PUBLIC HEALTH ASSESSMENT

Iodine-131 Releases

Oak Ridge Reservation (USDOE)
Oak Ridge, Anderson County, Tennessee

EPA FACILITY ID: TN1890090003

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Prepared by:
Site and Radiological Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

Foreword

The Agency for Toxic Substances and Disease Registry, ATSDR, is an agency of the U.S. Department of Health and Human Services. ATSDR was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as the Superfund Law. This law set up a fund to identify and clean up our country's hazardous waste areas. The U.S. Environmental Protection Agency (EPA) and the individual states regulate the investigation and clean up of the areas.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the areas on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to determine the level of contamination at an area, where it is, and how people might come into contact with it. In general, ATSDR does not collect its own environmental sampling data; rather, it reviews information provided by EPA, other government agencies, businesses, and the public. When there is insufficient environmental information, the report will indicate what additional sampling data are needed.

Health effects: If the review of the data shows that people have or could come into contact with hazardous substances, ATSDR then evaluates whether or not there are likely to be any harmful effects from these exposures. The report focuses on the health impact on the community as a whole, rather than on risks to individuals. ATSDR generally uses existing scientific information, which can include the results of medical, toxicological, and epidemiological studies, and the data collected in disease registries. The science of environmental health is still developing, and occasionally scientific information on the health effects of certain substances is not available. When this is so, the report will suggest what further research studies are needed.

Conclusions: The report presents conclusions about the level of health threat, if any, posed by an area. In its public health action plan, the report recommends ways to stop or reduce exposure. ATSDR is primarily an advisory agency, so these reports usually identify what appropriate actions are to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory to warn people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiological studies, disease registries, surveillance studies, or research on specific hazardous substances.

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

Comments

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

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List of acronyms and abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
Bq	becquerel (= 1 radioactive disintegration per second = $1/3.7 \times 10^{10}$ Ci)
Bq/m^3	becquerel per cubic meter
CAM	continuous air monitoring
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Ci	curie (a measure of radioactivity: 1 Ci = 3.7×10^{10} disintegrations per second)
cGy	centigray (1 cGy = 0.01 Gy = 1 rad)
DCF	dose conversion factor
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ERR	excess relative risk
IARC	International Agency for Research on Cancer
ICRP	International Commission on Radiological Protection
I-129	iodine-129
I-131	iodine-131
kg	kilogram (SI unit of mass)
LNT	linear no-threshold
mrem	millirem (1 mrem = 0.001 rem)
µCi	microcurie (1 µCi = 0.000001 Ci, or one millionth of a curie)
mSv/person	millisieverts per person
nCi	nanocurie
NCRP	National Council on Radiation Protection and Measurements
NPL	National Priorities List
NTS	Nevada Test Site
ORHASP	Oak Ridge Health Agreement Steering Panel
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
ORRHES	Oak Ridge Reservation Health Effects Subcommittee
PCBs	polychlorinated biphenyls
pCi	picocurie (1 pCi = 10^{-12} Ci, or one trillionth of a curie)
pCi/g	picocuries per gram
pCi/m^3	picocuries per cubic meter
rad	an older unit of absorbed dose of radiation (1 rad = 1 cGy)
RaLa	radioactive lanthanum
rem	dose equivalent: 1 rem = 0.01 Sv
Sv	sievert (a derived unit of dose equivalent based on W_R and W_T; it has the same units as the gray, but does not measure the same thing; 1 Sv = 100 rem)
TDEC	Tennessee Department of Environment and Conservation
TDOH	Tennessee Department of Health
TSCA	Toxic Substances Control Act
TSH	thyroid stimulating hormone
WHO	World Health Organization
W_R	radiation weighting factor
W_T	tissue weighting factor

I. Summary

I.A. Oak Ridge Reservation background

In 1942, as the United States entered World War II, the federal government established the Oak Ridge Reservation (ORR) in Anderson and Roane Counties, Tennessee. An extension of the Manhattan Project, ORR's mission was to research, develop, and produce special radioactive materials for nuclear weapons. The government immediately built four facilities at ORR to enrich uranium: the Y-12 plant, the K-25 site, and the S-50 site. Also, to demonstrate processes for the production and separation of plutonium, the government established the X-10 site. Each of these sites operated during and immediately after WW II. In the years following the end of the war, however, ORR's national security role, and specifically the Y-12 plant, K-25 site, and X-10 site, expanded to include a number of nuclear research and nuclear production projects.

Over the years, ORR operations generated various radioactive materials. Even the waste products from these operations included radioactive iodines as well as other nonradioactive materials. Although some of these wastes accumulated in disposal sites, others were released into the environment. Consequently, in 1989 the U.S. Environmental Protection Agency (EPA) added ORR to the National Priorities List (NPL). Currently, the U.S. Department of Energy (DOE) together with EPA and the Tennessee Department of Environment and Conservation (TDEC) are working together under a Federal Facility Agreement to clean up and remove hazardous materials from past and present ORR activities.

Most of the radioactive iodines generated at ORR came from the X-10 facility, now known as the Oak Ridge National Laboratory, or ORNL. At X-10 irradiated uranium fuel slugs—also known as spent nuclear fuel—were processed for nuclear weapons research and development. The major processing effort separated radioactive barium as a step toward recovering radioactive lanthanum (RaLa). Scientists at the Los Alamos, New Mexico site (now the Los Alamos National Laboratory) needed RaLa to evaluate bomb designs. After WW II and during the 1940s and 1950s, the government broadened X-10's mission to include the production of radioisotopes for commercial and medical use as well as for experimental reactor operations.

Byproducts of X-10 processing included large amounts of radioactive wastes and associated chemicals. During X-10's early years, demands for increased RaLa production overwhelmed the rudimentary treatment control systems then in place—the systems were simply not adequate to contain or to treat properly offgases released during production. As a result, nuclear-reaction byproducts or fission products were released into the air. Radioactive iodine, a byproduct of RaLa production, escaped from local stacks, from building vents, and from other chemical processes. As a result of an accident that occurred on April 29, 1954, additional significant amounts of radioactive iodine were released to the air surrounding ORR.

I.B. Agency for Toxic Substances and Disease Registry's (ATSDR's) evaluation of past, current, and future exposure to radioactive iodines

This public health assessment first evaluates past radioactive iodine releases from ORR's X-10 facility. It then assesses past, current, and future exposure to radioactive iodines. Finally, it addresses the community health concerns and issues associated with such exposure. This public health assessment does not, however, address other contaminants of concern such as uranium, mercury, polychlorinated biphenyls (PCBs), or fluorides released from other Oak Ridge facilities, nor does it address exposures to those contaminants. In separate public health assessments, ATSDR will evaluate these and other contaminants, as well as related topics.

I.B.1. Past exposure (1944–1991)

ORR's X-10 facility released radioactive iodines between 1944 and 1956. People who lived near ORR in the past might have come in contact with X-10's radioactive iodines in the air they breathed or the food they ate. Insufficient data are available to determine the precise area of past radioactive iodine releases from the X-10 facility. Because of such limited data, ATSDR is unable to determine the extent to which specific communities may have been affected by past radioactive iodine releases.

The state of Tennessee identified the RaLa process as the most important source of radioactive iodine released from the X-10 site. As stated, over a 13-year period many short-decayed reactor fuel slugs were processed without adequate treatment controls. The Tennessee Department of Health's (TDOH) Task 1 team conducted a dose reconstruction to evaluate iodine-131 (I-131) releases resulting from RaLa manufacture. Because limited actual environmental data were available for this 13-year period, the TDOH developed model data to evaluate past off-site concentrations and to estimate potential exposures to off-site populations. Using conservatively modeled data, the TDOH dose reconstruction inferred that airborne radioiodines reached communities as far as 24 miles away, and that persons who drank backyard cow or goat milk received the highest doses of radioactive iodine, estimated at 800 rad. To assess further any possible exposures from past X-10 releases, ATSDR also reviewed the TDOH Task 1 dose reconstruction results.

Since TDOH's Task 1 Oak Ridge I-131 dose reconstruction, historical continuous air monitoring (CAM) data and data on the thyroid iodine content of deer harvested from the X-10 site have become available. Taken together, the historical CAM data and the deer thyroid data strongly suggest two outcomes. First, releases of radioiodines did not extend past the X-10 site boundaries at levels that would constitute a public health hazard, and second, that the TDOH dose reconstruction results overestimated the atmospheric dispersion from the RaLa process. Nevertheless, while these data suggest that radioactive iodines did not travel far from the X-10 site, the X-10 CAM data were only reported as gross beta/gamma measurements of long-lived activity; no evidence suggests that such activity was due to iodine or any other radioisotope released from the facility. Thus to assess possible health implications of exposure to radioactive iodine at the levels presented in the Task 1 report or derived from available historical environmental monitoring data, ATSDR reviewed not only the X-10 data, but the medical, epidemiological, and radiological literature as well.

The most recent data on thyroid-induced diseases include studies from the Chernobyl reactor accident in 1986 and other reports concerning noncancerous and cancerous effects on the thyroid. From these studies, ATSDR found enough epidemiological evidence to conclude that persons at least 21 years of age during the RaLa operations were probably not exposed to harmful levels of radioiodines that would induce thyroid disease or cancer. Yet a review of these studies indicates that younger persons (under the age of 18) are more sensitive than are adults to the potential adverse health effects associated with thyroid uptake of radioactive iodines. Because of insufficient information about the actual areas affected by the RaLa releases, ATSDR cannot identify which communities near X-10 or which younger persons were affected in the past. ATSDR does, however, consider as the critical, sensitive population those persons who were under the age of 18 during the RaLa release years of 1944–1956 and who received a thyroid radiation dose above 10 rads.

ATSDR believes that to better assess public health hazards from radioiodine releases, more accurate estimates of radioactive iodine dispersion are needed. The agency recommends taking soil samples to 1) reduce the uncertainties associated with the modeled data in the Task 1 report, and 2) address the limitations of using CAM air monitoring data for gross beta and gamma activity. Sampling iodine-129* would enable researchers to redefine those areas affected by the iodine releases and would refine the doses received in the affected areas. ATSDR would use the results of such soil sampling to revisit its public health conclusions and the actions stated in this public health assessment.

ATSDR concluded that radioactive iodines released from ORR's X-10 facility in the past pose no current or future health concerns. As laboratory processes and operations have changed, few if any radioactive iodines are currently released from ORR, and current levels of I-131 in the air, soil, surface water, and biota are too low to cause observable health effects.

I.B.2. Current (1991–present) and future exposure

ATSDR does not expect that historical releases of X-10 radioactive iodines pose harmful *current (*1991–present) *or future exposures*. Little if any radioactive iodine is currently released from ORR. Additionally, because of I-131's short radioactive half-life (~8 days), any X-10 releases during the 1940s and 1950s and even through 2005 have decayed completely. Although the X-10 releases of I-129—which has a long radioactive half-life of about 15.7 million years—is still present in the environment, ATSDR believes that the levels are not of public health concern. The biological half-life for iodine is independent of the isotope—thus in about 66 days both I-129 and I-131 are entirely excreted from the body. Moreover, once I-131 enters the thyroid, where it is preferentially absorbed and stored, it is expelled in about 120 days. Some evidence also suggests that the amount of stable, nonradioactive iodine found in today's diets may offer sufficient protection against absorbing too much radioactive iodine from the environment. In other words, if a sufficient level of stable iodine is in the bloodstream, the thyroid will absorb it, and any additional uptake of radioactive iodine will be competitively inhibited. Therefore, on the basis of current and proposed operations, ATSDR does not reasonably expect anyone now or in the future to encounter radioactive iodine at levels that would put him or her at risk of adverse health effects.

* I-129 has a longer half-life than I-131 but is chemically identical and would exhibit a similar dispersion.

II. Background

II.A. Description and operational history

II.A.1. Oak Ridge Reservation

Shortly after the United States' entry into World War II, the federal government established the Oak Ridge Reservation (ORR) in Anderson and Roane Counties, Tennessee. ORR was the next stage in the Manhattan Project's mission to research, develop, and produce special radioactive materials for nuclear weapons. The government developed four sites at ORR: the X-10 site was a pilot facility for plutonium production, while uranium was enriched at the Y-12 plant, the K-25 site, and the S-50 site. Since the end of World War II and particularly at the Y-12 plant and the K-25 and X-10 sites, the government has expanded the ORR's national security role to include a variety of nuclear research and production projects.

> I-129 and I-131—the most biologically important radioactive isotopes released in the environment by the RaLa process—emit beta particles and gamma radiation during the decay process. Although nuclear testing releases large amounts of iodine-131, its short half-life means that little remains in the environment. I-129 on the other hand has a long half-life (15.7 million years), but the amount produced by nuclear testing is typically far less than is produced naturally in the environment.
>
> Source: EPA 2002

Today the X-10 site is known as the U.S. Department of Energy's (DOE) Oak Ridge National Laboratory (ORNL). When first created in 1943, it was a pilot plant to support the Clinton Pile,[†] the first fully operational nuclear reactor. At that time X-10 processed irradiated uranium fuel slugs—also known as spent nuclear fuel—for nuclear weapon research and development. During a 13-year period from 1944 to 1956 the major effort at X-10 involved separation of radioactive barium as a way to recover radioactive lanthanum (RaLa). Shipped from the X-10 site to the Los Alamos, New Mexico site (now Los Alamos National Laboratory), RaLa was largely used to evaluate nuclear bomb design. Also during 1944–1956, X-10's mission was expanded to include the production of radioisotopes for commercial and medical uses and for experimental reactor operations. These demands for increased production exceeded the capacity of the treatment control systems then in place to contain or to treat properly all of the released offgases.

Consequently, between 1944 and 1956 untreated byproducts or fission products of nuclear reactions were released into the air. Radioactive iodine, one byproduct of the RaLa process, was released from local stacks, from building vents, and from other chemical processes. An April 29, 1954, accident also released radioactive iodine to the air in significant amounts. Table 1 shows estimated maximum annual releases of radioactive iodine from ORR operations. Although other operations at X-10 released radioactive iodine, processing irradiated uranium fuel slugs through the RaLa process appears to have responsible for most of the radioactive iodine released into the environment.

[†] This document will continue to refer to the site as X-10.

Table 1. Estimated maximum annual radioactive iodine release by source area

Radioactive iodine source area (years of operation)		*Estimated maximum annual radioactive iodine release**	
		Curies	*Year*
Radioactive lanthanum processing	X-10 graphite reactor slugs (1944–1951)	64,200	1947
	Hanford slugs (1952–1956)	66,700	1956
Chemical separation of plutonium from Clinton Pile fuel (November 1943–January 1945)		23,600	1944
Thorex processing of short-decay irradiated thorium (July 1956–November 1957)		11,700	1957
Graphite reactor fuel slug ruptures (1944–1948)		96	1947

* Composition is presumed to be I-131.

Source: ChemRisk 1993

II.A.2. RaLa processing at X-10 and radioactive iodine releases

RaLa processing involved dissolving aluminum-encased natural uranium fuel slugs in an acid, followed by a series of steps to separate and purify the elements contained in the slugs (Figure 1). Initially, the slugs came from the Clinton Pile or from the Oak Ridge Graphite Reactor. During this same 1948–1952 time period, X-10 also began to use fuel slugs from the Hanford, Washington reactors as the starting material for the RaLa process. The first RaLa process, or “run” occurred in the 706-C building in 1944. When in 1945 processing demands exceeded the capacity of the original building, the government constructed Building 706-D.

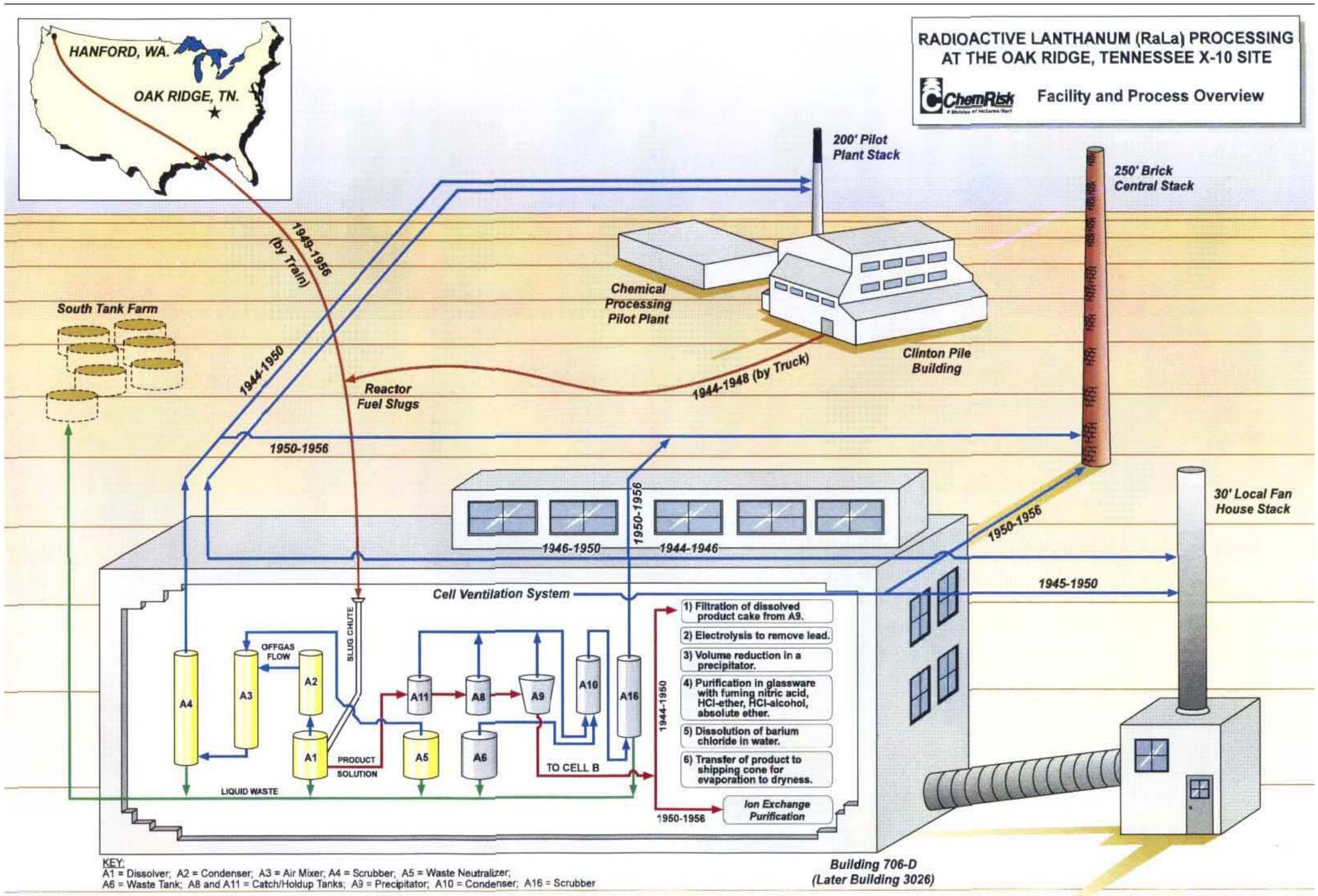
During the initial stages of RaLa processing, uranium slugs were added to nitric acid in a 165-gallon dissolver tank. The dissolver was heated, and the slugs began to dissolve. Figure 2 shows the dissolver and treatment components of the RaLa process. Upon reaching a certain temperature, the solution in the dissolver was diluted and cooled, and despite the fact that the slugs were only partially dissolved, the dissolving reaction was stopped. At this point the dissolver solution became a RaLa processing batch and was transferred to other vessels for the separation and purification steps. In any one batch, up to 85 slugs were dissolved. More nitric acid was added, and batch dissolution continued until little uranium was left in the dissolver. As the slugs dissolved, a vacuum applied to the system removed the volatile components through a condenser, then through a scrubber, and finally through the stacks. The condenser reduced the acid vapors in the offgas, and before their release into the atmosphere, a scrubber system neutralized the remaining acid vapors and any elemental iodines. During the early operations (1944–1950), the 706-C and 706-D buildings vented the exhaust gases through a 200-foot central pilot plant stack and a local 30-foot stack. Later (1950–1956), the exhaust stream was routed to a 250-foot stack (Figure 1 shows the locations of the plant stacks).

The types of radioiodines released are dependent on the length of time between the fuel’s removal from the reactor and its processing. The radioiodines produced in a reactor have various half-lives, ranging from seconds to millions of years. Those with a short half-live will decay away within 2 weeks of the fuel removal. Those with longer half-lives such as I-131 (~8 days) and I-129 (15.7 million years) will remain throughout processing and can be released to the environment.

During the dissolution step and during the transfers between each step, the gases escaped as offgases. Within the gases were volatile elements, including noble gases (various isotopes of krypton and xenon) as well as *radioactive iodines*, the most important of which were iodine-129 (I-129) and iodine-131 (I-131). Although other radioactive iodines were produced, their half-lives were less than 24 hours and would have decayed away before processing. In the early operational periods when few controls were in place, I-129 and I-131 could have been released through building vents and stacks in elemental, particulate, or organic form (DOE 1995). In 1947, some 64,200 curies (Ci)[‡] of radioactive iodines were released. Larger releases (up to 66,700 Ci) were estimated for 1952–1956, when the freshly spent uranium fuel slugs from the Hanford reactors were processed. Again, other radionuclides present in the batches contributed little to the offgas emissions. Not only were such radionuclides present in much smaller quantities, at the temperature set for RaLa processing they would not have escaped into the air. In total, X-10 processed about 30,000 slugs from which it produced over 500,000 curies of Barium-140 (for RaLa) for use at Los Alamos. The Oak Ridge process ended in 1956, when DOE's predecessor the Atomic Energy Commission moved the RaLa process to Idaho.

