes of uranium by inhalation and ingestion were also used to evaluate the potential for health effects due to the chemical toxicity of uranium compounds, specifically for damage to the kidneys. Uranium was assumed to be in its most soluble form and safety factors were included to minimize the potential for underestimation of the potential for toxic effects.

Study Subjects

The screening evaluation estimated potential off-site exposure and screening indices for hypothetical individuals in three reference locations (Scarboro, Union/Lawnville, and Jones Island). These reference locations represent residents who lived closest to the ORR facilities and would have received the highest exposures from past uranium releases. Thus, they are associated with the highest screening indices derived by the screening evaluation.

Exposures

The following potential air exposure pathways were evaluated:

1. Air to humans-direct inhalation of airborne particulates
2. Air to humans (immersion in contaminated air)
3. Air to livestock (via inhalation) to beef to humans
4. Air to dairy cattle (via inhalation) to milk to humans
5. Air to vegetables (deposition) to humans
6. Air to pasture (deposition) to cattle beef to humans
7. Air to pasture (deposition) to dairy cattle to milk to humans

The following potential water exposure pathways were evaluated:

1. Incidental ingestion by humans during recreation
2. Water to livestock (ingestion) to beef to humans
3. Water to dairy cattle (ingestion) to milk to humans
4. Water to fish to humans
5. Water to humans via immersion during recreation

The following potential soil exposure pathways were evaluated:

1. Soil to air (dust resuspension) to humans
2. Soil incidental ingestion
3. Soil to livestock (soil ingestion) to beef to humans
4. Soil to dairy cattle (soil ingestion) to milk to humans
5. Soil to vegetables (root uptake) to humans
6. Soil to pasture (root uptake) to livestock to beef to humans
7. Soil to pasture (root uptake) to dairy cattle to milk to humans
8. Soil to humans via external radiation

Outcome Measures

Health outcomes were not studied.

Results

Airborne uranium releases from the Y-12, K-25, and S-50 sites were found to be greater than previously reported. DOE estimated that the amount of uranium released from the Y-12 plant was 6,535 kilograms. The Task 6 team estimated that 50,000 kilograms of uranium was released to the air by the Y-12 plant. DOE estimated that the amount released from the K-25 and S-50 plants (combined) was 10,713 kilograms. The Task 6 team estimated that 16,000 kilograms were released to the air by the K-25/S-50 complex.

The Scarboro community was associated with the highest total screening index attributable to uranium releases from the Y-12 plant. The screening indices were 1.9×10^{-3} for the Level I assessment and 8.3×10^{-5} for the Level II assessment. While the overall Level I screening index for the Scarboro community is above the ORHASP decision guide of 1.0×10^{-4} (1 in 10,000), the Level II value is below that guide value. This indicates that the Y-12 uranium releases are candidates for further study, but that they are not high priority candidates for further study.

For the K-25/S-50 assessment, the total screening index for Union/Lawnville from the Level I assessment (2.7×10^{-4}) exceeded the ORHASP decision guide. The less conservative Level II screening result (4.0×10^{-5}) did not exceed the guide. This indicates that the K-25/S-50 uranium releases are also candidates for further study, but that they are not high priority candidates for further study.

The X-10 Level I assessment yielded a screening index for Jones Island (7.6×10^{-5}) below the decision guide. This indicates that releases from the X-10 site warrant lower priority, especially given the pilot-plant nature and relatively short duration of most X-10 uranium operations.

The Scarboro community was selected for the initial chemical toxicity evaluation since its screening index for radiological exposures was the highest. Estimated kidney burdens resulting from simultaneous intake of uranium by ingestion and inhalation under the Scarboro assessment do not exceed an effects threshold criterion (1 microgram per gram of kidney tissue) proposed by some scientists, but they do exceed an effects threshold criterion (0.02 micrograms per gram of kidney tissue) proposed by other scientists. The Task 6 team also evaluated the average-annual intakes using a reference dose/Hazard Index approach and concluded that further study of chemical toxicity from past ORR uranium exposures did not warrant high priority.

