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 curries (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.