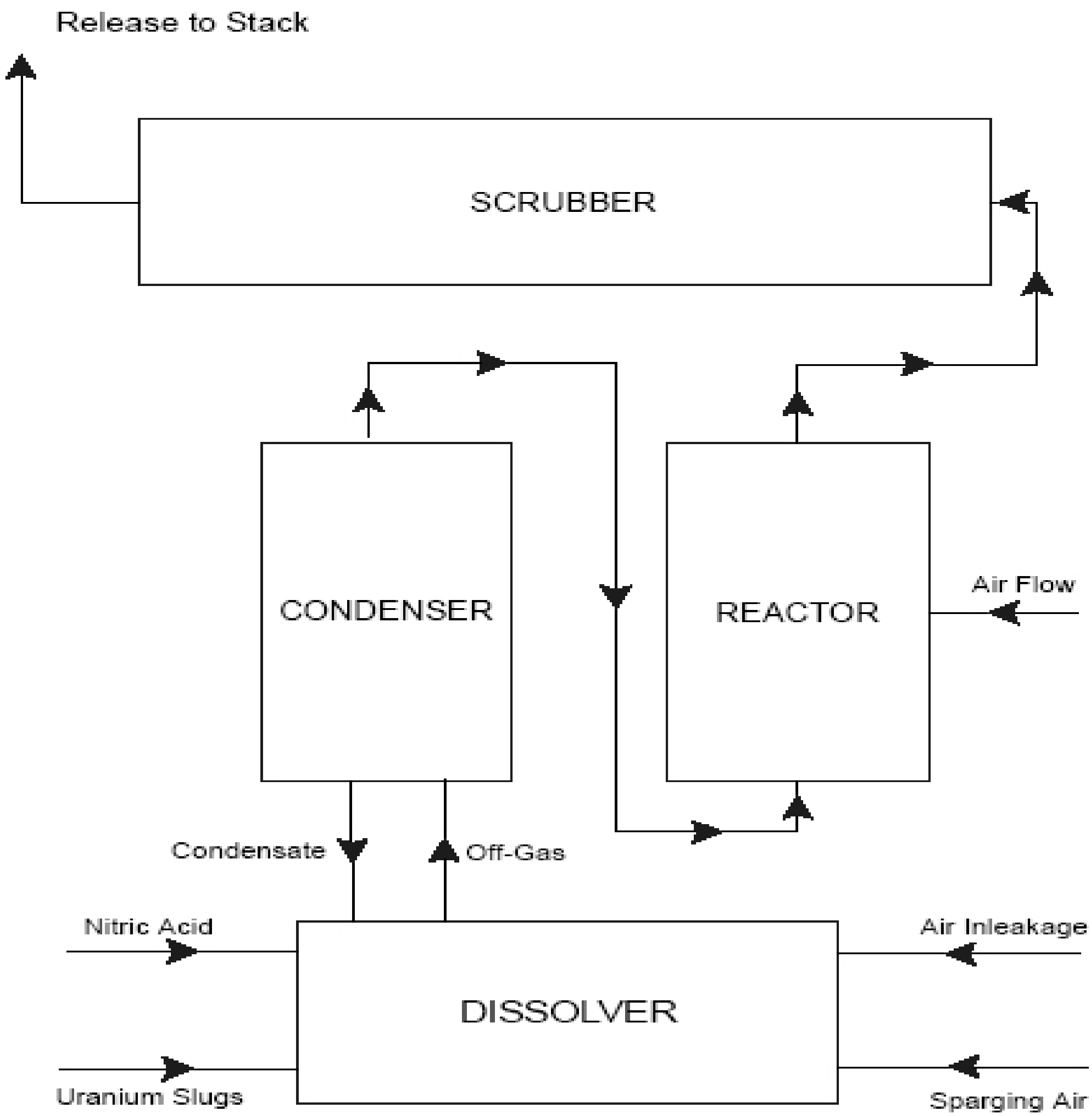
[‡] 1 Ci = 37×10^9 (37 billion) disintegrations per second.

Figure 1. Radioactive lanthanum (RaLa) processing at the ORR X-10 site



Source: TDOH 1999

Figure 2. RaLa process components



Source: TDOH 1999

II.A.3. Regulatory activities and follow-up health studies at ORR's X-10 facility

Over the years, ORR operations have generated a variety of radioactive and nonradioactive wastes. Some wastes have accumulated on site, while others have been released into the environment. Because of these aggregated accumulations and releases, in 1989 the U.S. Environmental Protection Agency (EPA) added ORR to its National Priorities List (NPL). DOE is now conducting cleanup activities at ORR. Under a Federal Facility Agreement, DOE, EPA, and the Tennessee Department of Environment and Conservation (TDEC) are working together to investigate and to take remedial action on the hazardous waste consequences of past and present site activities.

Through Phase I and Phase II of its Oak Ridge Health Studies, the Tennessee Department of Health (TDOH) conducted extensive reviews and screening analyses of the available information related to ORR. TDOH identified four hazardous substances related to past ORR operations that may have been responsible for adverse health effects: mercury, polychlorinated biphenyls (PCBs), radionuclides from White Oak Creek, and radioactive iodine. TDOH next conducted dose reconstruction studies on these four substances and performed additional screening analyses for releases of uranium, radionuclides, and several other toxic substances.

TDOH found that because reactor fuel slugs were processed for a 13-year period and because during that period treatment controls were inadequate, RaLa processing was the most important source of radioactive iodine releases at the X-10 site. Accordingly, TDOH and the Oak Ridge Health Agreement Steering Panel (ORHASP) recommended an in-depth evaluation of the radioactive iodine releases from RaLa processing. This evaluation would characterize the actual release history, predict past off-site concentrations, and estimate doses to exposed off-site populations. Through its evaluation of the dose reconstruction project for iodine, known as Task 1, TDOH evaluated the production, processing, and release of radioactive iodine mainly from the X-10 facility (TDOH 1999).

II.B. Demographics and land use of the Oak Ridge area

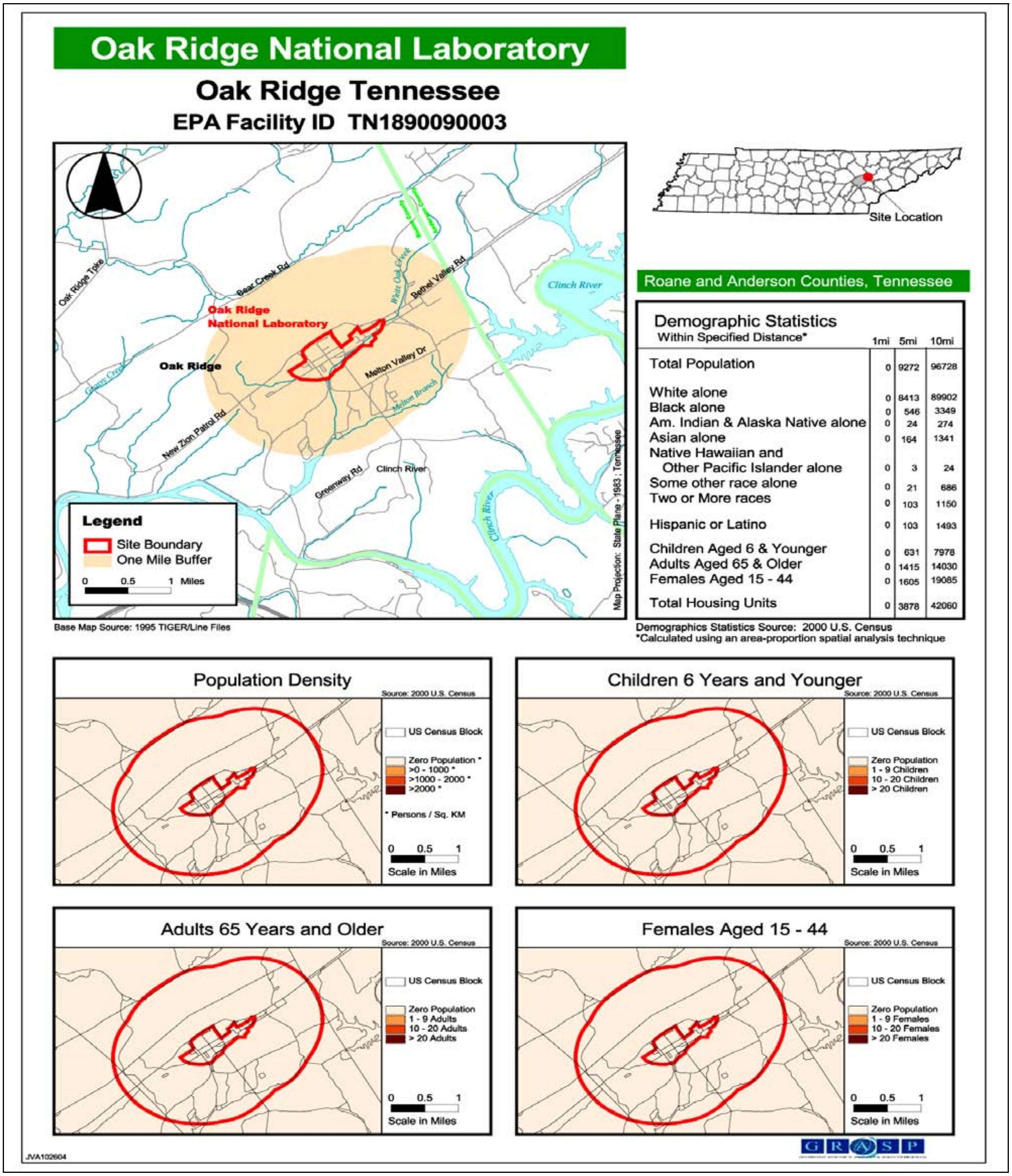
As part of its investigation of potential health effects from a specific site, the Agency for Toxic Substances and Disease Registry (ATSDR) examines demographic data. These data help to identify the presence of sensitive populations such as young children (6 years and under), the elderly (65 years and older), and women of childbearing years (ages 15–44). Demographic data also provide details on population mobility and residential history in a particular area. This helps ATSDR evaluate how long residents might have been exposed to environmental contaminants.

ORNL's 58 square miles of land are closed to general use. A staff of more than 3,800 is employed within ORNL. The demographic makeup of the area around ORNL, using year-2000 U. S. census data, is shown in Figure 3. As the figure indicates, no one lives within 1 mile of ORNL, and the population increases with distance from the site. From the ORNL center about 9,500 persons live within 5 miles and almost 100,000 within 10 miles. Oak Ridge, about 7 miles northwest of ORNL, is the closest city to the site and spans portions of Anderson and Roane counties. The largest metropolitan area is the city of Knoxville, about 20 miles east of Oak Ridge.

Because of the predominately rural nature of this part of Tennessee, local hospitals are limited. Smaller communities have only clinics or triage facilities, while Oak Ridge and Knoxville have major hospital facilities. Nursing homes in the area are limited as well, with facilities only in Oak Ridge and Rockwood. Before Oak Ridge's establishment in the 1940s, the area had no hospitals; the closest major cities with hospitals were Chattanooga to the south and Knoxville to the east.

Areas outside the ORNL property are typically mixed-use lands for agricultural, industrial, recreational, or commercial activities. The land use within the ORNL plant boundaries is limited. In 1980, DOE established one of seven National Environmental Research Parks at the Oak Ridge Reservation. This park, more than 20,000 acres in size, serves as an outdoor laboratory for studying the nature of present and future environmental consequences from energy-related events such as global and regional change, environmental stresses, and resource use.

Figure 3. Demographics surrounding ORNL



II.C. ATSDR's involvement and other health activities at ORR

ATSDR is the principal federal public health agency charged with evaluating human health effects of exposure to hazardous substances in the environment at the ORR. Since 1991, ATSDR has addressed the health concerns and requests of community members, civic organizations, and other government agencies regarding environmental contamination in off-site areas near ORR and possible public health threats. During this time, ATSDR has identified and evaluated several public health issues and has worked closely with many interested parties.

ATSDR scientists reviewed TDOH's Phase I and Phase II screening-level evaluations of past exposures (1944–1991) to identify contaminants of concern for further evaluation. Since then, ATSDR scientists have initiated several public health assessments. For example, an assessment of Y-12 uranium releases was completed in the spring 2004. In addition to this public health assessment, current assessments cover mercury releases from Y-12, radionuclide releases from White Oak Creek, PCBs, K-25 releases of uranium and fluorides, and other topics such as the Toxic Substances Control Act (TSCA) incinerator and off-site groundwater.

Public health assessments are the process ATSDR mainly uses to evaluate site contaminants. In undertaking a public health assessment, ATSDR scientists analyze the data and results of previous studies to assess exposure to the public. In preparing a public health assessment, ATSDR has the following goals:

1. Identify off-site populations that may have been exposed to hazardous substances at levels of health concern.
2. Determine the public health implications of the exposure.
3. Address the site-related health concerns of people in the community.
4. Determine whether follow-up public health actions or studies are needed to address the exposure.

III. Exposure pathway evaluation

III.A. Introduction

III.A.1. Exposure evaluation process

The five elements of an exposure pathway are 1) a source of contamination, 2) an environmental medium, 3) a point of exposure, 4) a route of human exposure, and 5) a receptor population. The source of contamination is where the chemical or radioactive material was released. The environmental medium (e.g., groundwater, soil, surface water, air) transports the contaminants. The point of exposure is where people come in contact with contaminated media. The route of exposure (e.g., ingestion, inhalation, dermal contact) is how the contaminant enters the body. The people actually exposed comprise the receptor population.

Not every release of a site-related contaminant negatively affects the off-site community. For a contaminant to pose a health problem, an exposure must first occur. That is, a person must come in contact with the contaminant by, for example, breathing, eating, drinking, or touching a substance containing it. If no one comes in contact with the contaminant, then no exposure occurs, and no health effects can occur. Still, even if the site is inaccessible to the public, contaminants can move through the environment to locations where people could come in contact with them. In the case of radiological contamination, because of the emission of radiation, which is a form of energy, exposure can occur without *direct* contact.

ATSDR evaluates site conditions to determine whether people could have been or could be exposed to site-related contaminants. When evaluating exposure pathways, ATSDR identifies whether, through ingestion, dermal (skin) contact, or inhalation, exposure to contaminated media (e.g., soil, water, air, waste, or biota) has occurred, is occurring, or could occur. With regard to radioactive contamination, a person can be exposed to both external radiation and internal radiation. Internal exposures result from radioactive sources taken into the body through the inhalation of radioactive particles or through the ingestion of contaminated food. External exposure results from radiation sources originating outside the body, such as radiation emitted from contaminated sediment. These external sources can sometimes penetrate human skin. Whether an exposure contributes to a person's external or internal exposure depends primarily on the type of radiation—that is, alpha and beta particles or gamma rays—to which that person was exposed. ATSDR also identifies an exposure pathway as *completed* or *potential,* or, if neither, *eliminates the pathway from further evaluation*. Exposure pathways are complete if all human exposure pathway elements are present. A potential pathway is one that ATSDR cannot rule out because one or more of the pathway elements cannot be definitely proved or disproved. If one or more of the elements is definitely absent, a pathway is eliminated.

III.A.1.a. Assessing health effects

As stated, exposure does not always result in harmful health effects. The type and severity of health effects that a person might experience depend on the dose, which is based on the person's age at exposure**,** the exposure rate (how much), the frequency (how often) or duration (how long) of exposure, the route or pathway of exposure (breathing, eating, drinking, or skin contact), and the multiplicity of exposure (combination of contaminants). Once a person is exposed, characteristics such as age, sex, nutritional status, genetic factors, lifestyle, and health status influence how the contaminant is absorbed, distributed, metabolized, and excreted. An environmental concentration alone will not cause an adverse health outcome—the likelihood that adverse health outcomes will actually occur depends on site-specific conditions, individual lifestyle, and genetic factors that affect the route, magnitude, and duration of actual exposure.

As a first step in evaluating radiation exposures, ATSDR health assessors screen the radiation doses against comparison values (CVs). ATSDR develops comparison values from available scientific literature concerning exposure, dose, and health effects. Comparison values represent radiation doses that are lower than levels at which, in experimental animals or in human epidemiological studies, no effects were observed. CVs are not thresholds for harmful health effects; rather, they reflect an estimated dose that is not expected to cause harmful health effects. Doses at or below the comparison values can reasonably be considered safe. Doses above comparison values, however, will not necessarily produce adverse health effects. This screening process enables ATSDR to eliminate safely from further consideration contaminants not of health concern and to evaluate further potentially harmful contaminants.

> ATSDR uses comparison values to identify those site-related hazardous substances that are not considered health threats.

If the estimated radiation doses at a site are above comparison values, ATSDR proceeds with a more in-depth health effects evaluation. ATSDR scientists now determine whether the doses are large enough to trigger public health action to limit, eliminate, or study further any potentially harmful exposures. ATSDR scientists conduct a health effects evaluation by 1) examining site-specific exposure conditions about actual or likely exposures, 2) conducting a critical review of radiological, medical, and epidemiological information in the scientific literature to ascertain the levels of significant human exposure, and 3) comparing an estimate of possible radiation doses to situations that have been associated with disease and injury. This health effects evaluation involves a balanced review and integration of site-related environmental data, site-specific exposure factors, and toxicological, radiological, epidemiological, medical, and health outcome data to help determine whether exposure to contaminant levels might result in harmful, observable health effects. By weighing scientific evidence and keeping site-specific doses in perspective, the health effects evaluation determines whether harmful effects might be possible in the exposed population. More details on the comparison values are provided in the appendices.

Additionally, information about the ATSDR evaluation process can be found in ATSDR's Public Health Assessment Guidance Manual at http://www.atsdr.cdc.gov/HAC/PHAManual/index.html or by contacting ATSDR at 1-800-CDC-INFO. ATSDR's Web-based public health assessment training course is available at http://www.atsdr.cdc.gov/training/pha_professional1/ (Overview 1 - Mission and Community), http://www.atsdr.cdc.gov/training/pha_professional2/ (Overview 2 - Exposure Pathways and Toxicologic Evaluation), and http://www.atsdr.cdc.gov/training/pha_professional3/ (Overview 3 - Evaluating Health Effects Data and Determining Conclusions and Recommendations).

III.B. Air exposure pathway

III.B.1. Current (1991–present) and future exposure

Today, no substantial air releases of radioactive iodine occur from ORNL. Thus, ATSDR does not expect any current or future exposures to radioactive iodine from this site. Furthermore, I-131 released from X-10 in the past is not expected to be present in the environment today. I-131 has an 8-day half-life, and any I-131 released from X-10 during the 1940s and 1950s (and even through 2005) has long since completely decayed. Radioactive iodine remains in the environment in the form of I-129, which decays by emitting a beta particle and has a physical half-life of about 15.7 million years.

Despite I-129's long radioactive half-life, it is minimally active—one billionth that of I-131. This limits the public health hazard of this radioactive iodine isotope. I-129 emits only low-energy beta particles—a weak type of radiation—and minimal gamma radiation. Moreover, I-129, as with I-131 and all other iodines, has a short biological half-life in the body—on the order of 12 days, or if in the thyroid, 120 days. The biological half-life is the time it takes to eliminate one half the amount of a radionuclide from the body or an organ. It provides a measure of how quickly the radioactivity from I-129 will decrease. Given this short half-life, I-129 is removed from the body quickly and without great risk of developing health effects. Furthermore, the amount of nonradioactive, or stable iodine typical of present-day diets offers sufficient protection against absorbing too much radioactive iodine. That is, a sufficient concentration of stable iodine in the bloodstream increases the likelihood that the thyroid will absorb it instead of any radioactive iodine. Consequently, ATSDR has determined that the air pathway is neither a current nor a future health concern.

> ATSDR does not expect people to come in contact with radioactive iodine now or in the future. I-131 released to the environment in the past has completely decayed, and no substantial, ongoing air releases of radioactive iodine now occur at ORNL.

The remainder of this document will therefore focus on evaluations of exposure that occurred from 1944 to 1991.

III.B.2. Past exposures (1944–1991)

III.B.2.a. TDOH Dose Reconstruction (1944–1956)

As mentioned in Section II.A.3, TDOH's feasibility study identified RaLa processing as the most important source of radioactive iodine releases at the X-10 site. TDOH and ORHASP recommended a deeper evaluation of RaLa iodine releases that would characterize the actual release history, predict historical off-site concentrations, and estimate doses to exposed off-site populations.

Through a 1999 Task 1 dose reconstruction study, TDOH investigators furthered their evaluation of the X-10 site and RaLa processing by assessing in detail radioactive iodine releases and potential human exposures. In deriving conservative dose estimates, the investigators 1) closely evaluated the RaLa process (the source of radioactive iodines), 2) determined the area affected (dispersion and deposition), and 3) identified important ways in which the surrounding communities could have come in contact with the radioactive iodine (exposure pathways). Each step is discussed below.

III.B.2.b. *Assessment of radioactive iodine sources*

Investigators used mathematical models and assumptions to derive their estimates of the source of radioactive iodines. This produced estimates much lower than those made in the feasibility study. The newer estimates suggest that the RaLa process released somewhere between 8,800 and 42,000 curies (Ci) of radioactive iodine per year. In other words, over the 13-year period (1944–1956) of the RaLa production, an estimated 28,558 reactor fuel slugs were dissolved in an estimated 731 batches in the process of separating over 500,000 Ci of radioactive barium as a source of RaLa. The accident of April 29, 1954, was also considered in the evaluation, and was found to have released 110 to 500 Ci over a 2½-hour period. Table 2 gives the Task 1 team's estimates of the releases that occurred from 1944 through 1956, both from the RaLa stacks and the RaLa accident in 1954.

Table 2. Estimated amount of I-131 released from RaLa processing, 1944–1956

I-131 (Curies)	*Percentile**		
	2.5	***50***	***95***
Normal Operations†			
Elemental I-131	6,300	16,000	36,000
Organic I-131	940	3,600	17,000
Particulate I-131	0.046	0.15	0.54
RaLa Accident‡			
Elemental I-131	110	280	560
Organic I-131	0.57	2.8	16
Particulate I-131	0.017	0.08	0.32
Estimated total I-131 released from RaLa	8,800	21,000	42,000

* The totals do not sum as a result of statistical analyses and uncertainty calculations. The percentile is a value on a scale of one hundred that indicates the percent of a distribution that is equal to or below it. So in the table, the 2.5th percentile means that there is a 2.5% chance the doses are equal to or lower than the value in the table.

† Data from Tables 3.15 and 3.16 of the Task 1 report.

‡ Data from Table 3.17 of the Task 1 report.

According to the Task 1 team, most of the offgases of radioactive iodines occurred during the initial stage in the RaLa process, when the uranium slugs were dissolved. As noted, before release to the atmosphere the condenser reduced the amount of acid vapors in the offgas, and the scrubber system neutralized any remaining acid vapors and elemental iodines. As the RaLa processing increased, however, the removal processes were thought to be less than 100% effective. In 1995, the Task 1 team convened a panel of experts to evaluate the processing system and estimate the removal efficiency of the dissolver, condenser, and scrubber systems. The team determined the removal efficiency to be greater than 99%. The Task 1 report contains a detailed explanation of the evaluation process (TDOH 1999). Although the RaLa process at X-10 ended in 1956, ongoing reactor operations and other processes at X-10 continued to release I-131 into the environment. For example, from 1967 to 1969, about 49 curies of I-131 were released from X-10 stacks (Binford et al. 1970). Table 3 shows annual concentrations of I-131 measured at ground level in communities around X-10.

Table 3. Annual Dispersion Concentrations of I-131 at Ground Level, 1967–1969

Community	Proximity of sampling station to the RaLa stack*		Annual I-131 concentration (pCi/m^3) †		
	Distance (miles)	Directions (approximate)	1967	1968	1969
Kerr Hollow	7.0	east	2.81	1.4	2.3
Hickory Creek Bend	4.7	east-southeast	0.8	0.1	1.1
Townsite	3.5	southeast	1.7	1.4	1.2
White Oak Dam	1.9	south	2.6	2.4	2.0
Midway Gate	6.6	northeast	1.9	0.9	1.9
Turnpike Gate	5.5	northeast	0.9	0.9	1.0
Gallaher Bend	8.6	northeast	2.3	1.8	2.5
Gallaher Gate	4.6	west	2.3	1.2	2.4
Blair Gate	4.4	northwest	1.0	1.0	1.4

* Relative to the RaLa stack in the central area of ORNL.

† Data derived from Table 4.7 of the Task 1 report.

III.B.2.c. Dispersion and deposition of radioactive iodine from the RaLa process

> TDOH Task 1's dose reconstruction was based on atmospheric modeling and modeling of I-131 releases from the RaLa process.

First, TDOH researchers determined how much radioactive iodine the RaLa process released. Then they used computer models to determine how far the iodine might have traveled and how much might have settled to the ground for possible human exposure. Again, I-131 is a highly volatile, short-lived fission product; it is released quickly into the air and remains only a short time before it decays—its half-life is ~8 days. Like all radioactive material, radioiodine can travel through the air as particles or as a gas and can enter soil, water, or biota. Prevailing winds would have carried much of the released radioactive iodine away from and downwind of the stacks. Thus, a number of factors were considered when determining how much radioactive iodine actually settled to the ground in communities near ORNL, including distance from the stacks, weather conditions that influence mixing or dilution of gases or particles in the air, and the chemical form of the iodine.