Conclusions

The Task 6 team reached the following general conclusions:

- Estimates of uranium releases previously reported by DOE are incomplete and; therefore, were not used in the Task 6 screening evaluation.
- Historical uranium releases from the Y-12 plant are likely significantly higher (over seven times higher) than totals reported by DOE. There are several reasons why previous estimates were so much lower.
- Historical uranium releases from the K-25/S-50 complex are likely higher than totals reported by DOE.
- Operations at the S-50 plant are poorly documented.
- The Scarboro community had the highest total screening index from uranium releases at the ORR, specifically the Y-12 plant. Since the Level II screening index is just below the ORHASP decision criterion, with most of the conservative assumptions regarding source term and exposure parameters removed, potential exposure to uranium releases could have been of significance from a health standpoint and should; therefore, be considered for dose reconstruction.
- The Union/Lawnville community evaluation (releases from the K-25/S-50 complex) had a Level II screening index below the ORHASP criterion. However, without quantification of the uncertainties associated with the release estimates and the exposure assessment, it is not possible to say that these releases do not warrant further characterizations.
- The Level I screening index for the Jones Island area (releases from the X-10 site) are below the ORHASP decision criterion.
- Because Pine Ridge separates the Y-12 plant from Scarboro, an alternate approach (chi/Q) was used to estimate uranium air concentrations in Scarboro.
- The concentrations of uranium in soil are a major factor in the screening analyses. Because limited soil data are available for the reference locations, alternative approaches should be considered for future analyses.
- While the estimated uranium intake from ingestion and inhalation exceed one effects threshold criterion, they do no exceed another. Calculated hazard indices indicate that further study of chemical effects of the kidneys rank as a low priority.

If the evaluation of ORR uranium releases is to proceed beyond a conservative screening stage and on to a nonconservative screening with uncertainty and sensitivity analyses, activities that should be evaluated for possible follow-up work include:

- Additional records research and data evaluation regarding S-50 plant operations and potential releases.
- Additional searching for and review of effluent monitoring data for Y-12 electromagnetic enrichment operations from 1944 to 1947 and data relating to releases from unmonitored depleted uranium operations in the 1950s through the 1990s.
- Uncertainty analysis of the Y-12 uranium release estimates derived in this study.
- Review of additional data regarding unmonitored K-25 uranium releases.
- Refinement of the approach used to evaluate surface water and soil-based exposure concentrations.
- Evaluation of the effects of the ridges and valleys that dominate the local terrain surrounding Y-12 and Scarboro and investigation of alternative approaches to estimate air concentrations at Scarboro with an emphasis on identifying additional monitoring data.
- Performance of a bounding assessment of the amounts of uranium that were handled at the X-10 site.
- Improvement of the exposure assessment to include region-specific consumption habits and lifestyles, identification of likely exposure scenarios instead of hypothetical upper bound and typical assessments, and inclusion of uncertainty analysis to provide statistical bounds for the evaluation of risk.
- Refinement of the chemical toxicity evaluation, possibly to include other approaches and models, as well as an uncertainty analysis.

Appendix E. Task 4 Conservative Screening Indices for Radionuclides in the Clinch River