Insofar as the site's early operational history is concerned, insufficient environmental samples are available with which to characterize deposition. Lacking such data, Task 1 team modelers reviewed reactor logs and other data sources to construct air dispersion models. These models indicated an affected area extending approximately 24 miles from the RaLa release point inside the X-10 facility. Moreover, these models suggested that the released I-131 was most highly concentrated in the downwind communities of Gallaher Bend and Bradbury (TDOH 1999). The maximum concentration of I-131 in these communities reached about 5.5 picocuries per cubic meter (pCi/m^3) in the air—about four times higher than the I-131 airborne concentrations recorded in the city of Oak Ridge.

III.B.2.d. Determining pathways with the greatest potential for affecting downwind populations

The Task 1 team evaluated a number of different *exposure pathways* by which people could have come in contact with radioactive iodine. The team examined key elements for each pathway, such as the presence of contamination in an environmental medium (e.g., air, water, soil, food) and the likely exposure route. Target populations and unique factors that could influence the extent and duration of exposure were also determined. From this information the researchers identified several *complete exposure pathways* for air, water, soil, and food.

> The TDOH Task 1 dose reconstruction, using modeled data, determined that drinking backyard cow and goat milk contaminated by radioiodines resulted in some of the highest exposures for residents in the surrounding off-site communities.

TDOH's Task 1 team determined that drinking milk contaminated with radioactive iodine was one of the most important ways in which people might introduce radioactive iodine into their bodies. A smaller amount of radioactive iodine also came from eating other dairy products, from eggs and leafy vegetables, and through inhalation. Because iodine tends to concentrate in cow and goat milk, a small amount of radioactive fallout can result in high concentrations in milk. Furthermore, children probably absorb higher doses of a given level of radioactive iodine contamination than do adults. Children generally drink more milk than do adults, and childrens' thyroids—where iodine concentrates in the human body—are smaller than adult thyroids. Children are also often more sensitive to contaminants in their bodies than are adults. These factors led the researchers to choose drinking milk as the primary exposure pathway of concern.

III.B.2.e. Estimating the radiation dose

The dose of radioactive iodine is determined by the amount of I-131 inhaled or ingested and by other factors such as age and location at the time of exposure. Whether inhaled or ingested, both stable and radioactive iodines are processed in the human body in the same way. Iodine accumulates in the thyroid gland, where it is used to produce hormones essential for human metabolism. Over time, the thyroid gland can accumulate both stable and radioactive iodine. The accumulation of radioactive iodine can result in health problems, including thyroid cancer, autoimmune hypothyroidism, and Graves' disease. (Section IV of this public health assessment discusses health effects from exposure to radioactive iodine in greater detail.)

The Task 1 team estimated the *radiation absorbed dose* to the thyroid gland for people living downwind of the RaLa processing facility during a 13-year continuous exposure period (1944–1956). Part of the challenge in deriving radiation doses lies in estimating the amount of radioactive iodine available to humans. To do this, the team used computer models to gauge how much radioactive iodine had settled on plants and grass and how much would be available over the long term in the form of contaminated cattle feed. Then the team estimated how much contaminated feed susceptible cattle would ultimately consume. Other conservative measures were used to account for ways in which food products get from producers to consumers and how much and how often consumers ate potentially contaminated foods or breathed potentially contaminated air.

Radiation doses were ultimately derived for the exposure pathways of concern: drinking milk, eating other dairy products (e.g., cottage cheese), eating eggs, and leafy vegetables, and breathing contaminated air. Milk was further distinguished by source: backyard cow, local dairy, regional mixing dairy, or goats. Because persons could have been exposed to more than one pathway of concern at a time, researchers also assessed radiation doses by four *diet scenarios* that grouped several of the pathways together by source (Table 4). For example, a person living in a rural area (*reference diet 1*) likely drank milk from a backyard cow, ate dairy products and leafy vegetables, and inhaled airborne contaminants. The Task 1 team selected 41 areas of concern within 22½ miles of the ORNL facility (Figure 4). Radiation doses for the pathways of concern were further stratified by the age of the person at the time of exposure,[§] location of the person during the exposure (i.e., in one of the 41 communities considered), and sex. With each of the age groups, the Task 1 report generated uncertainty analyses deriving a lower bound, central value, and upper bound of both the thyroid dose and excess cancer risks.

Table 4. Task 1 reference diets

Reference diet	***Dietary Source***	
	Milk	***Produce***
1	Backyard cow	Local
2	Local commercial dairy	Local
3	Regionally produced milk	Regional
4	Goat	

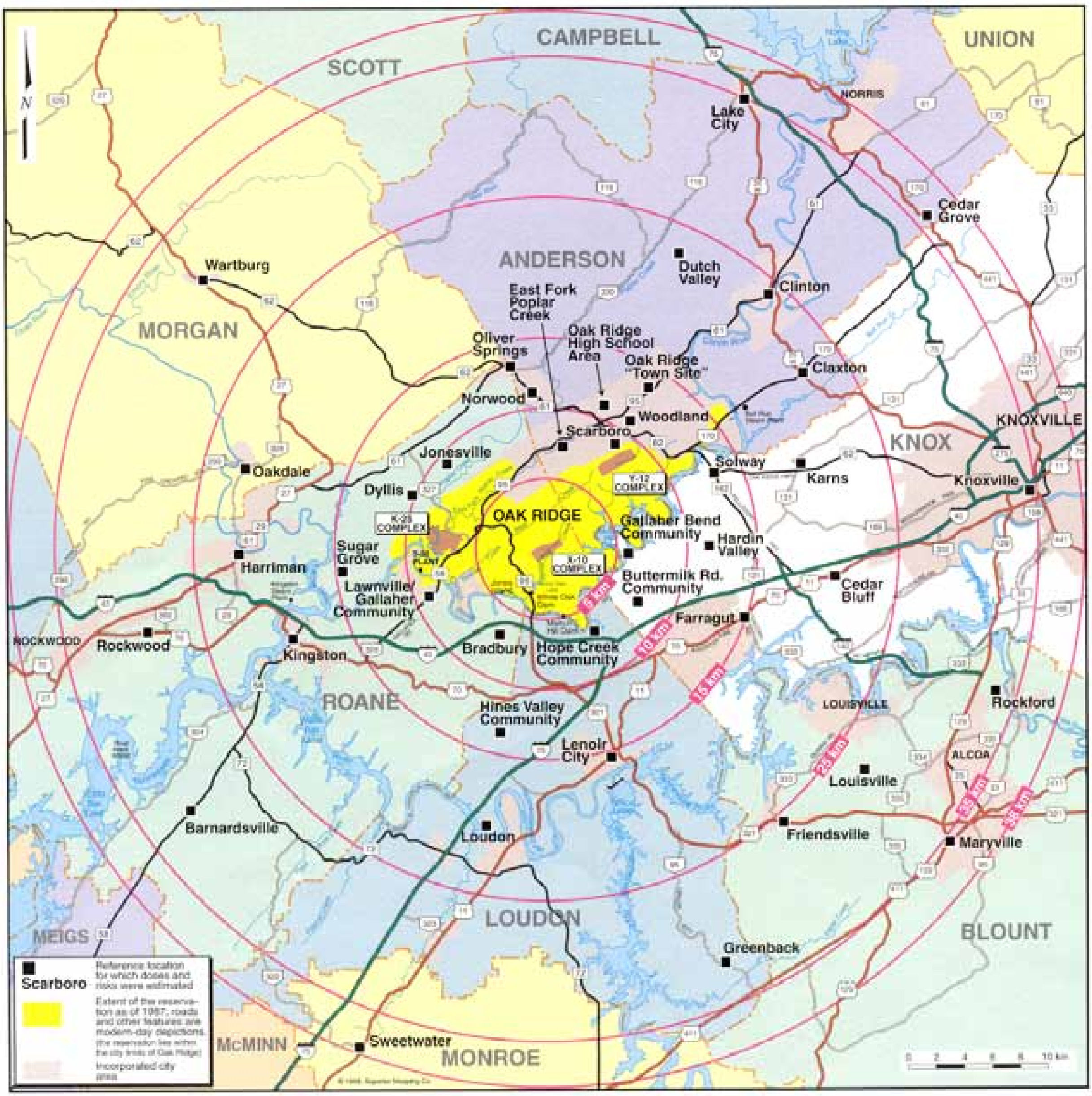
Note: The Task 1 team also considered exposure via inhalation of airborne radioiodines.

A person's diet largely influences the amount of I-131 taken into the body. In particular, the type of milk consumed and the source of the milk are important to the dose a person receives. TDOH found that the highest estimated I-131 doses to the thyroid were due to ingestion of goat's milk (reference diet 4), followed by ingestion of milk from backyard cows (reference diet 1).[**] Consumption of milk from commercial sources or regional distributors resulted in lower thyroid doses as the time from collection to consumption would allow for additional I-131 decay. Estimated doses from other food sources or from inhalation were about 1,000 times smaller than doses from goat's milk. Birth year and location of residence also influenced the dose received by an individual. On the other hand, sex differences accounted for only minor disparities in the estimation of radioactive iodine doses to thyroid doses.

[§] According to the birth years 1920, 1930, 1935, 1940, 1944, 1950, 1952, 1954, and 1956.

[**] The Task 1 doses were based on the assumption that individuals drank between one and five 8-ounce glasses of milk per day.

Figure 4. ORR areas studied for I-131 releases from the RaLa facility, 1944–1956



Source: TDOH 1999

The results of the Task 1 dose reconstruction study are summarized below:

- **Milk source/food group:** Persons who drank goat's milk received the highest thyroid doses of radioactive iodine (up to 800 rads, or 800 rad).[††] The next highest thyroid doses came from drinking milk from a backyard cow (up to 210 rads), followed by milk from a local commercial dairy (up to 84 rads) and milk that was regionally mixed (<10 rads). Concentrations of radioactive iodine in goat's milk were about 3 to 4 times higher than in backyard cow's milk, and about 1,000–8,100 times higher than the average airborne concentrations at the same locations. Compared with drinking goat's milk or cow's milk, much lower thyroid doses resulted from breathing contaminants in air or from eating locally raised beef, cottage cheese, from mother's milk, or from leafy vegetables.

- **Birth year:** The lowest thyroid doses were associated with birth years 1920, 1930, and 1956 (up to 66 rads); thyroid doses 4–5 times higher were estimated for people born between 1944 and 1952. People born in 1954 have about the same thyroid dose as those born in 1940.

- **Location:** The models indicate that the releases affected a study area as far as 24 miles from the facility (Figure 5). The contours in Figure 5 show the 13-year, routine-release average of upper estimates (in becquerels per cubic meter[‡‡]) for annual ground-level aerial concentrations of total I-131. Among the 41 selected locations within a 22½-mile radius of ORNL, the highest thyroid doses (up to 800 rads) were estimated for those living near Gallaher Bend, about 3½ miles east of ORNL. The lowest thyroid doses were estimated for those in Wartburg (up to 20 rads), about 20 miles northwest of ORNL.

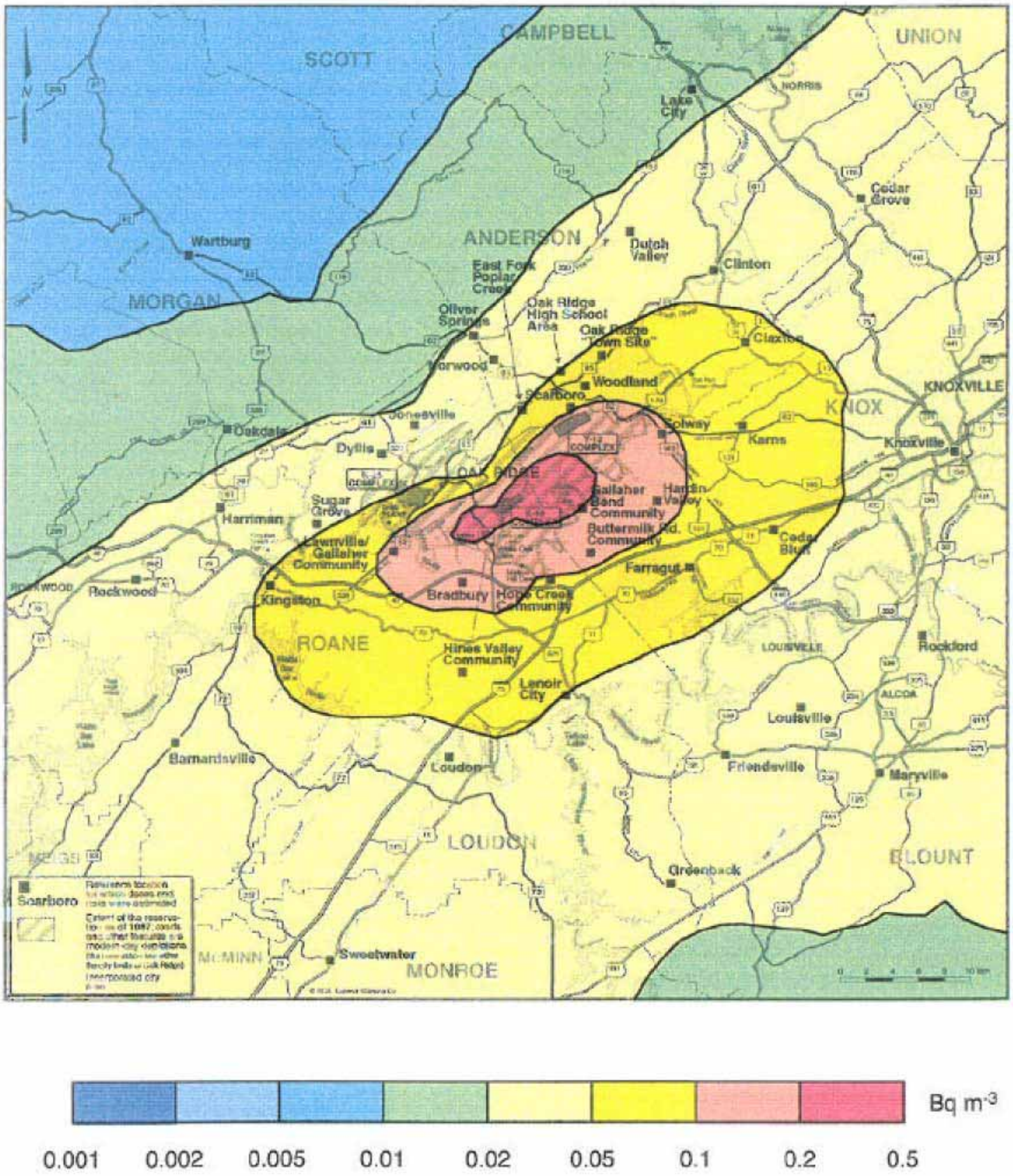
The results showed that, particularly for females born in 1952, the highest estimated doses from I-131 were from the ingestion of goat's milk (reference diet 1) followed by milk from a backyard cow (reference diet 2). The doses from other food sources or inhalation are perhaps 1,000 times smaller. The effect of the diet is shown in Figure 6. In the Gallaher Bend area, a female born in 1952 who drank goat's milk could have received a thyroid dose ranging from about 10 to 800 rads. The same female consuming milk from a typical backyard cow would have received a potential dose of 6–250 rads, and even lower (<1–110 rads) for milk from a local or regional dairy. Similar trends were observed at the other selected locations within the study area.

TDOH recognizes that because of the heavily modeled iodine releases with incomplete data, dose estimates in the Task 1 report involve much uncertainty. To illustrate this uncertainty, Figure 7 shows the range of absorbed doses based on different components of the diet for a female born in Solway, Tennessee in 1952. Many of these doses span two orders of magnitude, indicating that the estimated radiation dose to the thyroid from a particular ingestion pathway can vary 10 to 100 times above or below the estimated average thyroid dose. This wide range in lower and upper dose values shows the level of uncertainty in these estimates. The Task 1 team has, however, identified key contributors to the overall uncertainty and will use these to direct further studies.

[††] The upper 95% confidence limit.

[‡‡] 37 billion Bq = 1 Ci.

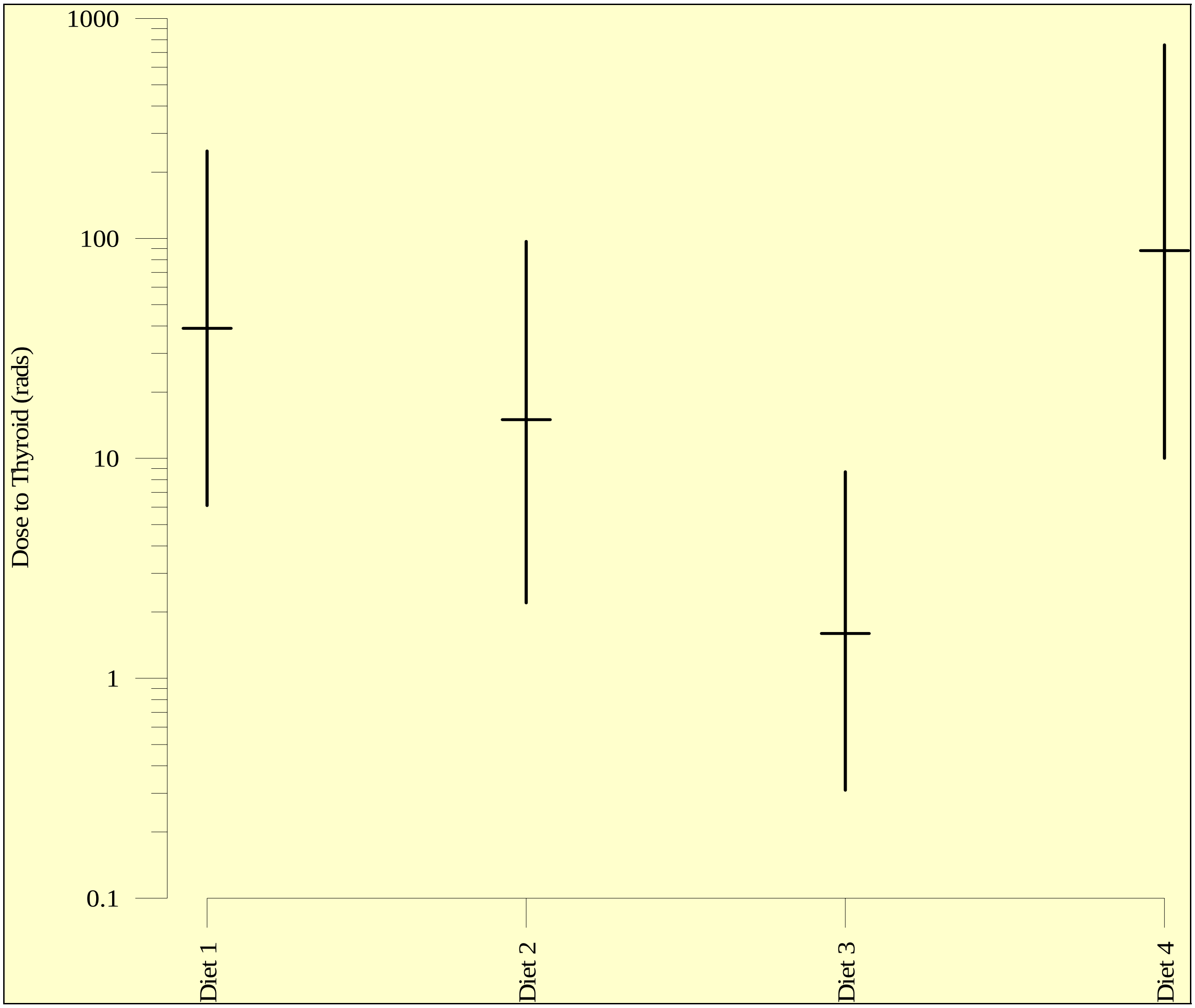
Figure 5. Upper 97.5% range of iodine release concentrations in air from RaLa



Source: TDOH 1999

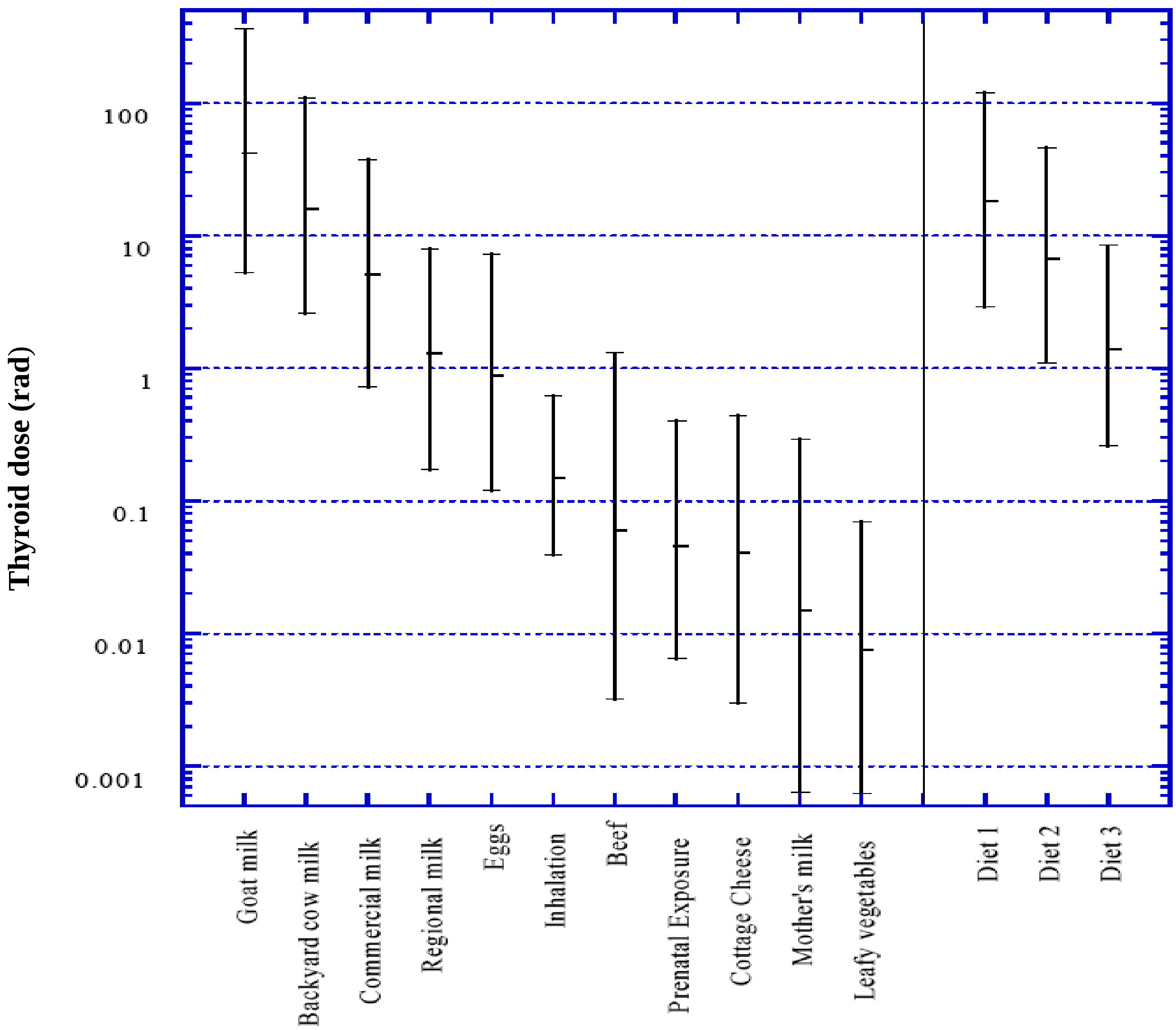
Note: The figure represents the contours of the 95% subjective confidence interval for the average annual, ground-level concentrations of total I-131 (in all three forms) in air. The actual concentration at a given location is highly likely to be less than the value presented in the figure.

Figure 6. Range of dose to the thyroid from diet for a resident of Gallaher Bend



Note: **Diet 1**: A rural diet composed of milk from backyard cows and locally grown produce. **Diet 2**: A rural diet composed of milk from a local commercial dairy and locally grown produce. **Diet 3**: Milk from regional dairy and regionally grown produce. **Diet 4**: Milk from goats. The vertical line represents the dose range and the horizontal line represents the 50 percent value.

Figure 7. Range of thyroid dose by exposure pathways and diet for a resident of Solway



Source: TDOH 1999

Note: Thyroid doses (rads) are from various exposure pathways and diets for a female born in 1952 who lived in Solway, Tennessee. The composition of the various diets is described in the text. The vertical lines indicate the 95% confidence intervals on the dose estimates; the horizontal lines indicate central values (50% percentile).

III.B.3. Evaluation of additional historical environmental monitoring data (1944–1991)

Since the development of TDOH's Task 1 I-131 dose reconstruction, additional historical data related to the RaLa process at X-10 have become available. The X-10 facility data were discovered when a team of researchers from the consulting firm of Auxier and Associates in Knoxville, Tennessee (Alvarez et al., in preparation), undertook a literature search for iodine issues associated with the 1986 Chernobyl accident. The team found reports from X-10 on I-129 in deer thyroids (Van Middlesworth 1993). They also found continuous air monitoring data covering much of the early and mid-1950s for locations at or near X-10. A review by Alvarez et al. (in preparation) notes that the TDOH Task 1 team modeled the I-131 releases with incomplete data. Consequently, with regard to the amount of radioactive iodine released from X-10 and its subsequent concentrations in air, the Task 1 team's estimates contain large uncertainties (Pritchard et al., in preparation). Because of this uncertainty, Alavarez et al. (in preparation) suggest that the TDOH Task 1 team results overestimate the true atmospheric dispersion from the RaLa process. In fact, Alvarez and his team suggest that the upper-bound average of the annual releases used in the Task 1 report is overestimated by approximately an order of magnitude. Because of this potential error, the effected areas and population and concomitant doses may all be overestimated.

III.B.3.a. Historical air monitoring data

III.B.3.a.i. Impact of X-10 sources

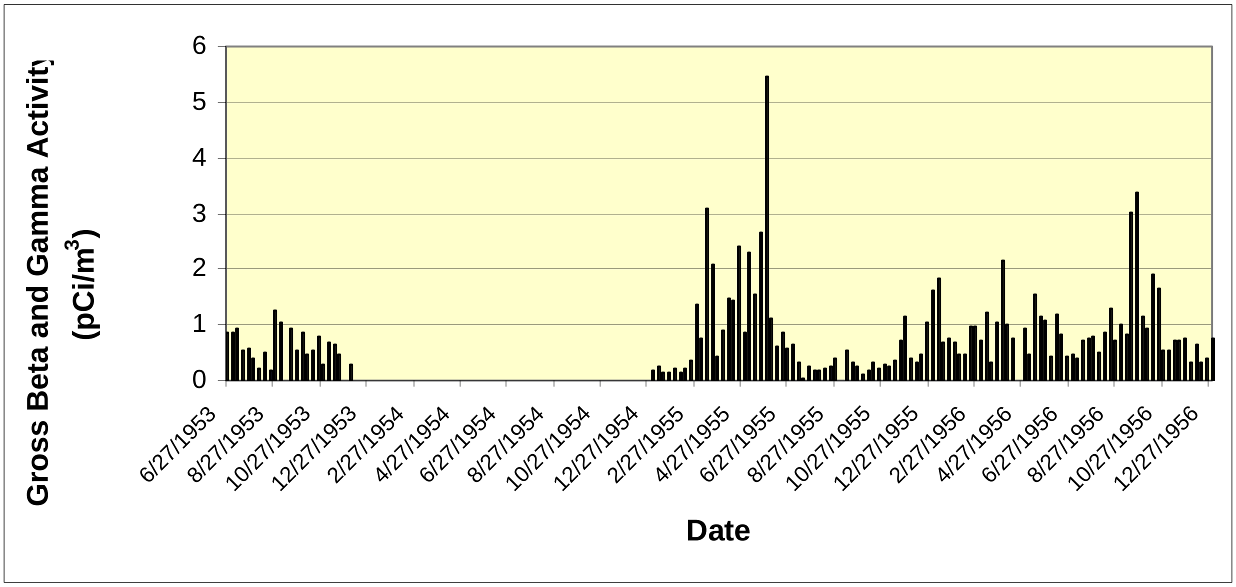
Historical monitoring data and memoranda recently obtained by Alvarez and coworkers and given to ATSDR found that ORR in fact established continuous air monitoring stations in and around X-10. During much of the RaLa processing from 1944 to 1956, 10 on-site continuous air monitoring (CAM) locations (HP-1 to HP-10) within the X-10 plant boundary were monitored weekly for gross beta and gamma-emitting, nonspecific radionuclides within the X-10 plant boundary, including locations around the RaLa facility (Bradshaw and Cottrell 1954).

Before the advent of high-efficiency detectors and methods to identify specifically radioisotopes, typical monitoring involved reporting the data as a combination of gross alpha measurements, gross beta measurements, or gross gamma measurements, or a combination of all three. In addition to the on-site locations within the X-10 plant boundary, seven stations (HP-11 through HP-17) around the periphery of the ORR were monitored at the gates along the perimeter of the ORR. Data for these CAM locations for the years 1953 through 1956 included long-lived radioactivity collected on filters, particulate measurements, and meteorological conditions. ATSDR independently analyzed these data following their conversion to electronic records. Detailed searches of the X-10 archives did not, however, reveal the CAM data for 1954, even though other documentation indicates that such data exist.

Besides the X-10 CAM system, the U.S. Public Health Service had several monitoring stations in the area and the Atomic Energy Commission (DOE's predecessor) had distant (background) off-site monitoring stations in Tennessee and Kentucky. These off-site samples included Berea, Kentucky (130 miles north), and Corryton (41 miles east) and Kingston (18 miles southwest), Tennessee. Searches at the laboratory in support of the CAM project, however, found no weekly, pre-1956 data for these monitoring stations.

In March of 1953, X-10 relocated one of the on-site CAMs (HP-8) to Rock Quarry on the X-10 property, located approximately 4 miles east of the main area of the RaLa process facility but within the same valley. HP-8 was relocated to optimize monitoring capabilities. Figure 8 presents the Rock Quarry air monitoring results. The weekly CAM data for the Rock Quarry monitoring station, in the form of nonspecific long-lived beta- and gamma-emitting radionuclides, included the last half of 1953 and all of 1955 and 1956. The data for 1954, however, could not be located. The highest radioactivity of 6 pCi/m^3 detected on the filters from HP-8 occurred during the week of May 30, 1955, when the prevailing wind was from the southwest, away from X-10.

Figure 8. Rock Quarry air monitoring (HP-8) results for 1953, 1955, and 1956



Note: No data are available for calendar year 1954. Prevailing winds during peak activity, the week of May 30, 1955, were from the southwest.

Figure 9 shows the data for the 125-week period for all on-site stations within the X-10 plant boundary. During the week of May 30, 1955, the average radioactivity from the other X-10 stations inside the plant boundary network was on the order of 6 pCi/m^3, or 0.2 becquerels per cubic meter of air (Bq/m^3)—the same concentration as at the HP-8 station. Two stations at X-10, S1000 (HP-3) and W300l were 40% higher, registering 7.7 pCi/m^3 (0.29 Bq/m^3) and 7.3 pCi/m^3 (0.27 Bq/m^3), respectively. The greatest discrepancies among the stations were recorded during the week of September 26, 1953, when

- HP-8 registered about 0.5 pCi/m^3 (0.02 Bq/m^3), and the station at E 2506 (HP-5) reported 441 pCi/m^3 (16.3 Bq/m^3);

and the week of March 14, 1955, when

- HP-8 registered about 3 pCi/m^3 (0.1 Bq/m^3) and the monitor at N3550 (HP-1) registered about 300 pCi/m^3 (11.1 Bq/m^3), a 100-fold increase.

Figure 9. Weekly gross beta and gamma activity at on-site air monitoring stations

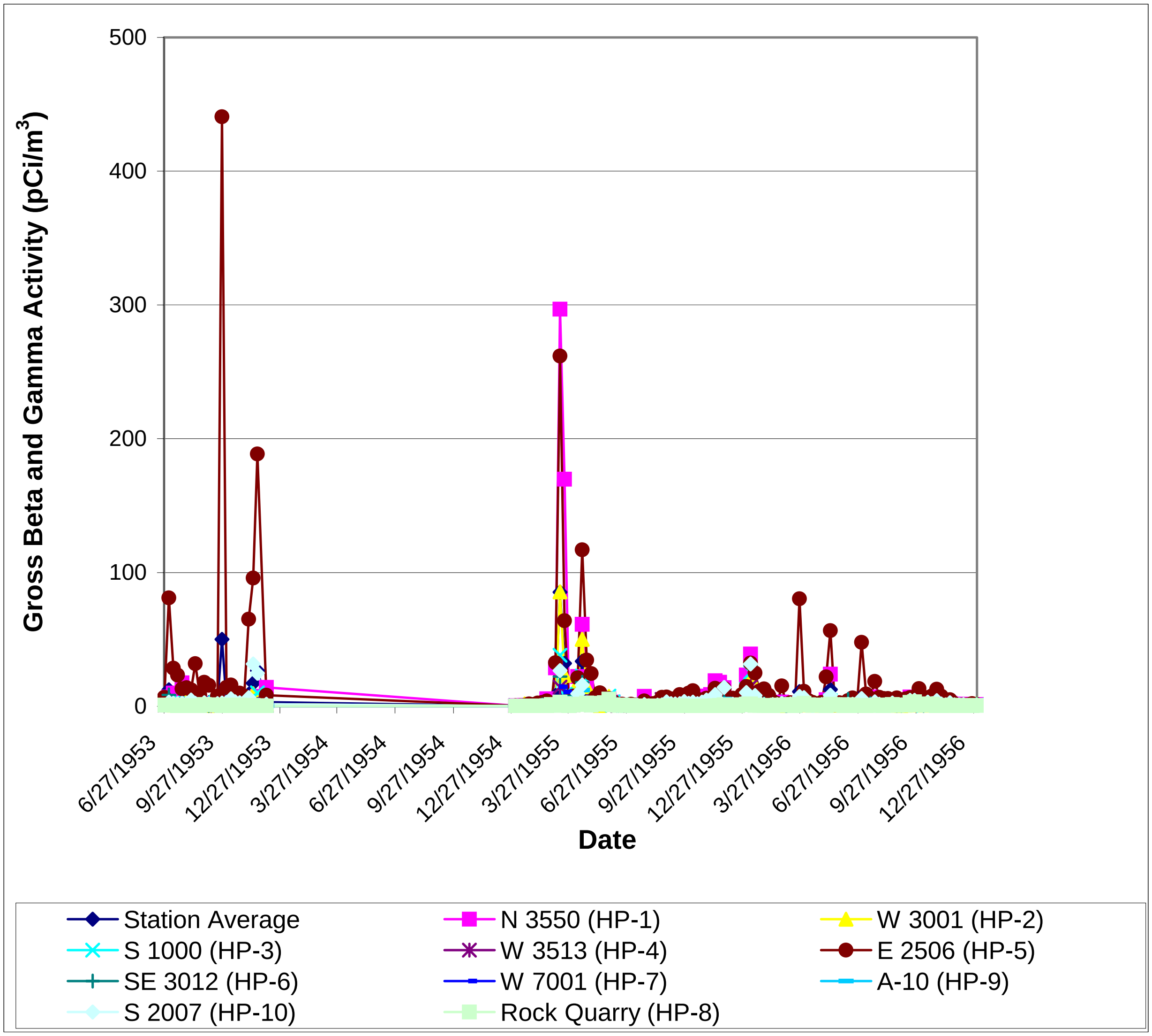


Table 5 shows the average long-term activity at on-site monitoring locations. HP-8 had a lower average long-term activity than other on-site stations. *If the releases from X-10 had traveled a significant distance off site, station HP-8 located in the same valley as the X-10 plant would also have shown elevated readings.* This strongly suggests that particulates released from ORNL did not travel much past the immediate X-10 area.

Table 5. Average long-term gross beta and gamma activity at onsite locations

Location/ X-10 buildings	*Station*	*Average long-term gross beta and gamma activity (pCi/m^3)*
N 3550	HP-1	84.4
W 3001	HP-2	35.1
S 1000	HP-3	27.7
W 3513	HP-4	18.9
E 2506	HP-5	190.7
SE 3012	HP-6	16.6
W 7001	HP-7	14.3
Rock Quarry	HP-8	8.5
A-10 site	HP-9	14.8
S 2007	HP-10	32.5

Note: The data cover the years 1953, 1955, and 1956.

ATSDR also compared the HP-8 station to monitoring locations established by ORR around the periphery of the ORR site and to monitoring stations established by the U.S. Public Health Service at distant off-site locations. The available data (1956 only) shown in Figure 10, Figure 11, and Table 6 indicate that HP-8 values were lower than those at the periphery or at distant off-site monitors. Although 1956 was not a period of major RaLa processing, the radioactivity detected on HP-8 filters was relatively constant compared with that at more distant locations. As shown in Figure 11, the annual radioactivity was 5 to 13 times lower at HP-8 than at the distant locations.

Figure 10. Comparison of gross beta and gamma activity at HP-8 and ORR perimeter air monitoring locations, 1956

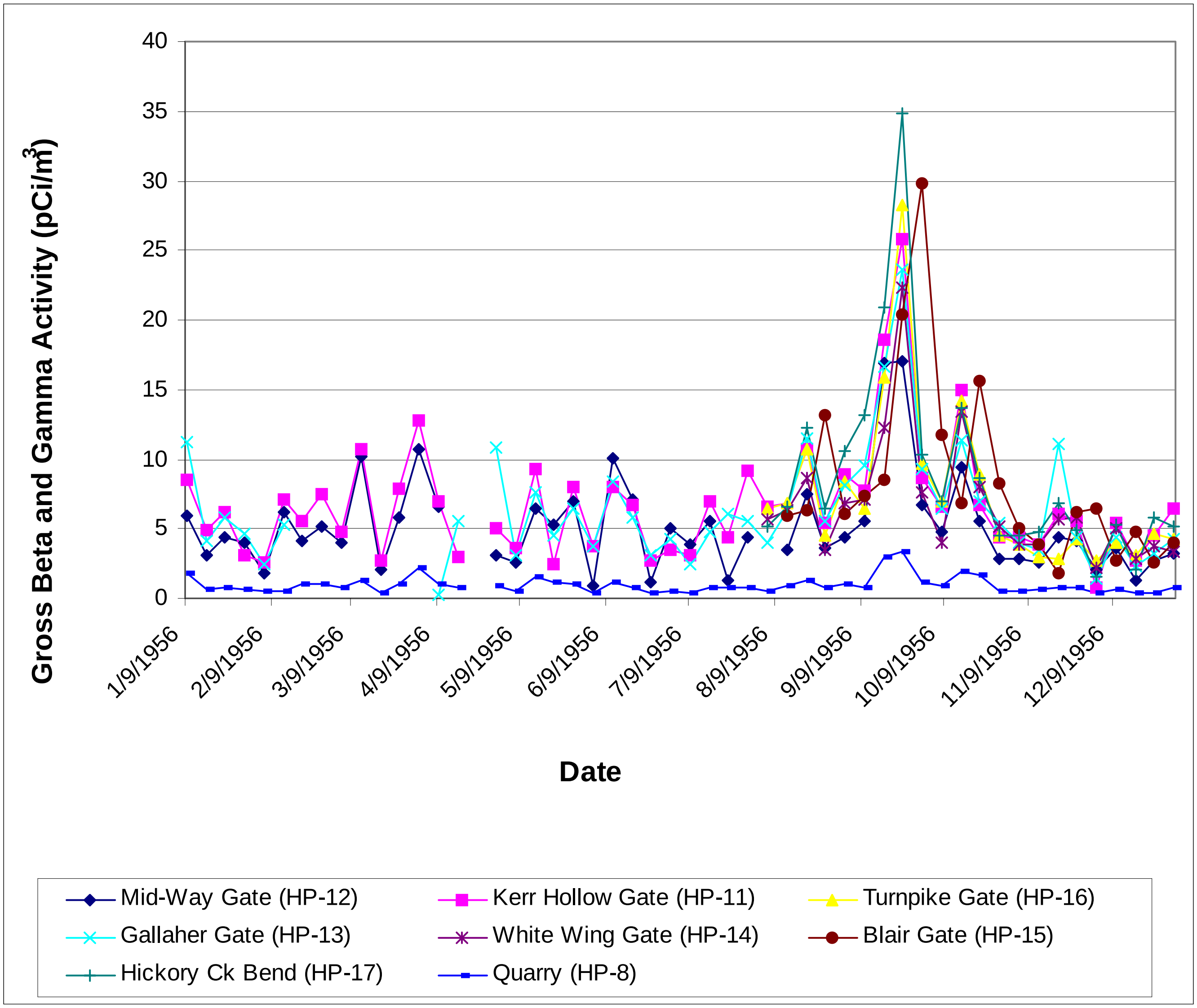


Figure 11. Comparison of gross beta and gamma activity at HP-8 and background air monitoring stations, 1956

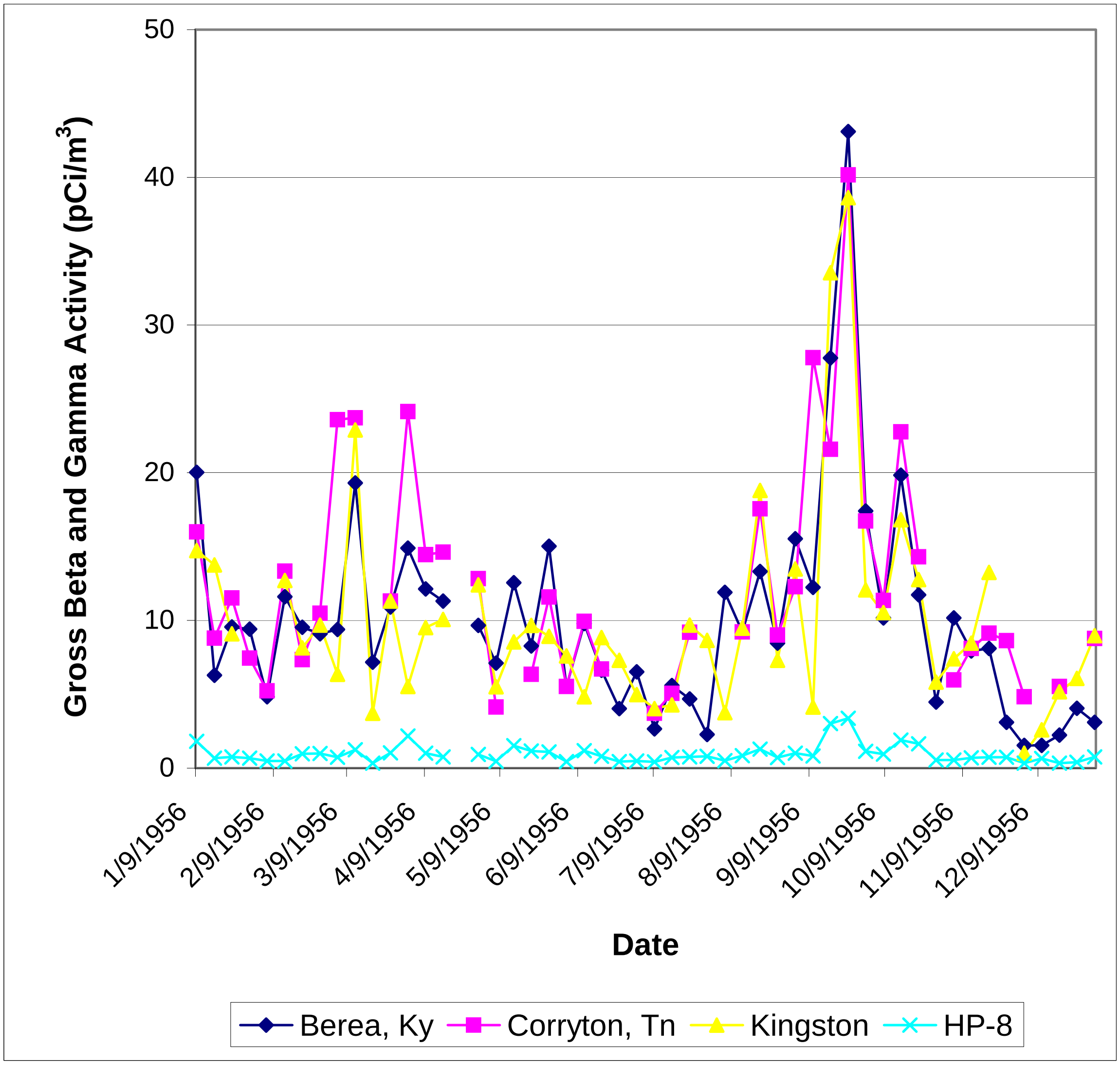


Table 6. Average long-term gross beta and gamma activity at Rock Quarry, ORR perimeter, and distant off-site locations, 1956

Location	***Station***	***Distance from the main X-10 stack (miles)***	***Average long-lived gross beta and gamma activity (pCi/m^3)***
Rock Quarry	HP-8	4.8	8.5
Kerr Hollow Gate	HP-11	4.7	6.7
Midway Gate	HP-12	6.6	5.0
Gallaher Gate	HP-13	4.6	6.3
White Wing Gate	HP-14	5.6	6.7
Blair Gate	HP-15	4.4	8.3
Turnpike Gate	HP-16	5.5	7.5
Hickory Creek Bend	HP-17	4.7	8.9
Berea, Kentucky	B	130	10.1
Corryton, Tennessee	C	41	12.4
Kingston, Tennessee	K	18	10.1

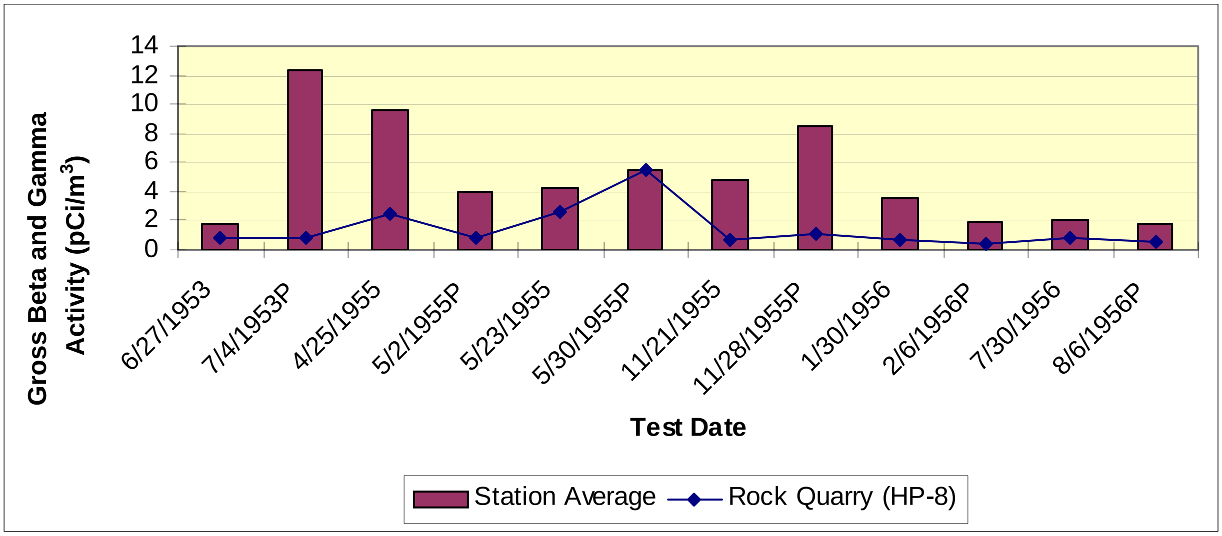
Note: The data cover the years 1953, 1955, and 1956.