Table E-1. Conservative Screening Indices for Radionuclides in the Clinch River

Isotope	Exposure Pathway								
	Drinking Water	*Fish Ingestion*	*External: Shoreline*	*Swimming*	*External: Dredged Sediment*	*Ingestion of Beef*	*Ingestion of Milk*	*Ingestion of Vegetables*	*Irrigation*
Cs 137	9.2 E-06	**4.0 E-04**	**8.0 E-03**	7.6 E-07	**1.6 E-03**	**5.9 E-03**	**5.7 E-03**	**5.6 E-04**	3.2 E-08
Ru 106	**7.7 E-05**	**1.7 E-05**	**1.1 E-03**	5.2 E-06	**4.5 E-05**	**1.6 E-04**	4.4 E-07	**5.8 E-05**	1.2 E-08
Sr 90	**2.5 E-05**	**3.3 E-05**	**7.1 E-05**	1.5 E-06	9.8 E-06	**1.7 E-02**	**2.5 E-02**	**6.4 E-03**	5.1 E-07
Co 60	2.8 E-06	**1.9 E-05**	**6.0 E-03**	1.7 E-07	**8.5 E-04**	**1.1 E-03**	**7.6 E-04**	**7.5 E-05**	6.2 E-09
Ce 144	4.2 E-06	2.7 E-06	**2.1 E-05**	2.6 E-07	7.2 E-08	1.1 E-08	7.4 E-08	3.2 E-07	2.2 E-09
Zr 95	8.1 E-07	5.3 E-06	**1.8 E-04**	4.3 E-07	5.1 E-09	8.8 E-11	2.7 E-10	2.1 E-12	3.1 E-12
Nb 95	4.2 E-07	2.7 E-06	**5.1 E-05**	2.0 E-07	3.1 E-09	1.4 E-11	9.1 E-11	1.4 E-11	3.7 E-12
I 131	**4.1 E-05**	6.7 E-06	7.2 E-08	4.1 E-06	3.2 E-12	6.0 E-07	**3.8 E-05**	1.1 E-11	9.3 E-10
U 235	1.5 E-07	3.2 E-08	5.0 E-06	9.4 E-09	7.8 E-07	2.8 E-07	2.7 E-07	4.6 E-07	1.8 E-10
U 238	1.3 E-07	2.9 E-08	8.4 E-07	8.0 E-09	1.4 E-07	2.5 E-07	2.4 E-07	4.2 E-07	1.6 E-10
Pu 239/240	9.8 E-07	6.4 E-07	1.4 E-07	5.9 E-08	1.5 E-09	3.8 E-07	2.8 E-08	3.1 E-06	2.4 E-10
Th 232	1.0 E-07	2.2 E-07	9.2 E-08	6.1 E-09	2.7 E-09	2.0 E-08	4.8 E-09	1.6 E-07	1.2 E-11
Am 241	1.0 E-07	6.7 E-08	3.8 E-06	6.2 E-09	2.0 E-07	1.7 E-08	1.6 E-08	2.8 E-07	2.5 E-11
Eu 154	4.9 E-06	5.3 E-06	3.6 E-08	1.1 E-06	5.1 E-09	1.3 E-06	1.7 E-07	1.0 E-06	4.4 E-10
La 140	4.9 E-06	2.7 E-06	1.0 E-06	1.8 E-06	2.0 E-09	1.1 E-07	1.6 E-08	7.2 E-12	3.9 E-13
Pm 147	7.4 E-07	4.8 E-07	2.6 E-08	4.4 E-08	1.1 E-11	1.7 E-08	2.8 E-09	6.0 E-10	3.6 3-11
Sm 151	2.3 E07	1.5 E-06	1.3 E-07	1.4 E-08	3.8 E-10	90 E-07	1.2 E-07	7.5 E-07	2.7 E-11
Sr 89	1.5 E-08	1.9 E-08	1.2 E-11	8.8 E-10	1.1 E-13	1.4 E-09	2.4 E-09	3.4 E-11	0.0 E+00
Ba 140	8.6 E-07	9.4 E-08	5.6 E-07	2.8 E-07	0.0 E+00	1.9 E-09	2.3 E-08	0.0 E+00	5.4 E-12
P 32	7.8 E-08	3.8 E-06	2.3 E-12	4.7 E-09	6.9 E16	4.2 E-08	3.3 E-13	3.3 E-13	1.6 E-13
Y 91	7.0 E-06	4.6 E-06	3.5 E-07	4.2 3-07	.3 E-11	7.6 E-08	2.3 E-08	1.1 E-10	2.9 E-11
Pr 143	3.5 E-06	2.3 E-06	9.6 E-09	2.1 E-07	1.5 E-12	7.6 E-08	1.1 E-08	8.3 E-12	0.0 E+00
Nd 147	3.1 E-06	2.0 E-06	1.6 E-06	2.7 E-07	3.6 E-10	6.8 E-08	1.0 E-08	6.0 E-12	0.0 E+00

Bold values represent radionuclides for each pathway that were carried into the next iteration of analysis in Task 4.
Screening indices are calculated probabilities of developing cancer.