The estimated 1956 releases of Pritchard's team were compared to both the annual concentrations at HP-8 and the Task 1 authors' estimates (Pritchard et al., in preparation). In essence, Pritchard and coworkers stated that, given the 13-year period reported by the Task 1 dose reconstruction project, 2.1 times more radioiodines were released in 1956, and the HP-8 site should have responded accordingly. When the values at HP-8 were compared to the Task 1 modeled air concentrations, the model overestimated the radioiodine concentration even when the upper-bound concentrations at HP-8 were used. The model overestimated 6–12 times more radioactivity than the amounts actually reported at HP-8.

III.B.3.a.ii. Effect of atmospheric nuclear weapons testing

Between 1945 and 1956, the United States conducted 85 nuclear tests (DOE 2000). Of these, 56 occurred between 1953 and 1956—32 at the Nevada Test Site and 24 in the Pacific. Eisenbud (1987) discussed the types of materials that testing injected into the atmosphere and which of those materials fall out in hours, days, or months. Although related to weather patterns, the fallout can occur at various locations around the country and the world. Thus, the X-10 CAM system could conceivably detect any aboveground tests anywhere in the world. ATSDR believes that any effect of atmospheric nuclear testing either by the United States or by other countries would be accounted for in the total amount of radioactivity detected on any of the filters in the CAM network and deposited on the ground, in surface water, and in the biota. The data plot in Figure 12 shows the level of radiation detected on X-10 CAM filters correlated with the dates of the United States atmospheric nuclear tests between 1953 and 1956.

Figure 12. United States nuclear test dates



Note: Dates followed by "P" indicate that no nuclear test occurred in the week after the indicated date. This allows for transport from Nevada to the Oak Ridge Area.

More tests took place than are shown in Figure 12; however, ATSDR only included those tests that were followed by at least a week in which no tests occurred (indicated by "P"). This would allow for transit time of the radioactivity to migrate across the country. Lower levels of radioactivity were measured on the more distant HP-8 filters than were measured at monitors within the central area of X-10. Furthermore, about half the tests show that the radioactivity on the CAM filters increased from the previous week. This suggests that the X-10 CAM filters were capturing radioactivity, but not exclusively I-131 associated with testing fallout—an important finding because any dose estimates based on the CAM measurements would also include exposure to radioactivity from test fallout.

III.B.3.b. Production of I-131 and I-129 in nuclear reactors and nature

During nuclear fission, a uranium-235 atom splits, releasing energy, neutrons, and a distribution of nuclear fragments called the fission yield. Fission yield curves show that while fuel is in the reactor, 3 times more I-131 atoms are produced than I-129 atoms. At some time during reactor operations, a steady state is reached where the amounts of radioiodines are constant. The iodine species have, however, different half-lives: once the fuel is removed from the reactor, the amount of I-129 remains essentially unchanged. Yet the other radioiodines begin to decrease rapidly, and the ratios of the atoms vary over time. During RaLa processing, the ratio of I-129 atoms to I-131 atoms was 3.4, although the activity of I-129 was much less than that of I-131 (Alvarez et al., in preparation).

The production rate of iodine is determined using standard computer codes for reactor operations. Once that determination is made, the current potential concentration of iodines in soils at various locations around the ORNL site can be approximated by using the Task 1 report's fission yield curves and air dispersion model estimates. Because chemical behavior of I-131 and I-129 are identical, the dispersion pattern of I-129 and I-131 is also identical. Thus, the same air dispersion model estimates can be used to identify initially those areas for environmental soil sampling and to compare the results of the soil samples to the iodine estimates by the dispersion models.

The elapsed time since production is sufficient for I-131 to have decayed away entirely. I-129, with its 15.7-million-year half-life, is nonetheless still present at essentially 100 percent of the original amount released from the RaLa process. In 1959, X-10 estimated that the amount of I-129 released between 1953 and 1956 was 110 microcuries (µCi) (JA Swartcut, ORNL, personal communication to HM Roth, ORNL, August 27, 1959).

In addition to production by nuclear reactors or even nuclear weapons, atmospheric interactions with the noble (inert) gas xenon will generate I-129 naturally. Before nuclear weapons testing, the level of naturally occurring I-129 in the atmosphere was 3.7×10^{17} atoms. Since testing began, the number has approximately doubled (Eisenbud 1987). Therefore, about 1 in 10 billion iodine atoms is I-129, with the remainder being nonradioactive iodine-127 (I-127) (Alvarez et al., in preparation).

III.B.3.c. Historical iodine concentrations in deer thyroids

Deer and other grazing animals can ingest iodine compounds deposited on grasses or on other food sources. Because iodine is concentrated in the thyroid, this organ is monitored to estimate the amount of contamination in the environment. Early studies by a number of laboratories (Ballad et al. 1976, 1978; Van Middlesworth 1993; Hou et al. 2003; Hanson et al. 1963) have shown the usefulness of gamma spectral analyses in determining the iodine content in thyroids, especially when coupled with or supplemented by mass spectroscopy. Numerous samples collected around several DOE sites, including X-10 and other locations showed no I-129 in deer thyroids from West Tennessee. That said, however, deer thyroids from the ORNL site showed amounts of I-129 in excess of 27 picocuries per gram (pCi/g) (1 becquerel per gram) of thyroid tissue (Van Middlesworth 1993).

Controlled hunting is the means by which the deer population around ORNL is managed. All harvested deer are evaluated by laboratory personnel before removal from the ORNL property (Alvarez et al., in preparation). The evaluation includes radiological scans and information about the area where the deer were harvested. Those deer are retained (or those samples are retained) for further analyses in which radiological scans are above the ORR screening value of 5 pCi/g of deer tissue for cesium-137 (ORNL 1995). From 1985 through 2003, ORNL retained 170 of the more than 8,500 deer harvested (ORNL 2004).

The Task 1 report indicated that several areas of ORNL received amounts of iodine more than two to three times fallout levels (TDOH 1999). This is an important factor because deer, other than young males, remain in one place, rarely roaming outside of a 0.4-square-mile area (Nelson et al. 1999). Using deer thyroid data from 1979 to 1989, the Alvarez team evaluated the I-129 deer data for the thyroids in relation to the collection location (Alvarez et al., in preparation). Only those deer collected within a small area of the reservation had elevated I-129 levels. When plotted against the RaLa areas, only those deer harvested near the White Oak watershed showed elevated thyroid levels of I-129. In other locations where Task 1 authors estimated iodine deposition to be much higher than the amount associated with fallout, the I-129 concentrations in deer thyroids reflected background locations. *The data indicate that deer taken near White Oak Lake had above-background I-129 in their thyroids; the same was not true of deer harvested off the reservation. The I-129 in the thyroids of other deer taken on X-10 had I-129 concentrations typical of background levels.*

III.B.4. Comparing Task 1 computer modeling results with environmental monitoring data

> Recently found continuous air monitoring data together with thyroid iodine content in deer harvested on X-10 grounds and off-site locations strongly suggest that releases of radioiodines did not extend beyond the X-10 site boundaries.

A review of the Task 1 dose reconstruction indicates that radioactive iodines were mainly released from X-10 via the atmospheric pathway.[§§] Computer modeling of the radioactive-iodine-contaminant atmospheric releases shows migration from X-10 and ORR to surrounding counties. Additional computer evaluation indicates where persons have or could come in contact with these contaminants via ingestion of food (e.g., milk) as well as inhalation. ATSDR's review of recently available historical air monitoring data covering most of the period from 1953 through 1956, strongly suggests that any emissions from the RaLa process did not extend more than 4 miles from the RaLa area. This conclusion is based on the radioactivity detected by a network of CAM stations within the X-10 plant boundary, around the perimeter of ORR, and at distant off-site locations. The highest amounts of radioactivity were detected on those monitors near the X-10 buildings. Similar amounts were not detected at the on-site Rock Quarry location (HP-8), at the periphery of ORR, or at distant off-site locations. The data also indicate that computer monitoring—which does have its limitations—can be compared to distant locations. That is, much of the time the concentration of radiological materials is similar to, if not lower than, distant background locations. Analyses of deer thyroids also indicate that I-129 (as a surrogate for I-131) was only elevated in those animals harvested on a small part of the X-10 area and not from off-site animals. While the CAM and deer thyroid data suggest that the radioiodines did not travel far from X-10, these numbers have certain limitations. In the following section, ATSDR discusses the uncertainties and limitations in the Task 1 dose reconstruction and in the X-10 CAM data, as well as measures to reduce the uncertainty about the area and the communities affected by the RaLa releases.

III.B.4.a. Uncertainties and limitations in available data

III.B.4.a.i. Uncertainties of TDOH's Task 1 I-131 dose reconstruction

Because of the limited available data, much uncertainty surrounds the calculations in the Task 1 report. This uncertainly in turn gives rise to further uncertainties about the area affected and the events between 1944 and 1956 that would expose persons to iodine releases from RaLa processing. The following explains the reasons for and the implications of the Task 1 dose reconstruction uncertainties.

- *Amount of radioactive iodine released.* Complete information on the amount of radioactive iodine released from the stack and vents is not available. During the RaLa process, radioactive iodine was released to the environment from building vents and from stacks. Yet these release points were not specifically monitored. Because of the absence of any known RaLa release data when the dose reconstruction was in progress, the Task 1

[§§] Releases to other pathways, such as water, have been addressed in the Public Health Assessment for White Oak Creek (ATSDR 2006) report relied on models for determining the releases and any subsequent radiological doses resulting from these releases. This is a major source of uncertainty.

- *Form of the released iodine.* The forms of the releases (e.g., particulates, elemental, and organic) were not precisely known. This has resulted in many discussions among technical experts and the dose reconstruction authors. The discussions focused, for example, on scrubber efficiencies, release rates, and chemical transformation in the atmosphere.
- *Efficiency of the RaLa process scrubbers.* Typically, in an attempt to remove the radiological contaminants from the air stream, the RaLa iodine releases were routed to scrubbers. The efficiencies of these scrubbers—as well as the form of the releases—were not precisely known. Scrubber efficiency, however, was known, and it varied with the form of the released iodine. For example, the scrubbers were able to remove 50% to 95% of elemental radioiodine but only 1% to 10% of organic radioiodine. This is important because the greater the removal efficiency, the less the amount of iodine released to the atmosphere to result in human exposures.
- *Type of processing considered.* According to RaLa operator logbooks and other sources of information, 80 processing “batches” or events occurred from 1944 until 1956. Every event consisted of numerous individual process cycles, each of which contained a different number of fuel elements. Each process cycle required about a week to complete. As noted in the TDOH dose reconstruction, during the RaLa process 80 batch events occurred over 13 years: about 5 batches per year, with 1 batch processing about every 8 weeks. It is thus clear that the release of radioiodines was not continuous from the facility. Rather, during any particular year releases occurred at various times. In many cases, the period between releases was more than the physical half-life of I-131. Although several radioisotopes could have been released, for this public health assessment I-131 (8-day half-life) and I-129 (15.7 million-year half-life) are the isotopes of interest.

III.B.4.a.ii. Limitations on the use of the historical air monitoring data

The study by Alvarez et al. (in preparation) of the historical ORNL air data and the ORNL deer data compiled by Van Middlesworth (1993) suggest that TDOH’s Task 1 overestimated atmospheric dispersion (upper-bound average of the annual releases) and radiological doses. Alvarez and his colleagues, in unpublished data, suggest that the Task 1 estimates are higher by an order of magnitude than the actual dispersed concentrations. Moreover, these overestimates have led to a further overestimation of the affected area and population. That said, the X-10 CAM data used in these analyses were reported as gross beta and gamma measurements of long-lived activity, and no indication surfaced that the activity recorded was from iodine or any other specific radioisotope. In that regard, ATSDR and Pritchard et al. (in preparation) made specific assumptions that, for example, the air monitoring data captures beta particulates from all sources (i.e., all ORR sources, coal-fired power generation plants, wood fires, and naturally occurring radioactive elements), not just from RaLa processing. On the other hand, Pritchard et al. (in preparation) assumed that 100% of the data came from RaLa processing. Using historical information, the Pritchard researchers also assumed the activity was 100% iodides and that the collection efficiency of the CAM system was 28%.

Other sources of variability could be related to the dust in the atmosphere from passing traffic and from atmospheric nuclear tests by the United States and other countries. Also, because airflow is greatly affected by topography, building location, and building height, those monitors located near buildings may not be reporting accurate values.

III.B.4.b. Identification of additional data needs

ATSDR believes that soil sampling is warranted within the ORR and in the predominant downwind directions from ORNL (on site and off site) to refine the areas affected by the iodine releases. Soil sampling for I-129 can also be used to describe historical I-131 concentrations because I-129 is chemically identical to I-131 and is still present in the environment. As discussed below, ATSDR believes environmental sampling can reduce the uncertainties associated with the Task 1 report and can better characterize the study area.

> ATSDR believes that soil sampling is warranted to reduce the uncertainties associated with previous studies and to better define the area affected by I-131 air releases.

Typical radiochemical analyses cannot measure I-129 in soils. The amount of the radioisotope in this medium is below detectable concentrations. Special detection processes have been developed, including neutron activation analysis and accelerator mass spectroscopy. In these procedures, the amount of I-129 is typically compared with the amount of naturally occurring, nonradioactive I-127. Most recently, these procedures have been used to measure iodine releases from Chernobyl. Mironova et al. (2002) compared I-129 levels in “pre-Chernobyl soils” to soils collected from a 30-kilometer (19-mile) radius from Chernobyl and from 85 other areas around Belarus and Ukraine following the 1986 accident. I-129 could give dependable estimates of previous releases, especially when it is above background levels, but this would depend on the number of I-129 atoms in the environment and their chemical signal. Mironova’s analysis also showed that cesium-137 concentrations, if sufficiently elevated, could also provide reasonable estimates for I-131.

As stated previously, although released in the 1940s and 1950s, I-129 may still be present at or near the earth’s surface. This is supported by two studies of I-129 mobility in soils associated with the DOE’s Savannah River Site near Aiken, South Carolina.

Boone et al. (1985) showed that I-129 released from the Savannah River Site could be determined in soil core samples taken at specified intervals. Furthermore, the estimated accumulation and translocation of I-129 in undisturbed soils showed a residence half-life of about 30 ± 6 years in the top 30 centimeters of soil. A linear model using data from both the Savannah River Site and a fuel reprocessing facility in Germany showed that the mean residence halftime for I-129 in the top 30 centimeters was about 40 years for both locations (Kocher 1991). Because fewer than 60 years have passed since the last RaLa releases, ATSDR believes that perhaps 25% or more of the I-129 released and deposited on the soil surface in the undisturbed ORNL properties may still be present. Soil sampling in the ORNL area would better enable ATSDR to identify exposed populations and the implications of those populations’ historical radioiodine exposures.

IV. Public health implications

In this section, ATSDR assesses the health implications of past, current, and future exposures to radioactive iodines released from X-10. These implications are primarily for people who have lived or currently live near the ORNL facility. In assessing exposure, ATSDR evaluated radiation doses presented in the Task 1 report or derived radiation doses using available environmental data. When deriving doses, ATSDR considered lifestyle and other area-specific factors about the frequency, duration, and magnitude of radiation exposures. These protective estimates allow ATSDR to evaluate the likelihood that exposure to radionuclides is associated with observable adverse health effects in accordance with agency mandates and responsibilities under the Comprehensive Environmental Response, Compensation and Liability Act, as amended (CERCLA; Superfund).

To evaluate health effects, ATSDR used a weight-of-dose approach coupled with reviews of literature published since the 1986 Chernobyl nuclear accident. This approach involved reviewing available radiological, medical, and epidemiological information to determine the levels of medically significant human exposure. It also included comparing the estimated radiation doses persons might have encountered with those associated with adverse health effects. This enables ATSDR to determine whether harmful health effects are possible and to determine if the doses require a public health action to limit, eliminate, or study further any potentially harmful exposures. This approach provides more information than a single criterion and therefore involves less chance of missing an effect or declaring an effect when one does not exist.

IV.A. Toxicological implications of iodine exposure

Effects of either radioactive or nonradioactive iodine exposure depend on a number of factors. These include the dose, the duration and manner of the exposure, personal traits and habits, and whether other chemicals are present. Iodine is a naturally occurring element essential in the production of thyroid hormones. Yet excessive levels of either stable or radioactive iodine can damage the thyroid. Iodine has therefore both beneficial and harmful effects on human health. Iodine-induced thyroid damage can for example affect other parts of the body such as the skin, lungs, and reproductive organs. Some human studies have found an increased risk of thyroid cancer in certain populations, particularly those receiving iodine supplements because of iodine-deficient diets. Still, other such studies have not found an association between high-level iodine exposure and cancer risk, and neither the EPA nor the International Agency for Research on Cancer (IARC) has reviewed the carcinogenicity of nonradioactive, stable iodine. Thus, exposure to high levels of radioactive iodine may increase the risk of thyroid cancer, but the evidence remains inconclusive.

For the growth and development of children, iodine is an essential element. Indeed, a healthy, iodine-infused thyroid gland is necessary for normal growth. Because childrens' thyroid glands continue to grow and to develop, children are more sensitive than are adults to the harmful effects of excessive levels of both stable and radioactive iodine. An infant or child receiving too much iodine can develop an enlarged thyroid gland (goiter), which will not produce enough thyroid hormone for normal growth. And too much iodine in the milk of a lactating mother can cause a baby's thyroid gland to become so large that breathing can become difficult or impossible. Radioactive iodine in food can be more harmful to babies and children than to adults, and, assuming both receive the same amount of radioiodine, a child's smaller thyroid gland will experience a higher radiation dose than will an adult's thyroid (ATSDR 2001a).

Reliable tests can measure iodine in the blood, urine, and saliva. These tests are not available at a doctor's office, but a physician can send the samples to a laboratory that can perform the tests. Specialized radiation detectors are also available that measure radioactive iodine inside the thyroid gland in the throat. Because the body quickly eliminates nonradioactive iodine as well as radioactive iodine, such tests should be done shortly after exposure (ATSDR 2001a). The effective half-life of I-131 in the thyroid is about 170 hours (7.4 days). This means that after 3 weeks, the amount of I-131 in the thyroid has decreased by almost 90 percent. After 75 days, the I-131 remaining in the thyroid is about 0.1 percent of the initial amount. That said, the tests cannot predict whether anyone will experience adverse health effects. The tests can only indicate whether anyone has an iodine allergy or has thyroid nodules.

IV.B. Radiological aspects of iodine dosimetry

IV.B.1. Radioactive iodine intake limits

IV.B.1.a. Pre-Chernobyl

In 1979, before the accident at Chernobyl, the International Commission on Radiological Protection (ICRP) established intake limits of radioactive iodine for workers. The model used for these limits indicated that iodine is rapidly absorbed from mainly the small intestine and secondarily from other portions of the gastrointestinal tract (ICRP 1979). For all forms of iodine, absorption is essentially 100 percent. For iodine taken into the body via inhalation, ICRP established a solubility class of "D." The "D" class indicated that the iodine in the lung was rapidly absorbed into the body. ICRP estimated that 30 percent of the iodine taken into the body is stored in the thyroid, with the remainder excreted from the body. Typically, the body contains about 13 milligrams of iodine, of which the thyroid stores 10 milligrams. On a daily basis, a person's diet is thought to contain about 0.2 milligrams of iodine.

> ATSDR reviewed dosimetry studies to understand how much radiation exposure results from substances that produce radiation. The science of dosimetry also deals with the effects that radiation has on the body.

The iodine stored in the thyroid remains in the gland with a biological half-life of 120 days. Ultimately it is excreted in an organic form that has a biological half-life of about 12 days in the rest of the body. Table 7 contains the annual limits on intake of selected radioiodines for workers. ICRP defines the annual limits on intake as the amount taken into the body during a work year that would impart a dose equal to or less than 5,000 millirems (5 rems, or 50 millisieverts) in the case of stochastic effects (e.g., cancer) or a deterministic dose equal to or less than 50 rems.

Table 7. Annual limits on intakes for workers exposed to radioactive iodines*

Isotope	*Oral*	*Inhalation*
I-129	5.4 µCi	8 µCi
Thyroid (stochastic†)	19 µCi	27 µCi
I-131	27 µCi	54 µCi
Thyroid (stochastic)	108 µCi	162 µCi

* The data for this table were derived from ICRP Publication 30 (ICRP 1979).

† Unlike deterministic effects, for which there is a threshold dose below which no damage will occur, stochastic effects have no threshold (i.e., can occur at any dose level) and exhibit a dose-dependent probability of occurring.

IV.B.1.b. Post-Chernobyl

In 1986, the Chernobyl Nuclear Power Plant released an estimated 35.1 to 86.5 million curies of I-131 (UN 2000). This event, along with the determination that the intake limits developed for workers were not applicable to members of the public, prompted ICRP to develop a new dosimetry system for members of the public. ICRP developed intake and dose parameters for the general public in 1989, and updated the parameters they put forth in 1990 (ICRP 1991). In revising their previous recommendations, ICRP reviewed more recent data, including metabolic and biokinetic parameters. ICRP determined that iodine followed a recycling model in which iodine deposited in the body is excreted into the blood. Portions of the iodine are then redeposited in the thyroid as the blood circulates through the thyroid gland. This new model generated new biokinetic parameters and ultimately, new dose coefficients. Table 8 gives the new data for the biological parameters (ICRP 1993), based on age at intake. A tissue weighting factor (discussed below) of 0.05 was assigned for the thyroid.

Table 8. ICRP data for the biological kinetics of iodine

Age at intake	*Half-time in blood (Days)*	*Half-time in thyroid (Days)*	*Half-time in body (Days)*
3 months	0.25	11.2	1.12
1 year	0.25	15	1.5
5 years	0.25	23	2.3
10 years	0.25	58	5.8
15 years	0.25	67	6.7
Adult	0.25	80	12

Note: Data from ICRP 1993. For all ages, 30% of the iodine in the body is assumed to be distributed in the thyroid.

The tissue weighting factors (W_Ts) are defined by ICRP (1995) as "dimensionless factors to derive the effective dose from the equivalent dose. They are based on the different sensitivities of tissues to radiation." Therefore, they represent the relevant contribution of a particular organ or tissue to the total detriment received from whole-body irradiation. The dose to the entire body is the sum of the radiation to the specific organs times the weighting factors. Since the tissue weighting factor (W_T) of the thyroid is 0.05 (5%), a thyroid dose of 1 rad is equivalent to 0.05 rads of radiation to the whole body. In other words, the chance of cancer from a dose of 1 rad to the thyroid is the same as the chance of cancer from a dose of 0.05 rad to the whole body.