Appendix F. Discussion of Risk

During the public health assessment process, ATSDR uses *radiation doses rather than risk*

- to evaluate potential human exposures and health effects associated with site-specific exposure factors, and
- to develop public health conclusions.

Public health assessments differ from the U.S. Environmental Protection Agency's (EPA) risk assessments, which evaluate hypothetical risk to determine safe regulatory limits and prioritize sites for cleanup. Typically, ATSDR does not incorporate risk numbers in public health assessments. Nevertheless, in response to public requests to describe the methodology used in this public health assessment to convert doses to risk numbers, ATSDR includes this supplemental risk appendix. By applying the methods described in this appendix, community members can estimate for themselves the theoretical risk from exposure to X-10 radionuclides released to the Clinch River and the Lower Watts Bar Reservoir via White Oak Creek.

Differences between Dose and Risk

Dose, as defined by ATSDR, is the "amount of a substance to which a person may be exposed, usually on a daily basis." For chemicals, dose is often referred to as the "amount of substances(s) per body weight per day" and is the basis for determining levels of exposure that might cause adverse health effects. In the case of radiation, dose is the amount of energy deposited in a specific body mass.

The Society for Risk Analysis defines **risk** as the "potential for realization of unwanted, adverse consequences to human life, health, property, or the environment; estimation of risk is usually based on the expected value of the conditional probability of the event occurring times the consequence of the event given that it has occurred."[18] The EPA defines risk as "a measure of the probability that damage to life, health, property, and/or the environment will occur as a result of a given hazard."[19]

18 [SRA] Society for Risk Analysis. 2004. Glossary of risk analysis terms. Available from: http://sra.org/resources_glossary.php. Last accessed 25 January 2006.
19 [USEPA] US Environmental Protection Agency 2006. Terms of environment: glossary, abbreviations and acronyms. Available from: http://www.epa.gov/OCEPAterms/rterms.html. Last accessed 14 April 2006.

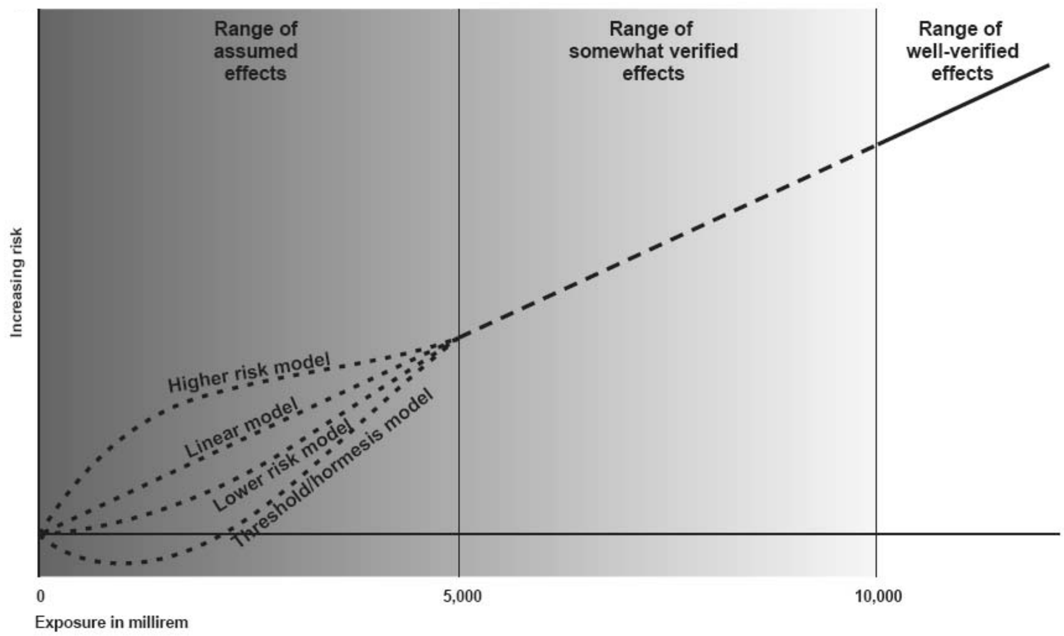
__How Does a Risk Assessment Differ from a Public Health Assessment?__

Again, EPA defines a risk assessment as a "qualitative and quantitative evaluation of the risk posed to human health and/or the environment by the actual or potential presence and/or use of specific pollutants." Risk assessments—useful in determining safe regulatory limits and prioritizing sites for cleanup—provide estimates of theoretical risk from possible current or future exposures and consider all contaminated media, regardless of whether exposures are occurring or are likely to occur. Quantitative risk estimates developed using the EPA risk assessment methodology include multiple safety factors and are not intended to predict the incidence of disease or measure the actual health effects in people resulting from hazardous substances at a site. By design, EPA risk estimates are conservative predictions that generally overestimate risk. Risk assessments do not provide a perspective on what the risk estimates mean in the context of the site community and do not measure the actual health effects hazardous substances have on people.

The mathematical formula used to calculate risk estimates assumes a linear (i.e., straight line) response to exposure, even though an actual effect may not be detected in an exposed population. The inability to detect an effect could result from the absence of an effect at lower levels of exposure or because the current epidemiological tools are not sufficient to demonstrate the existence of a very small excess of health effects, such as cancer incidence. The conservative approach to risk assessment, which likely overestimates the true potential impact of exposure, is appropriate for exposure prevention and prioritizing site cleanup. Please see Figure F-1 for examples of different models of low-level radiation effects, including the linear model used by governmental and nongovernmental entities to estimate radiation risks.

ATSDR recognizes that every radiation dose, action, or activity may carry an associated risk. ATSDR uses the public health assessment process to evaluate the public health implications of exposure to environmental contamination and to identify the appropriate public health actions for particular communities. A public health assessment provides conclusions about the level of the health threat (if any) posed by a site, as well as recommendations to stop or reduce exposures. Because of uncertainties regarding exposure conditions and because of adverse effects related to environmental levels of exposure, definitive answers are not possible on whether health effects

Figure F-1. Examples of Different Models of Low-Level Radiation Effects[20]



actually will or will not occur. It is possible, however, for a public health assessment to provide a framework that puts site-specific exposures and the potential for harm in perspective.

ATSDR uses the public health assessment process to answer site-specific questions for people potentially exposed to hazardous substances:

- Have health effects been associated with my level of exposure?
- If so, which health effects have been seen at this level of exposure by physicians, epidemiologists, or toxicologists?
- What can I do to lessen the effects of exposure?

When answering community members' questions about impacts from past, current, and future exposures, extreme overestimations of possible effects can cause unnecessary fear and worry. Therefore, instead of using mathematical formulas to estimate *theoretical harm* caused by potential exposures, ATSDR provides the public with answers about health effects associated

20 [GAO] US General Accounting Office. 2000. Radiation standards. Scientific basis inconclusive, and EPA and NRC disagreement continues. Report to the Honorable Pete Domenici, US Senate. Washington, DC: US General Accounting Office. Report GAO/RCED-00-152; June. Available from: http://www.gao.gov/new.items/rc00152.pdf. Last accessed 25 April 2006.

with exposures based on *real observations* by physicians, epidemiologists, or toxicologists. Using this information, ATSDR will make necessary recommendations to prevent and to mitigate exposures potentially occurring at levels that have been shown to cause adverse health effects. If, however, exposures were at levels below those associated with adverse health effects, further actions would not be recommend.