As previously discussed, ICRP assigned workers an inhalation class of "D" for the various chemical forms of iodine. In 1995, ICRP released new guidance on inhalation and the modeling of the respiratory tract (ICRP 1993). Human studies showed that elemental and particulate iodine clears from the lungs quickly with a half-life of about 10 minutes (Class F). Once deposited, organic iodine in the form of methyl iodine clears the lungs very quickly (less than 5 seconds).

IV.B.2. Health implications of radioiodine exposure from the Chernobyl accident

Many peer-reviewed studies of populations surrounding Chernobyl have been published and many more will appear in the future. Chernobyl releases impacted the entire globe and resulted in the relocation of about a quarter of a million people from Chernobyl's immediate vicinity. At one time following the accident, the World Health Organization (WHO) reported that about 600,000 workers were cleaning up the site.

Despite many studies of thyroid cancer and external radiation (NAS 1990), the induction of thyroid cancer by radioiodines is not as well understood as its initiation via external radiation (WHO 2001). Radioiodine effects are generally placed into one of three categories: thyroid cancer, leukemia, and other cancer types. Iodine intake studies strongly suggest that the age of the person at the time of exposure to radioactive iodines is important.

The International Agency for Research on Cancer (IARC), an agency within WHO, reviewed pre-2001 cancer studies and issued a report on its findings. IARC reviewed the major studies of involving persons who received radioiodines for various reasons, including diagnostic procedures and therapy for both hyperthyroidism and thyroid cancer. The WHO review found few correlations of radioiodine exposures and thyroid cancer; however, few of the subjects in these studies were children.

Recent studies of Chernobyl victims showed a rapid rise in the rates of thyroid cancer in children since 1990, particularly in Belarus, Ukraine, and the Russian Federation. In Belarus, the rate of thyroid cancer in children under 15 increased 100-fold from 1981–1985 to 1991–1994 (from 0.3 to 30.6 cases per million people exposed). In the Gomel area of Belarus, the numbers increased 182-fold, from 0.5 to 96 cases per million (WHO 2001). Additional reports indicate that the highest incidence of thyroid cancer occurred when the radiation dose was equal to or greater than 0.3 grays (30 rads). Pritchard reported that before these studies, such a high incidence and short induction period for thyroid cancer had not been observed in exposed populations (Pritchard et al., in preparation). Although quantifying children's risk of developing thyroid cancer was difficult, in 1986 over 1,000 thyroid cancers were detected in persons classified as children (WHO 2001).

IV.B.2.a. Specific studies of the effects of radioactive iodine on the thyroid

ATSDR reviewed scientific publications regarding iodine effects on the thyroid gland. The following abstracts outline many of these studies.

IV.B.2.a.i. Radiation dose to the thyroid

Following the Chernobyl accident, I-131 activity was measured in 30 human fetal thyroids in the Zagreb district of the former Yugoslavia (Basic et al. 1988). Using a newly developed model, the authors estimated that the average mother's intake of I-131 was about 36 nanocuries (nCi), or 36 billionths of a curie (36×10^{-9} Ci). The fetal thyroid dose reached a maximum of 1,600 rads/nCi intake at about the fifth month of gestation. The authors determined that the risk of having a child adversely affected by the presence of I-131 in the mother was negligible. A Czechoslovakian study of the I-131 content in 416 postmortem thyroids calculated the dose rates at the time of death (Beno et al. 1991). Estimates of mean dose commitments (i.e., the individual radiation doses received) were from mathematically transformed dose plots. The mean committed dose estimates (i.e., average dose delivered over a lifetime) in thyroids of adults were 0.074 and 0.058 rads for linear and quadratic-periodic regression, respectively. Similar analyses of thyroids obtained from fetal donors and donors up to 18 years of age were 0.167 and 0.177 rads for linear and quadratic-periodic regression, respectively. Estimates of absolute risk for thyroid cancer showed that any excess thyroid cancer incidence that could be expected would be obscured by the "spontaneous" or background incidence of the disease in the study location.

A Russian study of thyroid I-131 contents (Bratilova et al. 2003) found the highest concentration (up to 9.5 µCi) in Russian residents was in the Bryansk region west of Moscow and north of Chernobyl, and in the Tula and Orel regions (up to 2.7 µCi). The average thyroid I-131 activity in the middle of May 1986 reached 2 µCi for inhabitants of some settlements in the Bryansk region, 0.2 to 0.5 µCi in the Tula region, and 0.1 µCi in the Orel region.

Another study screened travelers to the United States from Europe for I-131 in the thyroid (Castronovo 1987). For purposes of dosimetry the 58 travelers were divided into 3 age groups: adults (older than 18), children (18 or younger), and two fetuses (one at 17 weeks and the other at 26 weeks). Detectable quantities of thyroid I-131 were found in 74% of the subjects, ranging from 1 nCi (37 becquerels) to 900 nCi, with the highest adult radiation dose equivalent of 5.18 millirem (mrem). Because of their smaller thyroid masses, the children had considerably higher dose equivalents: one infant received 37 rem. Several other children were above 1 rem. The fetal dose equivalents were less than 14 mrem.

The Centers for Disease Control and Prevention (CDC) recently completed the Hanford Thyroid Disease Study of those persons living around the DOE Hanford Reservation in the State of Washington. This study suggested the low dose from Hanford iodine releases was about 0.29 rads, the maximum dose was less than 300 rads, and the median dose was about 10 rads. The study found no statistical significance in the health effects of those exposed as compared with the control group (CDC 2002).

IV.B.2.a.ii. Noncancer effects on thyroid function

In March 1954, during atmospheric nuclear testing in the South Pacific, residents of the Marshall Islands were contaminated with fallout. These residents have been studied for many years, and in some cases, concerns persisted regarding the radiation dose to the thyroid. The National

Academy of Science finds a strong correlation between hypothyroidism and thyroid nodules prevalence and apparent dose associated with radioactive iodine (NAS 1990).

A thyroid function screening 7 years after the Chernobyl accident involved 1,097 persons who took part in Chernobyl activities (Bebeshko et al. 1999). The study showed that 94.6% of the workers who were present during the iodine releases had normal levels of thyroid-stimulating hormone (TSH) and 4.79% had elevated levels. On the other hand, 90% of the "noniodine-period" defined as the time when no iodine was released, persons had normal levels of TSH, while 8.8% had elevated levels. While 95% of the iodine workers had normal levels of the thyroid hormone thyroxin, 3.7% showed a slight rise, and 1.6% showed a decrease. Out of 92% of workers who were present when no iodine released, 5% of this group had elevated thyroxin levels, the remainder had normal thyroxin levels. The other 3% showed a decrease in free thyroxin. Similar trends were seen in studies of antibodies to the thyroid protein thyroglobulin. No statistically significant differences were found in these groups, which suggests that the uptake of radioiodine does not result in non-cancerous thyroid function.

Another study evaluated approximately 160,000 children under 10 years of age when exposed to radioiodine as a result of the Chernobyl accident (Goldsmith 1999). These children were residents of five regions near Chernobyl. They were examined by standardized screening protocols over 5 years from 1991 to 1996. Among boys 56 cases of hypothyroidism were found as compared with 92 among girls.

Similarly, Ishigaki et al. (2001) showed the relationship between iodine deficiency and childhood thyroid diseases by comparing urinary iodine levels in children from Nagasaki, Japan, with the levels found in children from Gomel, Belarus, near Chernobyl. They found levels of urinary iodine were at least 2.5 times lower in the children near Chernobyl, an iodine-deficient area, and the rates of goiter were about 10 percent higher than those for the children in Nagasaki, an area considered iodine-rich. They concluded that iodine deficiency was an essential contribution to the number of goiters and cysts observed in children who lived around Chernobyl.

IV.B.2.a.iii. Thyroid cancer

A United States study of estimated individual and population doses received by the United States population following the Chernobyl accident used EPA data from the national monitoring system (Broadway et al. 1988). In all media, I-131 was consistently detected. The highest calculated individual-organ dose, 98% of which was due to milk ingestion during May and June 1986, was 52 mrem to the thyroid of an infant living in the State of Washington. The maximum United States collective dose equivalent to any organ was calculated to be 330,000 person-rem to the thyroid (dose to the entire United States population). Risk estimates from exposure during the May–June 1986 interval indicated three excess lung cancer deaths and an additional four deaths due to cancers of thyroid, breast, and leukemia in the United States population over the next 45 years. The authors also acknowledged the uncertainty in the estimates based on the data and noted that all estimates of excess cancer could vary by least a 50–200% range. Compared with the typical cancer mortality from all other causes—41,000 fatalities from thyroid cancer and 3,800,000 fatalities from lung cancer estimated to occur in the United States population during the next 45 years—increased deaths from radioiodine exposures would not be detectable.

In a study of 119,785 patients born in 1968–1986, 34 cases of thyroid cancer were registered within 12 years after Chernobyl (Shakhtarin et al. 2002). The study included people with either iodine excesses or iodine deficiencies. The results indicated that iodine deficiency could promote tumors. The ERR of thyroid cancer in young patients suffering from severe iodine deficiency was almost twice as high as in healthy subjects.

The risk of thyroid tumors during childhood increases from average doses as low as 10 rads. As the dose increases, the risk apparently increases linearly, with an ERR of 7.7 per 100 rads if the thyroid radiation dose occurs during childhood. The risk to the thyroid is affected by age of exposure, by sex (women are affected more than twice as often), by genetic makeup, and by dose or dose rate to the thyroid. In the case of age, ATSDR's data review suggests that risk decreases with age and appears to be inconsequential after age 20. (Almost no carcinogenic effect on the adult thyroid gland occurs when I-131 is administered in medical settings.) Nonetheless, the Chernobyl accident has clearly shown that the risk of thyroid cancer after childhood exposure to I-131 is important (Schlumberger et al. 1999).

Another study evaluated thyroid cancer incidence from 1982–1995 in about 5.3 million persons from the Bryansk, Kaluga, Orel, and Tula regions (Ivanov et al. 1999). Of the 2,599 evaluated thyroid cancer cases, 143 were children at the time of the 1986accident. The standard incidence ratio (the ratio of the observed-to-expected new cases of cancer based on the age-specific rates) was 6 to 10 times higher in children who were under 5 years of age at the time of the accident than among adults. Typically, the standard incidence ratio of thyroid cancer for children and adolescents at the time of exposure is about three times higher than in adults.

The levels of iodine and degree of iodine deficiency were measured in 3,070 residents from the Bryansk region, the region most heavily contaminated by the Chernobyl accident (Shakhtarin et al. 2003). Of these, 2,590 were 6–18 years of age and the rest were adults. Tissue samples confirmed the 34 thyroid cancers found in those born between 1968 and 1986. The findings were linear with dose and inversely correlated with the urinary concentration of iodine. Persons who were severely deficient in iodine had an excess relative risk (ERR) of 24.1 at a dose of 100 rads—about twice that of persons with normal urinary iodine levels (ERR of 13).

Recently, the Hanford Thyroid Disease Study released its final report (Davis et al. 2004). That study found no evidence of a relationship between the dose resulting from radioiodine intakes and any of the outcomes evaluated, including thyroid cancer, noncancerous nodules, auto-immune thyroid diseases, and hypothyroidism. The study estimated that the thyroid doses of those who participated in the study ranged from less than 1 millirad to over 280 rads.

Catelinois et al. (2004) used a modeling technique known as age-period-cohort to project the trends of thyroid cancer incidence rates in men and in women by assuming a Poisson distribution for the number of cases observed in each age and calendar period group. This distribution is an expression of the probability of observing various numbers of a particular event in a sample when the mean probability of that event on any one trial is very small. They observed an increased incidence of thyroid cancer over age and calendar time that was more pronounced for women, and risk calculations significantly increased the number of spontaneous and excess cases for both men and women. They also evaluated a hypothetical thyroid dose of 10 rads, using conservative assumptions about the risks of radiation-induced thyroid cancer after exposure to radioactive iodine. The absolute number of excess thyroid cancers calculated was of the same order of magnitude as the uncertainties associated with the spontaneous thyroid cancer trend. They concluded that uncertainties related to incidence trends in thyroid cancer are relatively important and need to be taken into account. Furthermore, it would be necessary to quantify all uncertainties in the risk evaluation, including dose measurements and extrapolation methods.

IV.B.2.b. Summary of ATSDR's review of public health implications

On the basis of its review of these studies published after the Chernobyl reactor accident in 1986, ATSDR has identified and summarized below several key points about radioactive iodine releases and human exposure.

- Radioactive iodines released into the atmosphere can be dispersed over large areas via atmospheric pathways, resulting in deposition onto and uptake by potential food sources used for human and animal consumption.
- Using the appropriate techniques within a specific time frame following releases, iodines ultimately ingested or inhaled by people and animals can be readily detected in the thyroid.
- Regarding human exposure, ample information in peer-reviewed scientific journals indicates that the most sensitive populations to radioactive iodine intake are those younger than 18 years of age. Persons in this age group are still growing and have smaller thyroid glands than adults have. This is particularly important for younger persons who need a healthy thyroid gland for normal growth. Persons older than 20 are less sensitive to radiation because the weight of their thyroid remains relatively constant. The literature also suggests that females are more likely than males to be affected by radiation exposure (dos Santos Silva and Swerdlow, 1993).
- The amount of iodine in the diet plays an important role in the development of adverse health effects. Persons in iodine-deficient areas or those whose diet is deficient in iodine are most affected. A thyroid tumor can result from 10,000 millirems (10 rads) which may be the lowest dose that increases the observable risk.
- Following exposure, noncancerous health effects cannot be conclusively ruled out because of the uncertainty in the derived iodine deposition patterns and the radiological doses as a result of these depositions.

V. Community health concerns

ATSDR actively gathers comments and other information from persons who live or work near ORR. ATSDR is particularly interested in hearing from residents of the area and from civic leaders, health professionals, and community groups. ATSDR will address these community site-related health concerns in the ORR public health assessments that are related to those concerns.

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

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

The community health concerns addressed in this public health assessment are those in the ATSDR Community Health Concerns Database related to radioactive iodine from X-10. The following table, derived from the ATSDR database, contains comments and agency responses. In some cases, the responses are similar to those given in other public health assessments.

<table>
<tr><th colspan="3">Community concerns from the Oak Ridge Reservation community health concerns database</th></tr>
<tr><th></th><th>Actual comment/issue</th><th>ATSDR's response</th></tr>
<tr><td colspan="3">Dose reconstruction</td></tr>
<tr><td colspan="3">Sources/releases of radionuclides</td></tr>
<tr><td>1</td><td>A community member suggested that some issues do not greatly change outcomes. She believes the most important item on the list is getting all the sources (source terms). A knowledgeable community member said there were probably lots of small releases that weren't identified. Altogether, those small releases could form a substantial amount of iodine.</td><td rowspan="2">ATSDR agrees that a complete understanding of the source term is important in the overall assessment. ATSDR is aware that there could have been other sources of radioiodines from the X-10 facility. However, ATSDR and apparently the Oak Ridge Health Effects Steering Panel believe the RaLa process releases were far greater than any other releases of radioiodine from the plant.

Considering that the initial review of the reactor operation logs was used to estimate the total production of radioiodines, the Task 1 authors should have had the necessary information to perform the dose reconstruction. For more information on the source terms, please see the Task 1 report (TDOH 1999).</td></tr>
<tr><td>2</td><td>A community member asked whether ATSDR and the ORRHES (Oak Ridge Reservation Health Effects Subcommittee) would make a concerted effort to evaluate whether or not major sources of releases of radioiodines from the Oak Ridge Reservation could have been overlooked during Phase I and Phase II of the Oak Ridge Dose Reconstruction (ORDR). The Task 1 ORDR report focused almost entirely on releases of iodine-131(I-131) from the production of radioactive lanthanum (RaLa) from 1944–1956. Other sources of potentially significant releases of radioiodines were from plutonium production beginning in 1944, fuel ruptures at the Graphite Reactor, and from the THOREX process. There may have been sources of I-131 release as well.</td></tr>
<tr><td>3</td><td>What we want is with the outstanding issues we have like source term, uncertainty, confidence interval, central value, adding other sources (like NTS), use of thyroid vs. total body dose; how do these things impact the final assessment?</td><td>ATSDR's evaluation of the data from the 1950s would have included any and all sources of radioactive material in the atmosphere regardless of its site of origin. Still, ATSDR believes that soil sampling for the presence of I-129 could supply information to address some of these issues, such as unidentified releases from the X-10 facility.</td></tr>
<tr><td>4</td><td>There's one issue that was brought up and it is important—the other ORNL event besides RaLa could expand the time period during which people were impacted. Where RaLa occurred in a certain period of time, evidently thorex or some others were from a different timeframe.</td><td>That is correct. Iodine was released after the end of the RaLa process. Please refer to pages 4–20 of the Task 1 report (TDOH 1999).</td></tr>
</table>

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
5	Could the Savannah exposures contribute to exposures in the Oak Ridge area because of Savannah's proximity to Oak Ridge?	Because of the topography and distance between the two plants (over 200 miles point to point), there is little chance that typical releases from the Savannah River Site would impact the Oak Ridge area.
6	Are the Oak Ridge radionuclide releases much higher or similar to other sources? Are the ORR iodine releases substantially larger than the NTS?	For comparison, the amount of radioactive iodine released from the ORR is about a tenth of that released from Hanford, about 1,500 times less than that released from Chernobyl, and about 2,500 times less than the amounts detected in the United States atmospheric nuclear tests from the Nevada Test Site (NTS).
7	A community member asked what other I-131 releases at the Oak Ridge site were not included in the original I-131 source term.	Iodine production processing was not included in the original source term.
Contaminants selected for further study		
8	Thus far, the only radionuclide for which doses have been reconstructed at several sites and for Nevada Test Site (NTS) releases is I-131. I-131 is the radionuclide that is associated with thyroid cancer, a cancer less often lethal than the cancers that can be caused by the other biologically significant radionuclides released in fallout. There were ranges of other biologically significant radionuclides released from local former AED sites, contained within NTS fallout, and within global fallout. These other radionuclides have not yet been the subject of a detailed dose reconstruction within this country.	CDC was tasked by the Department of Health and Human Services to evaluate this issue. A feasibility study was released in 2003. Briefly, the preliminary findings suggested that the health risks from exposure to fallout from past nuclear weapons tests may be small, but also it would be technically possible to conduct a detailed study of the health impact on Americans of exposure to radioactive fallout from the testing of nuclear weapons in the United States and abroad. The CDC report was peer reviewed by the National Academy of Sciences, which recommended no expanded study of exposure to radionuclides other than I-131. The reasoning was that radiation doses from other radionuclides were much lower than those resulting from the exposure to iodine.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	**ATSDR's response**
9	Why was X-10 not shown as an arsenic source? It burned coal for a very long period.	During Phase I and Phase II of the Oak Ridge Health Studies, the TDOH conducted extensive reviews and screening analyses of the available information and identified four hazardous substances that may have been responsible for adverse health effects: radionuclides from White Oak Creek, iodine, mercury, and PCBs. In addition to the dose reconstruction studies on these four substances, the TDOH conducted additional screening analyses for releases of uranium, radionuclides, and several other toxic substances. ATSDR scientists conducted a review and a screening analysis of the department's Phase I and Phase II screening-level evaluation of past exposure (1944–1990) to identify contaminants of concern for further evaluation. Based on this review, ATSDR scientists are conducting public health assessments on the X-10 site release of iodine 131, Y-12 mercury releases, ORR PCBs, radionuclides from White Oak Creek, Y-12 uranium releases, K-25 uranium and fluoride releases, and other topics such as the Toxic Substances Control Act (TSCA) incinerator and off-site groundwater.
10	Fluoride and certain other mixed chemicals have the same effects as iodine does. In all of the releases from K-25, fluoride could be a contributing factor.	The release of fluoride and uranium from K-25 will be evaluated in another public health assessment.
11	Back in the 1950s and 1960s when they were doing a lot of testing, strontium was a big worry. I'd never heard of I-131. Everyone was concerned then about health effects from strontium. Now all this talk about I-131. All of this was from same fallout (I-131 and strontium). Strontium's pathway is basically the same as iodine's.	The deposition pathway from the atmosphere is similar between strontium and iodine, but the critical organs are different: for strontium, bone is the critical organ; for iodine, the thyroid is the critical organ. For a reference individual, the skeleton's mass is about 10 kilograms and that of the thyroid about 30 grams—some 333 times smaller. An equal amount of radioactivity will result in a larger dose to the thyroid than to the skeleton because radiation dose is related to the energy of the radioactive decay and the mass of an organ.
Pathways of exposure		
Groundwater Pathway		
12	Has the porosity of the limestone bedrock below K-25, Y-12, and X-10 been quantified?	ATSDR evaluated the porosity of the bedrock beneath K-25 and X-10 in public health assessment on off-site groundwater releases at the ORR.