For more information on the intentional differences between public health assessments and risk assessments, please see ATSDR's *Public Health Assessment Guidance Manual* (http://www.atsdr.cdc.gov/HAC/PHAManual/toc.html), EPA's *Risk Assessment Guidance for Superfund – Human Health Evaluation Manual* (http://cfpub1.epa.gov/superapps/index.cfm/fuseaction/pubs.results/results.cfm), and *A Citizen's Guide to Risk Assessments and Public Health Assessments at Contaminated Sites* (written jointly by ATSDR and EPA Region IV; see http://www.atsdr.cdc.gov/publications/CitizensGuidetoRiskAssessments.html).

Radiation Risks

Radiation risks are derived from many exposure studies that have undergone review by governmental and nongovernmental international groups, including

- the EPA,
- the U.S. Nuclear Regulatory Commission (NRC),
- the U.S. Department of Energy (DOE),
- various universities,
- the National Council on Radiation Protection and Measurements (NRCP),
- the International Commission on Radiological Protection (ICRP), and
- the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

These reviews assist scientists, legislators, regulators, and others in estimating the risks of cancer and deaths associated with radiological exposures and radiological doses.

In its 1991 Publication 60,[21] the ICRP discussed risk in terms of radiation detriment and derived probabilities of developing fatal cancers in various organs as measured by the effective dose. The commission also evaluated organ detriment by deriving tissue weighting factors. The ICRP defines a tissue weighting factor as "The factor by which the equivalent dose in a tissue or organ is weighted to represent the relative contribution of that tissue or organ to the total detriment resulting from uniform irradiation of the body." Thus weighting factors convert an organ dose equivalent to a committed effective dose for the whole body. (See Section III.A.1. in the PHA for more information on tissue weighting factors, organ dose equivalents, and effective doses). These weighting factors are applied to ensure the detriment produced is "broadly the same degree" regardless of the tissue or organ irradiated. As mentioned throughout this White Oak Creek public health assessment, the ICRP has a recommended annual radiation ***dose limit*** for the public of 100 millirem (mrem)/year. ICRP continues to state, however, that "The Commission does not yet recommend an annual [radiation] ***risk limit*** for individuals."

In 1993, the NCRP published risk estimates designed for radiation protection. The NCRP developed these estimates based on a review of studies from UNSCEAR and the National Academy of Sciences' Committee on Biological Effects of Ionizing Atomic Radiation (BEIR). These studies, which included investigations on radiation effects on the thyroid and the fetus, reported the risks associated with exposure to low doses of ionizing radiation. Given its review, the NCRP estimated the following risks for members of the public exposed to ionizing radiation: a lifetime cancer mortality risk of 0.05 per sievert (Sv) (5%); a hereditary risk of 0.01 per Sv (1%), and a risk of severe mental retardation for fetuses exposed at 8–15 weeks gestational age of 0.04 per Sv (0.4%).[22]

In 1994, the EPA published its methodology for estimating cancer risks from low-level radiation exposures. These estimates, derived from similar data used by the NCRP in Report 115, incorporated 1980 vital statistics to develop organ-specific risks for a stationary US population.[23] In Federal Guidance Report 13, released in 1999, the EPA presented refined risk estimates for low-level radiation exposures to be used for various purposes, such as assessing individual sites

21 [ICRP] International Commission on Radiological Protection. 1991. 1990 Recommendations of the International Commission on Radiological Protection. New York: Pergamon Press; ICRP Publication 60.

22 [NCRP] National Council on Radiation Protection and Measurements. 1993. Risk estimates for radiation protection. NCRP Report 115. Bethesda, MD: National Council on Radiation Protection and Measurements.

23 [USEPA] US Environmental Protection Agency. 1994. Estimating radiogenic cancer risks. EPA 402-R-93-076; June. Available from: http://www.epa.gov/radiation/docs/rad_risk.pdf. Last accessed 15 March 2006.

and conducting general analysis for rule making. These estimates include risks from numerous radionuclides, routes of exposure, and ages of exposure.[24]

In 2005, the EPA released draft guidelines for carcinogenic risk assessments that discussed guidance for developing and using risk assessments.[25] The EPA stated "where alternative approaches have significant biological support, and no scientific consensus favors a single approach, an assessment may present results using alternative approaches. A nonlinear approach can be used to develop a reference dose or a reference concentration." Thus, the EPA indicates that multiple approaches using linear and nonlinear methods are appropriate if more than one mode of action exists. Also, in an EPA Risk Assessment Task Force report titled *An Examination of EPA Risk Assessment Principles and Practices,* the agency stated that the "risk estimates are designed to ensure that risks are not underestimated, which means that a risk estimate is the upper bound on the estimated risk." Further, the EPA explicitly stated that the true cancer potency "could be as low as zero."[26]

In a proposed risk assessment bulletin released in 2006, the US Office of Management and Budget (OMB) issued new technical guidance to improve risk assessments prepared by the federal government.[27] The bulletin emphasizes the importance of high-technical-quality risk assessments that present scientific issues in an objective manner. According to the OMB, risk assessments need to describe the basis of every critical assumption and specify how the assumptions affect the risk assessment's main findings. An assessment should also discuss the empirical data that both supports and conflicts with the assumptions. The OMB proposed bulletin stated that these discussions should include "the range of scientific opinions regarding the likelihood of plausible alternate assumptions" and "whenever possible, a quantitative evaluation

24 [USEPA] US Environmental Protection Agency. 1999. Cancer risk coefficients for environmental exposure to radionuclides. Federal Guidance Report 13. EPA 402-R-99-001. Washington, DC: US Environmental Protection Agency; September. Available from: http://www.epa.gov/radiation/docs/federal/402-r-99-001.pdf. Last accessed 15 March 2006.

25 [USEPA] US Environmental Protection Agency. 2005. Guidelines for carcinogen risk assessment. EPA/630/P-03/001B. Washington, DC: US Environmental Protection Agency; March. Available from: http://www.epa.gov/IRIS/cancer032505.pdf. Last accessed 25 April 2006.

26 [USEPA] US Environmental Protection Agency. 2004. An examination of EPA risk assessment principles and practices. EPA/100/B-04/001. Washington, DC: US Environmental Protection Agency; March. Available from: http://www.epa.gov/osa/pdfs/ratf-final.pdf. Last accessed 20 April 2006.

27 [OMB] US Office of Management and Budget. 2006. Proposed risk assessment bulletin. Available from: http://www.whitehouse.gov/omb/inforeg/proposed_risk_assessment_bulletin_010906.pdf. Last accessed 20 April 2006.

of reasonable alternative assumptions should be provided. If an assessment combines multiple assumptions, the basis and rationale for combining the assumptions should be clearly explained."

To summarize, many governmental and nongovernmental agencies use a linear approach for estimating radiation risks. This linear approach, called the linear nonthreshold (LNT) model, assumes an inherent risk irrespective of the dose. Although this risk has not been seen to date, various agencies use this approach to set regulatory limits, to develop recommended exposure limits for the public, and to evaluate public health hazards (e.g., ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years incorporates the LNT model).

Risk Limits

Table F-1 summarizes the organ-specific risk estimates developed by the ICRP (1991) and the EPA (1994 and 1999). The table expresses the results in units of equivalent (organ) dose, and the totals are expressed in terms of effective (whole-body) dose. For the purposes of this discussion, the dose units of Sv and gray (Gy) are interchangeable. The dose unit of rem is equal to 0.01 Sv or 0.01 Gy.