	Community concerns from the Oak Ridge Reservation community health concerns database	
	Actual comment/issue	***ATSDR's response***
Food Consumption Pathway		
13	A Subcommittee member asked if ATSDR was able to get any ecological data from X-10 and other places regarding animal and vegetable consumption by Scarboro residents.	ATSDR's public health assessment for the ORR's Y-12 site evaluates consumption of vegetables grown in Scarboro as the primary pathway of exposure to uranium. For more information, please refer to ATSDR's public health assessment on Y-12 uranium releases, available at http://www.atsdr.cdc.gov/HAC/PHA/oakridgey12/oak_toc.html.
Data and uncertainties in the data		
14	[ATSDR] has been working with DOE management to obtain iodine data. [ATSDR] is working with this air monitoring data that were received from DOE. One critical year, 1954 weekly monitoring data is missing, but DOE is still looking for it. There are also some outstanding questions about how to use the data. These data were from monitors that picked up all particulates, regardless of source, RaLa or wherever. These data could potentially make some of our discussion in obsolete because everything would already be included in the data.	ATSDR was not able to locate the missing 1954 data. On the basis of the other years and comparing the activity in the monitoring and the dates of the atmospheric nuclear tests, ATSDR believes that the monitoring data include the impacts of the nuclear tests. If the recommended soil sampling is performed, then ATSDR will not be ruling out the NTS as any I-129 detected in and around the monitoring locations or any other areas sampled will contain NTS iodine.
15	Do the recently found air monitoring data include fallout from the Nevada Test Site (NTS)?	Yes. Because the historical CAM data non-selectively included the radioactivity in air, the radioactivity detected on the CAM would include any materials injected into the air from the test site and transported across the country.
16	How and where were the new air monitoring data obtained?	The air monitoring data were obtained by a contracting firm in the Knoxville area and supplied to ATSDR.
17	Will the NTS, I-131, and I-133 exposures be included in the analysis?	ATSDR believes that the CAM data from the 1950s include the NTS fallout and the associated radioiodines in the fallout.
18	Will the new air monitoring data on I-131 have any effect on adding doses?	ATSDR believes that the CAM data from the 1950s include releases from X-10 and the NTS. Any future dose assessment would, therefore, represent the estimated total dose from both sites.
19	If the new monitoring data already include the fallout component from NTS, care must be taken not to add the component from NTS into the thyroid dose twice.	ATSDR agrees. This is an important public health message that ATSDR needs to impart to the community.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
20	One reason [a local scientist] thought it would be important to go back and look at the other releases was they were small and of shorter timeframe and much lower releases. RaLa was over an extended period of time. Others are important if you're going to look at probability of causation. For that end, every little bit counts.	Although the RaLa process occurred over several years, the data in the Task 1 report indicate that the releases did not occur continuously during that time frame. This is important because I-131 has such a short half-life. ATSDR will not be evaluating any of the releases for the purposes of probability of causation, as that is used exclusively for adjudication of legal issues.
Estimated radiation doses and cancer risk		
Dose (general)		
21	How does knowing your dose help you interact with the health system?	Once a dose range can be determined, then the health effects observed in that dose range can be determined. This can be passed on to the medical community so that proper monitoring can be conducted and proper treatment. can be given if health effects are found.
22	How do you think a reconstructed dose would compare with a dose derived from film badge data? Even better for me would be a peer-reviewed publication that validates the models you are using. The issue of trust was a major concern to some ORRHES and community members, and people who do not trust DOE may not trust the results of a DOE-funded report on dose reconstruction (or the results from NIS, state government, or ATSDR for that matter, including this subcommittee). It would certainly be easier for me to argue in favor of using information on reconstructed doses if some parts of the methods and results have been published in a peer-reviewed journal.	ATSDR believes that comparing a reconstructed dose related to releases of I-131 to a film badge will not result in a comparable dose for several reasons. For example, film badges typically are used to evaluate external exposure, which is converted to a whole-body dose. The film badge can be modified to respond to specific energies and types of radiation. Film badge efficiencies have increased over time and older film badges begin to fade; this increases the difficulty of determining older exposures and doses. Many results of other dose reconstruction projects in the United States and other areas of the world have been submitted and published in peer-reviewed journals. Peer review also took place during the grant/contract proposals before the efforts began. The National Academy of Sciences also has reviewed many, if not most, of the dose reconstruction projects in the United States. Their opinions are publicly available at www.nas.edu. ATSDR had the TDOH Task 1 report on the X-10 iodine 131 dose reconstruction technically reviewed by independent experts to evaluate the quality and completeness of the dose reconstruction and to determine if the dose reconstruction provides a foundation on which to base follow-up public health actions or studies.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
23	Individual-specific estimates of the probability of developing thyroid cancer from exposure to fallout from the Nevada testing program are uncertain to a greater degree than the dose estimates because of the additional uncertainty, in particular about the cancer-causing effect of low doses of I-131.	ATSDR agrees. As with any large retrospective dose reconstruction study, there is much uncertainty in the NTS estimates. These uncertainties contributed to the findings of the Institute of Medicine, which stated that doses at the county level have too much uncertainty to serve as a basis for estimates of individual doses.
24	Should the county specific estimates of I-131 released during above ground weapons testing at the NTS be used to determine the thyroid doses from the I-131 to individuals living in that county? Won't excluding the NTS data understate the radiation dose to the public?	According to the Institute of Medicine, doses at the county level have too much uncertainty to be used in an estimate of individual doses. However, peer reports show that soil sampling for I-129 may be useful as an indicator for I-131 distributions. ATSDR believes the NTS releases would have been collected by the air monitoring system. Thus, included in the dose estimates.
25	As you walk across the county line, your dose changes quite a bit.	This is an important fact to realize, especially since the dose reconstruction reports were based on modeled information and not on environmental sampling or monitoring results. Environmental samples, where available, are preferred over modeled values.
26	A Subcommittee member asked [a CDC scientist] about the significance of the dose.	CDC said that the dose number itself is not important. From NTS, this dose ranged from 0 to 200 millirems—a very large range. What are more important are the factors of exposure: How old were you and where were you at the time of exposure? What is your sex? Did you drink backyard milk? Unless you are going to assess the probability of causation, exact dose is not so important.
27	It's mainly young people, so they're going to grow up and they're not the ones who get that second blast. But there will be a new generation there who did get it. All I'm asking is put together a table to show me, and show me the years, and show me the relative doses or something.	ATSDR refers the reader to Table 11.3 and 11.4 on page 11-8 and 11-9 of the 1999 Task 1 report entitled (TDOH 1999). The tables give the estimated thyroid doses to consumers of commercial produce and milk at specified times.
28	How did they/are we looking at the X-10's major processes that may still be delivering an effect? There were cesium releases from the dam in 1985 and a flood in 1964 along with regular releases.	The dose reconstruction focused on historical exposures. In this public health assessment, the dose reconstruction's historical data will be combined with the data collected in the past 20 years.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	**ATSDR's response**
29	I would be more interested in seeing copies of publications in peer-reviewed journals (by you or your staff) that explain the mathematical and statistical details of ATSDR methods for estimating a person's thyroid doses from I-131.	ATSDR estimated the radiological dose to the thyroid using accepted methodology of the ICRP. The dose coefficients published by ICRP contain inherent uncertainties that are outlined in its methodologies.
30	One commenter stated that although there is uncertainty with the dose estimates, there is an even greater degree of uncertainty when you translate those dose estimates to risk estimates.	Yes, that is true.
Dose and organ-specific estimates		
31	The conversion of organ doses to effective doses is a questionable practice for a public health assessment. It is of interest to note that the use of effective dose for communicating risks to the public for exposure to I-131 was severely criticized by stakeholders at Hanford. The objection to the use of effective dose is that the organ dose has been partially weighted by ICRP for disease severity, years of life lost, and differences between morbidity and mortality for an individual exposed at an average age. Large differences in the ratio between disease incidence and mortality are given a maximum weight of only a factor of 2.	ATSDR agrees with this comment. During the startup of the ATSDR public health assessment, the initial thoughts were to determine the dose to the thyroid, then convert that to a whole body dose; at the time, ATSDR guidance was to evaluate effects on the entire body. Since then, the agency has adopted a more organ-specific dose assessment policy, especially when there are sufficient scientific data (such as in the case of the thyroid and radioiodine exposure) to justify the organ approach.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
32	A community member asked if the GAO used the term cumulative effective dose. The community member explained that there was epidemiological evidence of radiological effects in utero down into 1,000 mrem for effective dose. For 5,000 mrem, the organ dose would be used. For example, a child's thyroid would receive 100,000 mrem, which was well into the range of epidemiologically significant effects for both cancer and noncancer. The community member continued that there were several single organs for which an effective dose of 5,000 mrem would be an organ dose of 100,000 mrem, and for some organs, it could be as high as 500,000 mrem. The community member was present at the PHAWG meeting to raise the issue that the use of effective dose was a poor surrogate to risk assessment. He added that if the numbers that ATSDR were proposing were to be organ doses, then he would not have a problem. However, he stated that he has a professional issue with the use of the effective dose for retrospective analysis.	ATSDR understands the community member's concerns. ATSDR lists the effective dose, but also lists the organ dose for the critical organs as proposed by the ICRP.
Dose and whole-body estimates		
33	A community member asked why the I-131 thyroid doses would be converted to whole-body doses.	ATSDR uses minimal risk levels as an estimate of daily human exposure that is unlikely to result in noncancer effects. The agency also evaluates organ-specific exposures and radiological doses, using the weight of evidence approach to compare these doses to levels associated with effects as reported in the toxicological literature.
Dose and worst case assumptions		
34	The public will interpret that differently. If we use the worst-case approach, we may indeed be laying foundations for lawsuits.	The use of worst-case approaches in health assessments is typical for initial screening evaluations. This approach gives an upper limit to the impacts that a contaminant might have. The central value, assuming the data are robust, can be used as a "normal" exposure scenario. In 1995, the National Academy of Science also stated that screening values are an initial method of uncertainty analysis that can be used to evaluate the need for additional studies.

	Community concerns from the Oak Ridge Reservation community health concerns database	
	Actual comment/issue	***ATSDR's response***
Dose and sensitive populations		
35	A Subcommittee member added that workers were not the most sensitive population to radioactive iodine—children residing in the affected area outside the gates were the most sensitive population.	That is correct. Children appear to be more sensitive to iodine exposure than individuals over the age of 19.
Combining doses		
36	A Subcommittee member understood that the Idaho Health Effects Subcommittee was the only one that had asked to have the combined doses evaluated.	The Subcommittees in Idaho and at Savannah River Site have been assured that when the I-131 doses are reached in their project, fallout doses will be considered.
37	If you're trying to do a PHA and give people a reasonable idea of what their health risks are, if there's I-131 both from ORR and NTS, it's in this area and affecting the public health. If you ignore the NTS part of it, you won't get accurate health assessment unless our data is so uncertain and we're so conservative on our conclusions that it covers it anyway. Before I would want to approve not adding NTS data in, I'd want to know if would have any affect in the end.	Because the uncertainty in the Task 1 Report is relatively large, and because the uncertainty in the on-line dose is large, the effect of adding doses may not be significant. A recent estimation indicated that the maximum and minimum dose varied by a factor of 3 or more, depending on the county in Tennessee, date of birth, and milk ingestion rate. In addition, ATSDR's recommended sampling would include I-129 from all sources.
38	The basic question is do we add sources. Iodine-131 from ORNL/Oak Ridge has to be in the assessment—no question about that. But then you look at the NTS and iodine; if you carry that logic to the extreme, you also must include Chernobyl, and on and on. You could add at least a dozen sources of I-131, many of them so small that they're not going to impact at all. Follow on: if we accept that we add other sources to Oak Ridge sources, then what about lead, gasoline from automobiles, fallout from TVA because they emit uranium and thorium, etc.?	Doses from radiological exposures can be added; however, if the quality of the individual data sources is not comparable, then the results would be highly questionable. For example, if one set is based on environmental samples while another is based solely on modeled results, then there may be no strong correlation between the data sets. This public health assessment does not address impacts of non-radiological chemical releases; however, there have been efforts to determine the best methodology to combine both chemical and radiological doses, but with no consensus. ATSDR does not support the effort to combine the doses from dissimilar exposures that may affect different target organs.

<table>
<tr><th colspan="3">Community concerns from the Oak Ridge Reservation community health concerns database</th></tr>
<tr><th></th><th>Actual comment/issue</th><th>ATSDR's response</th></tr>
<tr><td>39</td><td>We must combine these exposures to NTS atomic tests, with exposures to local site I-131 and I-131 contained in global fallout. These combined exposure doses must then be translated into health risk.</td><td rowspan="5">Combining doses might be possible if the data were less uncertain. As pointed out by the Institute of Medicine, the uncertainty is quite large. If the doses are combined, then ATSDR would evaluate the exposure and doses based on observable health effects, not on perceived risk numbers.

In an attempt to reduce the uncertainty in the potentially impacted areas, ATSDR evaluated the air monitoring data from the 1950s, which includes any and all sources of radioactive materials in the atmosphere regardless of its site of origin. Also, ATSDR is recommending soil sampling for I-129 to address some of these issues, such as unidentified releases from the X-10 facility and releases from the NTS to determine the areas impacted by I-131 releases.</td></tr>
<tr><td>40</td><td>The question is should we combine doses? I think when we look at this, even though we look at iodine, we need to look at some of the generic logic that we're talking about and where we're going with this. Are we vs. should we combine doses What does that do to our program or charter?</td></tr>
<tr><td>41</td><td>Since one can add the doses and combine the uncertainties, anything this committee puts out has got to combine the NTS and the Oak Ridge data. If we do not do this, we will run a terrible risk of discrediting ourselves. Also, we should be dealing with central values when we have distributions of values.</td></tr>
<tr><td>42</td><td>A Subcommittee member summarized that the NTS data has tremendous variability, more so than the data for ORR. When there is a lot of uncertainty involved it does not provide a clear picture for members of the public. However, for the purposes of full disclosure, he noted that it seems the general consensus is to use the NTS data, but provide a clear discussion of the uncertainty involved.</td></tr>
<tr><td>43</td><td>A Subcommittee member suggested that the recommendation focus on the impact of the Oak Ridge Reservation itself rather than complicating the issues with added doses from the NTS or other DOE sites, which may also have had impacts.</td></tr>
</table>

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
44	A community member commented regarding the combining of doses from radioiodine from Oak Ridge and from the Nevada Test Site, it may be impossible to produce risk estimates from the doses. His opinion is that if risk estimates cannot be produced, time should not be spent producing the dose estimates because people do not know how to interpret dose estimates, but risk estimates are meaningful. His recommendation consisted of eliminating the addition of I-131 doses from Oak Ridge and the Nevada Test Site if the risks cannot be estimated.	See response above.
Dose calculator		
45	A Subcommittee member recommends not adding the doses but having a dose calculator. She interprets the National Academy of Sciences (NAS) report as meaning that there are things more important than adding doses. Namely, these more important things are risk factors. Even [a local scientist] didn't recommend adding doses. He recommended adding probability of causation. [CDC] didn't say that we had to add the doses. At a later point, additional data will be coming in on global exposure. If new data becomes available, will we have to go back in and update our results to account for the new data? Let's just stick to the Oak Ridge data.	A dose calculator is available. It can be accessed at the Web site of the National Cancer Institute: http://cancer.gov/i131 and http://ntsi131.nci.nih.gov/. ATSDR recommends its use for community members if they have specific symptoms associated with thyroid disease and do not know that they were exposed to I-131. The resource can tell them that they may have been exposed to I-131 and that they should see a doctor.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	**ATSDR's response**
46	PHAWG recommends that ORRHES recommend that CDC/ATSDR establish an online dose calculator so that individuals may obtain estimates of their thyroid doses due to releases of I-131 from the Oak Ridge Department of Energy Reservation and from the Nevada Test Site, along with an option for adding the doses. CDC/ATSDR should provide information to the public on interpretation of the results from the dose calculator and any follow-up action the individual should take as a result of the estimate. Once you've done the work to make the calculator. I'm not sure that calculator is available.	ATSDR is not planning to develop an online calculator for the Oak Ridge releases.
47	A Subcommittee member clarified that the calculator can be used in situations where a person already knows he/she was exposed to I-131. She said that a particular community member is suggesting a resource for people to use if they have X, Y, and Z symptoms and they do not know that they were exposed to I-131. The resource can tell them that they may have been exposed to I-131 and that they should go see a doctor.	ATSDR agrees with this comment, especially in the light of the Institute of Medicine report stating that the doses at the county level are too uncertain to estimate individual doses.
Boron		
48	A commenter asked if boron was used as part of the iodine dose reconstruction process.	Boron was not used as a surrogate to look at iodine. Any boron that may have been detected at the site occurs naturally in the background soils.
49	This boron, is that for the iodine levels that were released during that time period?	

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
Uncertainty analysis		
50	What is uncertainty analysis? What are the weaknesses (distortions) inherent in using central values? Upper 95th percentile? What are the strengths in each?	Uncertainty analysis is a process generally used in model validations and quantitative risk assessments. The uncertainty is defined as the subjective distribution (not the frequency distribution) of an unknown value, generally a representation of the subjective estimate of the probability of a value occurring as seen by the individual. These estimates are subjective because the confidence intervals are chosen on the basis of expert opinions, not on data. For example, natural variability exists in the data. It is therefore very important to distinguish between natural variability and uncertainty due to lack of knowledge. If one cannot separate out the contributions from natural variability and unknown values, then it is important to use the upper 95th percentile of a distribution to draw conclusions.
51	Just because you can rub two numbers together, should you? What about the dose and the uncertainty associated with it? When you rub these two numbers together and combine them, and there is so much uncertainty, how important is the uncertainty? When you go from dose to risk, the uncertainty skyrockets.	ATSDR agrees in principle with the comment. As stated in the previous comment, uncertainty analysis is very important to the concept of model validation. At issue, however, is the concept of error propagation: that is, the uncertainty in the individual parameters is carried through the complete calculations. When the final uncertainty of the calculated value is determined to be essentially equal to or exceeds the nominal value (the result), then the usefulness of the nominal value comes into question.
Cancer risk estimates		
52	Should ATSDR public health assessment focus on dose estimates or risk estimates of I-131? Estimates of lifetime excess cases of thyroid cancer are more appropriate from a public health perspective. A public health response can be developed around dose and estimates of excess cases of cancer.	ATSDR is mandated by Congress to focus on dose. Public health assessments include a preliminary assessment of the risk, but the final assessment is dose-based.
53	Do the risk estimates include benign and malignant thyroid lesions? If benign lesions are included, then the risk estimates are overestimated. Applying the linear threshold model should preclude consideration of benign lesions, because benign lesions are consistent with a nonlinear mode of action and a threshold model.	Typically EPA risk estimates include benign and malignant lesions since risk is determined for morbidity and mortality. ATSDR agrees with the statement that including benign lesions is over-conservative, as about 30% of the population has benign thyroid nodules.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
54	Since the past diagnosis of thyroid cancers may be underestimated, and cancer registries are of little help, is there enough present knowledge to extrapolate to what might have occurred in the past?	ATSDR does not believe there is sufficient information for extrapolation to the past, especially since we believe there were problems with the model used to estimate the iodine exposure, distribution, and uptake as related to environmental factors.
55	Although the formula probability of causation PC=R/(B+R) seems simple enough, it is (or should be) based on complicated life-table calculation. As you know, the calculation of R is based on models of the age-specific excess relative risk, which in turn, depend on a radiation dose-response model in which dose may change with time and/or age at risk. The baseline risk also seems to be problematic in the case of I-131 and thyroid cancer. My concern is that other Subcommittee members have not had the background at this point to understand these issues since there has not been a discussion of even the most basic concepts from epidemiology.	Because of this perceived lack of basic epidemiological knowledge, ATSDR provided an overview of the science of epidemiology and helped ORRHES members evaluate the Mangano paper. Copies of the presentations are available at http://www.atsdr.cdc.gov/HAC/oakridge/presentations/index.html.
Task 1 evaluation process		
56	Does Task I estimate the total impact of off-site exposures to the public (both local and non-local) affecting the health of the thyroid gland? If the impacts are under-or-over estimated, estimate by how much.	The Task 1 Report evaluates the impacts of the iodine releases to residents at a distance of about 24 miles from the release point. Based on the modeled information, ATSDR does not believe it is possible to estimate the "over-or-under" estimates because the data are lacking. The modeled information is not detailed enough for ATSDR to determine whether its impact estimates are high or low.
57	There is no mention of the information from Appendix 11-C of the Task 1 Report (i.e., levels of probability of causation of current thyroid cancers due to past exposures to RaLa I-131) in reports from the State of Tennessee. Why was this material not included?	Probability of causation was developed for adjudication of legal claims under the Energy Employees Occupational Illness Compensation Program Act of 2000. An Executive Order from the President ordered the Department of Health and Human Services to develop guidelines (Probability of Causation) to be used by the Department of Labor to assess the likelihood that an employee with cancer developed that cancer as a result of exposure to radiation in performing his or her duties at a DOE facility or Atomic Weapons Employer ("AWE") facility. ATSDR does not use Probability of Causation in public health assessments.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
58	I have taken an initial quick look at this report and see no explanation or justification for Equations 2.1 and 2.2. Can you identify references in the peer-reviewed literature that explain why these equations are appropriate, how the lifetime absolute risk factors are estimated, and how these equations would be useful in describing the potential adverse health effects to any specific group of individuals that may have been exposed to releases of iodine-131 from the ORR?	ATSDR recommends that you contact the original authors of the Task 1 report to have them address this question.
Health effects/disease		
Thyroid disease non-cancer		
Non-cancer (general)		
59	To what extent could the thyroids of workers and residents have been adversely affected by exposure to contaminants in addition to iodine-131 from the RaLa process? Discuss the cumulative impacts from other radionuclides from RaLa; other radionuclides from other processes at X-10; other thyroid-impacting contaminants released from X-10, Y-12, and K-25; and non-local exposure.	The thyroid gland is the critical organ for exposure to radioactive iodine. For this reason, radioactive iodine—or any of the radioactive materials released—would have the greatest impact on the thyroid gland of workers and residents. Releases of gamma radiation during the RaLa process may have also impacted workers. In addition to radioactive material, endocrine disruption might affect the thyroid. These thyroid dysfunctions may be caused by organohalogens such as PCBs, pesticides, and other compounds. ATSDR has an extensive list of toxicological profiles on its Web site: http://www.atsdr.cdc.gov/toxpro2.html.
60	A community member commented that she has lived in Oak Ridge since birth, her mother was the first woman to work at Y-12 and worked with the calutrons, many family members came to work in Oak Ridge over the years. Now, many family members have developed thyroid problems, nodules, cysts, and Hashimoto's disease. She said that no one in previous generations of her family had thyroid problems. Has there been any research or documentation on thyroid diseases in second generation Oak Ridgers who worked at the plants or whose parents worked at the plants?	ATSDR brought a thyroid disease expert to the Oak Ridge area to inform the medical community about the issues associated with thyroid disease. The expert responded that he saw a study of thyroid cancer incidence in Oak Ridge showing that only children exposed at an age of less than 1 year who had high exposure from drinking local goat's or cow's milk were significantly vulnerable to thyroid cancer or nodules. Nodules occur more frequently with radiation exposure; 5 to 10 nodules are very common in the population even without radiation exposure. Autoimmune thyroid disorders such as Hashimoto disease are familial, but the genetic mechanism has not been discovered. It could come from either side of the family.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
61	A community member noted that there are various thyroid disorders in the community. She thinks the public would want to know any effects I-131 has on any other symptoms, not just malignant tumors, since any damage to the thyroid has the potential to affect other body parts.	ORRHES requested that ATSDR conduct an assessment of health outcome data (cancer incidence) in the eight counties surrounding the ORR. Therefore, ATSDR conducted an assessment of cancer incidence using data already collected by the Tennessee Cancer Registry. This assessment is a descriptive epidemiological analysis that provides a general picture of the occurrence of cancer in each of the eight counties. The purpose of this evaluation was to provide citizens living in the ORR area with information regarding cancer rates in their county compared to the state of Tennessee. The evaluation only examines cancer rates at the population level—not at the individual level. It is not designed to evaluate specific associations between adverse health outcomes and documented human exposures, and it does not—and cannot—establish cause and effect. The results of the assessment of cancer incidence, released in 2006, indicated both higher and lower rates of certain cancers in some of the counties examined when compared to cancer incidence rates for the state of Tennessee. Most of the cancers in the eight-county area occurred at expected levels, and no consistent pattern of cancer occurrence was identified. The reasons for the increases and decreases of certain cancers are unknown. ATSDR's ORR Assessment of Cancer Incidence is available online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html.
62	A community member's health problems consist of an enlarged thyroid and autoimmune disease. The condition began when handling uranium samples for school and civic demonstrations.	Typically, the kidneys, and not the thyroid, are most sensitive to the effects of uranium (i.e., the critical organ for uranium exposure is the kidney, not the thyroid). Even so, ATSDR believes that the amount of uranium most likely used in these demonstrations was not sufficient to cause any adverse health effects.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
63	A Subcommittee member noted the role of endocrine disruption within the thyroid. The community member further explained that if the feedback mechanisms for the thyroid hormone are disrupted, the level of thyroid stimulating hormone (TSH) could be controlled. If you have a situation in which thyroid hormone levels are constantly low then your TSH level will be constantly high, which overstimulates the thyroid and causes cell proliferation. If you control the feedback mechanism then you can control the proliferation that is induced by the TSH. This control mechanism can be set up in the thyroid or in the liver. If you have increased metabolism of thyroid hormones in the liver your thyroid hormone levels can be lowered, which will increase TSH production and cause the cells to keep reproducing within the thyroid. Therefore, there are two different modes of action and using only one model to account for those modes of action overestimates the risk.	ATSDR believes that this is not precisely correct. TSH does not induce proliferation of cells in the thyroid. Rather, its mode of action is to bind to cells within the gland and stimulate those cells to produce and release thyroid hormone, also called thyroxine.
64	A Subcommittee member mentioned that there are other contaminants in the environment that are endocrine disruptors, such as pesticides. Also, low iodine diets in children are believed to exacerbate the effects of I-131 on the thyroid, causing high cases of malignant thyroid cancer in children.	ATSDR agrees. As previously noted, there are a number of nonradioactive materials in the environment that can impact thyroid function. In addition, iodine-deficient diets, as shown in residents around Chernobyl, can result in adverse thyroid health effects.
Hypothyroidism		
65	A Subcommittee member asked [the thyroid expert] about the frequency of hypothyroidism in the general population.	Hypothyroidism is common, as it is found in 5% of the general population and subclinically in 10% of the older population. If TSH is mildly elevated and the thyroid is normal, most doctors will treat the patient. If TSH is only mildly elevated (5%–10%) and the patient has no complaints, there is a tendency just to observe. If TSH exceeds 12 milli-international units per liter in adults, the disease will progress. The international unit is an arbitrary amount of a substance agreed upon by scientists and doctors.