EPA guidance states that carcinogens should be limited to a risk range of 1 in 10,000 to 1 in 1,000,000 (1×10^{-4} to 1×10^{-6}), presumably above background exposure. EPA applies this range in its baseline risk assessments to rank sites relatively (primarily) for cleanup; EPA does not, however, determine the likelihood that health effects might occur. The following risk numbers are calculated when the ICRP risk coefficients presented in Table F-1 (converted to 0.0005 per rem) are multiplied by the background radiation dose of 360 mrem/year (including radon) and ATSDR's radiation screening value of 100 mrem/year (for radiation exposure in excess of background):

- Annual risk to average background radiation (360 mrem): $0.36 \times 0.0005 = 0.00018$
- Annual risk to the ATSDR screening value (100 mrem): $0.10 \times 0.0005 = 0.00005$

Exposure to average background radiation (1.8 in 10,000), which cannot be avoided and to which everyone is exposed, exceeds the EPA risk range. The ATSDR screening value of 100 mrem is, however, equivalent to a risk of 5 in 100,000, which falls near the center of EPA's prescribed risk range.

Table F-1. Summary of Organ-Specific Risk Estimates

Organ	*ICRP[*] (rem)*	*EPA[†] (rad)*	*EPA FGR 13[‡] (rad)*
Bladder	3E-05	2.49E-05	2.38E-05
Bone marrow	5E-05	4.96E-05	5.57E-05
Bone surface	5E-06	9.00E-07	9.50E-07
Breast	2E-05	4.62E-05	5.06E-05
Colon	8.5E-05	9.82E-05	1.04E-04
Liver	1.5E-05	1.50E-05	1.50E-05
Lung	8.5E-05	7.16E-05	9.88E-05
Esophagus	3E-05	9.00E-06	1.17E-05
Ovary	1E-05	1.66E-05	1.49E-05
Skin	2E-06	1.00E-06	1.00E-06
Stomach	1.1E-04	4.44E-05	4.07E-05
Thyroid	8E-06	3.20E-06	3.24E-06
Remainder	5E-05	1.29E-04	1.54E-01
Total (whole body) risk	5E-4 per rem per year	5.09E-04 per rad per year	5.75E-04 per rad per year
0.1 rem/y (100 mrem/y)	5.00E-05 per year	5.09E-05	5.75E-05

Calculation of Risk for the Oak Ridge Public Health Assessments

As previously discussed at public meetings, ATSDR does not perform risk assessments, nor does it report its findings in terms of risk. Calculating the risks from the doses reported by ATSDR in this PHA, however, only involves one additional step. To calculate the risk, multiply the doses reported by ATSDR by the appropriate organ risk factor from Table F-1, being sure to use consistent units throughout the calculations.

Using the following equation, here are some examples of how to calculate the risk from an estimated radiation dose.

$$\text{Risk} = \text{Annual Dose} \times \text{Risk Coefficient} \times \text{Years of Exposure}$$

Examples of Calculating Risks From Estimated Radiation Doses

Whole-body dose

Annual Dose (in rem):	100 mrem per year (0.1 rem)
Risk Coefficient:	0.0005 per rem per year
Years of Exposure:	5 years

Risk = 0.1 × 0.0005 × 5 = 0.00025 (2.5 per 10,000)

This result of 2.5 per 10,000 can then be compared to the estimated risk an individual would receive from typical exposures to background radiation during the same time period:

Risk = 0.36 × 0.0005 × 5 = 0.0009 (9 per 10,000)

Dose to the bone marrow

Annual Dose (in rem):	100 mrem per year (0.1 rem)
Risk Coefficient:	0.00005 per rem per year
Years of Exposure:	5 years

Risk = 0.1 × 0.00005 × 5 = 0.000025 (2.5 per 100,000)

Dose to the thyroid

Annual Dose (in rem):	10,000 mrem per year (10 rem)
Risk Coefficient:	0.000008 per rem per year
Years of Exposure:	5 years

Risk = 10 × 0.000008 × 5 = 0.0004 (4 per 10,000)