	Community concerns from the Oak Ridge Reservation community health concerns database	
	Actual comment/issue	***ATSDR's response***
Hashimoto disease		
66	A community member stated that recently she was diagnosed with Hashimoto's disease and asked for a brief summary of this disease.	Hashimoto disease is a chronic autoimmune inflammation of the thyroid that is common in the population and occurs more frequently with age.
Children and iodine deficiency		
67	A Subcommittee member commented, going back to the children of Chernobyl, he had heard that general areas had been iodine deficient, what role would uptake of iodine have played, especially with in utero exposure?	The expert replied that iodine deficiency would have an effect. The fetal thyroid is very active and it would take up whatever iodine—including radioactive iodine—it could get from the mother. The fractional uptake is higher with iodine deficiency, and iodine deficiency would contribute to taking up more of this radioactive iodine that can cause thyroid cancer.
68	A Subcommittee member wanted to know what would have been the iodine intake forty to fifty years ago.	Iodine deficiency is more common in children of mountainous regions or the Midwest. In fact, 25%–30% of the children in the Midwest have goiter. Children around the ocean were less affected because they got plenty of iodine. Due to concerns about iron deficiency in children, a world-wide program was developed to eliminate iodine deficiency by providing iodized salt.
69	Do children pick up more radioactive iodine because of their iodine deficiency?	Yes. Children pick up more radioactive iodine due to their iodine deficiency.
70	A Subcommittee member asked if kids were deficient in iodine in Chernobyl and how their diets compare with those of U.S. children.	Children in Chernobyl probably have diets low in iodine, with intakes of 50 micrograms per day. As a result of the iodine deficiencies, there is a 20% incidence of adolescent thyroid disease in Chernobyl On the other hand, diets of United States children contain 150–200 micrograms of iodine per day; 150 is considered deficient, 50–100 is borderline. Iodine is also ingested from milk, as well as from fortified bread. Although iodine intake overall has fallen 50% in the last 20 years, the U.S. intake is still considered good.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
71	A community member stated that all of her tests had been normal until her family doctor ran an ultrasound, which found all sorts of problems, and since that time she has run into many people in the Oak Ridge area who experience the same situation. Tests are normal until they insist on additional testing, and probably half of them have cancer. The community member stated that she personally knows 37 people who went through 3 to 4 years of having something wrong, which was undiagnosed because their thyroid tests kept coming back normal, and then when further tests were done, such as ultrasound and biopsies, they had major thyroid problems.	The vast majority of thyroid cancer patients—nearly all—have normal thyroid function. That is to say that cancer usually occupies a small part of the thyroid, and the rest of the thyroid functions normally, yet cancer can still be present. So a thyroid nodule can contain cancer, but thyroid gland function is normal. This is probably true in more than 95% to 98% of thyroid cancer cases. Nodules are very common: one half to two thirds of adults have thyroid nodules. Probably 95% of these nodules are benign and not cancerous.
Thyroid disease: cancer		
72	Why are females and children (under the age of 5) more susceptible to thyroid cancer and is that true for all cancers?	According to the National Cancer Institute, no one knows the exact causes of thyroid cancer. Doctors can seldom explain why one person gets this disease and another does not. Most people who have known risk factors for thyroid cancer do not get thyroid cancer. On the other hand, many who do get the disease have none of these risk factors.
73	A Subcommittee member asked if people exposed to fallout should be screened for thyroid cancer.	Any nodules in exposed individuals should be biopsied. Nodules in young people, adolescents, are particularly suspicious.
74	So thyroid cancer occurs about four years after exposure?	Thyroid cancer can appear as soon as 4 years after exposure, or earlier depending on the thyroid dose, as was seen in cases of people who received high thyroid doses following Chernobyl.
75	A Subcommittee member asked if thyroid cancer cells are confined to the thyroid.	Thyroid cancer cells are initially confined to the thyroid, but can eventually spread into the bloodstream.
76	In regards to thyroid incidentaloma (occult Thyroid Cancer), a Subcommittee member asked whether the small microcarcinomas progress.	The progression of thyroid incidentaloma, as measured by ultrasound and fine needle biopsy, was 12% in a retrospective study (Seong Nam-Goong et al. 2004).

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
77	A community member emphasized that cancer is not the only outcome from radiation exposure. The iodine-131 work is almost entirely focused on cancer as the only endpoint, but cancer is not the only health concern that people have in Oak Ridge. She suggested that ATSDR solicit community people by advertising. Many people in the community are not aware that the issues are being discussed She was particularly concerned about chemicals and the interactive effects with radiation. The toxicological literature includes information on work with synergistic effects that should be coming to the subcommittee. These data gaps are critical data.	Currently, cancers are the only diseases clearly shown to be related to radiation exposure; however, new evidence emerging indicates there are diseases other than cancers that are associated with radiation exposure in atomic bomb survivors.
78	A Subcommittee member asked if there has been significant research on lower levels of exposure over long periods of time.	The government has for many years supported studies of low-level radiation exposure (e.g., reactor leaks). Even so, there are no data to show increased thyroid cancers in adults, but in very young children (under the age of 1), there may be some effect. The studies show that the effect is usually greater from an amount of radiation delivered as a single exposure rather than several smaller exposures.
79	A community member suggested comparing the data for thyroid cancer at ORR to those for the Hanford site.	The final report from the Hanford Thyroid Disease Study stated that "there was no evidence of a statistically significant association between estimated thyroid radiation dose from Hanford and the cumulative incidence of any of the 14 primary outcomes. There was also no evidence of any statistically significant dose-response relationship for any of the alternative definitions of outcome." Furthermore, the estimated amounts of iodines released from Hanford are 10 times more than the amount thought to have been released from X-10. For these reasons, ATSDR does not believe a comparison would be valid.
Diagnoses and treatment of thyroid disease		
Diagnosis of thyroid disease		
80	RaLa did expose people to iodine, and there probably are health effects. People still have to be advised to go to their doctors and be checked for thyroid cancer.	ATSDR feels that general medical evaluations are a component of good health practices. A physician should examine the thyroid for nodules as part of a general physical exam.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
81	Suppose you were born in 1980 and lived just across river from ORNL. You were absolutely unaffected by RaLa, but you may have been affected by the later release. You decide to send them a postcard to say go see your doctor. You may have gotten a level that makes you a little more likely to have trouble than the average. That would be the typical response. So if you were trying to decide whom to send postcards to, you would send to that individual.	According to information in the Task 1 report, "later" releases occurred in the late 1960s. Releases during this time frame would not have affected individuals born after 1980s (see page 4-20 of the Task 1 report). ATSDR supports annual physical examinations by your family physician.
82	A community member asked if the TSH test is supposed to show if something is wrong with the thyroid.	A TSH test will not show if something is wrong with the nodule, it will not show that there is a cancer. The patient can have thyroid cancer and a normal TSH. Thyroid cancer occurs most of the time in people who have normal thyroid function. Well over 90% of patients who have thyroid cancer have normal thyroid function until they are operated on, and the thyroid is removed.
83	A community member asked if a lack of nodules means the thyroid is o.k.	No, a lack of nodules does not indicate that the thyroid is disease free.
84	A community member also asked whether, because of the frequency of thyroid nodules, examining for them was part of a general physical exam.	Examining thyroid nodules is part of a general physical exam.
85	A Subcommittee member asked if the tests are generally covered by insurance.	Screening for TSH could possibly be covered, as the test is easily justified for people over age 60.
86	A Subcommittee member stated, as a person who had had a false positive result and the surgery, that having a surgery and living for any length of time with the terror that one might have cancer is not a trivial thing; it is really a life-altering experience.	ATSDR agrees. The issue of false positives as well as the risk from fine-needle biopsy of the thyroid has been addressed by the Institute of Medicine. They state that a fine-needle biopsy may yield indeterminate or unsatisfactory results probably 20% to 30% or more of the time.
Treatment of Thyroid Diseases		
87	A community member reported that pharmacists have said to her that synthroid medication is distributed from their pharmacies by the truckload each month.	ATSDR is not aware of the number of synthetic thyroid compounds distributed in the area. However, an Internet search indicated that the medication to which this comment refers was the third most commonly prescribed in the country during 2003, with 47.2 million prescriptions written.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
88	A Subcommittee member asked if immunosuppressants are used to treat underactive thyroid.	Large amounts of Prednisone could be used to treat an underactive thyroid, but that bad side effects outweigh the benefits.
Rate of thyroid disease		
89	No one has counted all the thyroid cancers in the area for the last 20, 30, 40 years. There is no documentation of that. And also the non-cancer effects. That's not being documented either, anywhere. So that's the problem. It's that there is no documentation. And there is no record, there is no registry counting—and we can find out a little bit more about registries at the next meeting.	ATSDR believes that this is true. Because of this lack of data, ATSDR has brought in outside experts on thyroid disease and health effects related to radiation exposure. These experts have discussed these exact issues following public service announcements as to their availability to meet with the public.
90	A community member asked for which years the Tennessee Cancer Registry has achieved 80% reporting, and if the data would help the Subcommittee determine what counties are impacted by the Oak Ridge facilities, particularly thyroid cancer.	According to an epidemiologist with the state of Tennessee, the early and mid-1990s have achieved 80% reporting and that the Tennessee Cancer Registry could be used to make estimates of the incidences of specific cancers.
91	A Subcommittee member asked if there had been an elevation in thyroid diseases for women who were born between 1944 and 1956.	To address these concerns, ORRHES requested that ATSDR conduct an assessment of health outcome data (cancer incidence) in the eight counties surrounding the ORR. Therefore, ATSDR conducted an assessment of cancer incidence using data already collected by the Tennessee Cancer Registry. This assessment is a descriptive epidemiological analysis that provides a general picture of the occurrence of cancer in each of the eight counties. The purpose of this evaluation was to provide citizens living in the ORR area with information regarding cancer rates in their county compared to the state of Tennessee. The evaluation only examines cancer rates
92	Effects on the thyroid resulting from doses of iodine are evident in the community, as well as thyroid diseases, cancers and other maladies. The Subcommittee and community members can work together to change people's minds in Congress.	

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
93	Have we seen any real increase in thyroid diseases, cancer included, in this particular area? What's this, the 7 county area, 9 county area that we live in? Compared against something outside the counties—on the perimeters.	at the population level—not at the individual level. It is not designed to evaluate specific associations between adverse health outcomes and documented human exposures, and it does not—and cannot—establish cause and effect. The results of the assessment of cancer incidence, released in 2006, indicated both higher and lower rates of certain cancers in some of the counties examined when compared to cancer incidence rates for the state of Tennessee. Most of the cancers in the eight-county area occurred at expected levels, and no consistent pattern of cancer occurrence was identified. The reasons for the increases and decreases of certain cancers are unknown. ATSDR's ORR Assessment of Cancer Incidence is available online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html.
94	Where did the figure of 28% of the total thyroid cancers in the population being diagnosed and reported come from?	That figure represents the percent of individuals nationwide with nodules in the thyroid. According to the National Cancer Institute, thyroid cancer represents approximately 1% of malignancies occurring in the United States.
95	A community member explained a person who reviewed the work in the Dose Reconstruction Study commented that certain counties had a higher incidence rate than the rest of the state because of an absence of African Americans. The community member wanted to examine if this was an issue, and if the reason was because the reported incidence of thyroid cancer among African Americans was low enough that it had a noticeable effect on the overall incidence rates.	ATSDR was not able to obtain the proper demographics information to evaluate the incidence of disease in the 1950s.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	**ATSDR's response**
96	There is, of course, a large amount of uncertainty in the risk term as well as the dose term. It is also unclear to me exactly how reconstructed doses and the related uncertainty would be used in evaluating the potential adverse health effects on the communities near ORR. I will be interested to learn if ATSDR decides to use this information in their PHA and how it will be used. For example, how will the "background" incidence rates for thyroid cancer from the 1940s to the 1970s be estimated? Also, would potential risk from I-131 from nuclear testing be part of "background" since ORR was not the source of this contaminant?	The problem associated with the uncertainty in the distribution of the radioactive iodines and the transfer to humans and the resulting dose is daunting. To address this uncertainty, ATSDR has recommended soil sampling for I-129 in an attempt to reduce the uncertainty in the distribution following the releases.
ATSDR's public health process of evaluating exposure and thyroid disease		
Use of screening values in ATSDR's evaluation		
97	A Subcommittee member suggested that the I-131 releases should be compared to standards in effect at time of release, in addition to present standards.	The standards in place at the time of releases, if they existed at all, can be used. One must remember that as science has progressed and as the ability to detect and identify radioactive materials improves, the standards have a tendency to become more restrictive. In 1963, the limit for I-131 in air for the public was 3,000 pCi/m^3 of air. Today, the Nuclear Regulatory Commission limits the concentration in air to 200 pCi/m^3.
98	A Subcommittee member asked what the effect would be from setting a screening level for radiological dose to the thyroid.	ATSDR believes that after dose calculations are made and compared to the lifetime screening level, anything below the screening value will be considered not of health concern. If it is above the lifetime dose, ATSDR will perform a more detailed evaluation to determine what, if any, health consequences may result from the dose. In addition, ATSDR will develop a different screening value for the thyroid.
99	A Subcommittee member questioned the appropriateness of 5 rem/year resulting in the determination that there is no public health concern.	ATSDR has discussed the criterion and general process of setting this screening value at several ORRHES and workgroup meetings. The CDC also reviewed and accepted the criteria used by ATSDR. The rational for using these criteria is described in ATSDR's public health assessment on Y-12 uranium releases available at: http://www.atsdr.cdc.gov/HAC/PHA/oakridgey12/oak_toc.html.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	**ATSDR's response**
100	As you know, epidemiological significant health effects have been detected at a thyroid dose of about 10,000 mrem, which, given the ICRP weighting factor of 0.05 for the thyroid gland, is equivalent to an effective dose of 500 mrem. Note, a 5,000 mrem effective dose (which is proposed by the ATSDR as an MRL for radiation) is equal to a thyroid dose of 10,000 mrem.	Comment noted. ATSDR has stated in several public meetings that the 5,000 mrem over 70 years to the whole body is to be applied to the whole body only and not to be used as an organ dose. The agency also stated that for specific organs, such as the thyroid, an organ-specific dose would be developed. Also important is the correct application of the ICRP weighting factor methodology for effective dose. For example, iodine is concentrated in the thyroid (about 30% of the intake, with the remainder throughout the body). If following the intake of radioactive iodine, the dose to the thyroid is found to be 10,000 mrem and the dose to the rest of the body is found to 20 mrem, the effective dose is (10,000 × 0.05) + (20 × 0.95) or 519 mrem, not the 5,000 mrem as stated in the comment.
ATSDR authority and the public health assessment process		
101	Someone suggested a separate focus group of those with thyroid disease, because I-131 exposure is one of the concerns.	ATSDR addressed concerns about thyroid disease with presentations by Dr. Jerome Hershman.
102	If we base our conclusions only on information about the Oak Ridge Reservation without considering any other public health sources, that's a very isolated thing. If we want a real and good assessment and real conclusions, we need as a base the health effects from base of contaminants (besides Oak Ridge) either layered on or combined from other sites. Contaminants, wherever they came from, affect health (whether its arsenic or lead or iodine or whatever).	ATSDR is preparing public health assessments on specific contaminants released from the ORR. We will then combine and develop an overall document addressing the health of the area, which will include all releases and contaminants.
103	Yes. How are you planning to present the overall picture on one piece of paper? There has got to be a way where you can do a time frame, show the contaminants. Because iodine was only an issue in the past. On the other hand contaminants in the ground water are an issue today if you're drinking well water. So there is a visual way to show that. How are you going to do that?	

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
104	Maybe we should do best case and worst case (100–150 potential health effects) and say to ourselves that we will never know exactly how many, even if we had good data. Therefore, the most time- and cost-effective measure we can take is to make a recommendation to ATSDR for their Public Health Assessment to say something like if you're female, if you were born between years ~1935 and ~1960, if you lived in affected area, and/or if you drank backyard cow's milk, goat's milk, etc., get to your doctor and get checked for thyroid cancer and ATSDR will pay for it. In the end, it will be quicker, cheaper, etc. If you go through all these dose reconstructions, we still don't know who the individuals are so there is still going to have to be this recommendation made for them to get to their doctor and be checked.	ATSDR, in general, agrees with the comment. ATSDR does not, however, pay for medical evaluations. In this public health assessment, ATSDR makes specific statements with regards to exposures to I-131 at specific ages and the chance of iodine-related issues. ATSDR also supports the evaluation prepared by the Institute of Medicine and the National Research Council. They state that a fine-needle biopsy may yield indeterminate or unsatisfactory results probably 20% to 30% or more of the time.
105	A community member stated that he would be a proponent for risk-based decision making because ATSDR was trying to establish a risk below which public exposures would not warrant any further analysis. He understood that ATSDR was putting its limited resources into where the agency could do the most good for the public, which was a valid approach. However, he argued for a risk-based approach. The community member added that if ATSDR were going to use a dose based approach, then it should be sure that the criteria did not lead to a situation where cancer and noncancer effects could occur.	ATSDR has selected dose over risk because the statute creating ATSDR states that the agency is to evaluate the tolerable doses and observable health effects. ATSDR uses risk numbers for initial screening and establishment of minimal risk level values. When evaluating doses to specific organs, other than the thyroid, it is not really clear what dose level constitutes a health risk. This is because most radiation-related illnesses are not expressed within a short time frame. In most cases, radiation experts believe that it may take from 5 to 30 or more years for a radiation-related illness to be expressed.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
106	Confusing this subcommittee with the ORHASP, he stated that ten years of this committee's work and dose reconstruction had produced far too little. Rather than science the work done here has been a smoke screen to confuse the public. Aside from the I-131, the public has not been reassured that they have not been exposed to carcinogenic levels of uranium, fluorine, nickel, arsenic, mercury, chromium, neptunium, plutonium, or beryllium. He called the work done to date pseudoscience done with randomly selected exposure standards and falsified reported data. He called for closer scrutiny of where the data originated from. In his opinion, what Oak Ridge needs and has asked for is a health study to show the exposures have been, and health care for those already sick and dying. He cited increased local cancer rates and the disruption of many area residents' immune systems. He called for an end to cover-ups of toxic exposures and real study of the health effects of low doses that display no overt symptoms for years but continuously undermine the immune and central nervous systems.	To address these concerns, ORRHES requested that ATSDR conduct an assessment of health outcome data (cancer incidence) in the eight counties surrounding the ORR. Therefore, ATSDR conducted an assessment of cancer incidence using data already collected by the Tennessee Cancer Registry. This assessment is a descriptive epidemiological analysis that provides a general picture of the occurrence of cancer in each of the eight counties. The purpose of this evaluation was to provide citizens living in the ORR area with information regarding cancer rates in their county compared to the state of Tennessee. The evaluation only examines cancer rates at the population level—not at the individual level. It is not designed to evaluate specific associations between adverse health outcomes and documented human exposures, and it does not—and cannot—establish cause and effect. The results of the assessment of cancer incidence, released in 2006, indicated both higher and lower rates of certain cancers in some of the counties examined when compared to cancer incidence rates for the state of Tennessee. Most of the cancers in the eight-county area occurred at expected levels, and no consistent pattern of cancer occurrence was identified. The reasons for the increases and decreases of certain cancers are unknown. ATSDR's ORR Assessment of Cancer Incidence is available online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html.
107	A Subcommittee member asked for an estimate of when the ATSDR PHA process will be completed for I-131 and when it will be completed for other substances.	ATSDR has developed a timeline for this and other public health assessments. Information on the schedules for the remaining public health assessments has been presented at both workgroup and ORRHES meetings.
108	I hope you will advise us on the extent to which the Iodine-131 Releases ORR Task 1 Report and related documents have been subject to critical review at any level (technical experts, community members, etc.), and the results of that review process.	ATSDR contracted with several technical experts in the areas of uncertainty analysis, radiation biology and health physics, nuclear engineering, and environmental aspects of nuclear technology to review the Task 1 report. ATSDR transmitted this review to the state of Tennessee.

Community concerns from the Oak Ridge Reservation community health concerns database		
	Actual comment/issue	***ATSDR's response***
109	A Subcommittee member suggested that ATSDR provide fact sheets (for physicians and the public) that discuss health effects of contaminants. She said that the fact sheets could provide the necessary information in a way that will not also imply self-diagnosis. A community member suggested electronically providing fact sheets on the ORRHES Web site.	ATSDR developed fact sheets on contaminants associated with releases from X-10. We have also brought in outside physicians with expertise in thyroid diseases and in birth defects, effects of radiation in teratology, and cancer.
110	A community member has not been able to obtain several references in the I-131 dose reconstruction report. She made a motion that ORRHES postpone discussion and framing decisions on the I-131 dose reconstruction until the Tennessee Department of Health allows access to the references listed in the I-131 Oak Ridge dose reconstruction.	The community member should contact the TDOH.
111	A Subcommittee member stated that because there are volumes of documentation on previous efforts, ATSDR should make summary information available, which could be used to make the connection between the previously considered approaches and the one we're considering now.	One purpose of the ATSDR public health assessment is to review these materials and develop a synopsis of that information during the development of its health call. The agency also prepares summary documents to describe the process, findings, and recommendations.

VI. Conclusions

Having thoroughly evaluated past public health activities and available current environmental information, ATSDR has reached the following conclusions.

VI.A. Past exposure

> ATSDR uses an ***indeterminate public health hazard*** category when a professional judgment about the level of health hazard cannot be made because data critical to such a decision is lacking.

ATSDR has categorized past exposure to radioactive iodines from the radioactive lanthanum (RaLa) process as *an indeterminate public health hazard* (see text box) In assessing the potential for past public health hazards, ATSDR reviewed the TDOH's Task 1 dose reconstruction of modeled past exposures to radioactive iodines released from the X-10 site, plus recently available historical data. This includes continuous air monitoring data for ORNL during the RaLa processing and radioactive iodine concentrations in deer harvested from ORNL. After reviewing this data, ATSDR could not determine conclusively that exposures to radioactive iodine occurred off the ORNL property at levels that could cause harmful health effects. The basis for ATSDR's determination is given below.

- ATSDR's review of the Task 1 dose reconstruction suggests that radioactive iodines affected areas extending as far as 24 miles from the RaLa release point within the ORNL. ATSDR recognizes that the Task 1 team had very limited available environmental data while preparing its I-131 dose reconstruction. Lacking sufficient environmental data, the Task 1 team developed its conclusions based on modeled scrubber efficiencies, air releases, atmospheric transport models, deposition rates, and biological transfer rates. Large uncertainties are associated with the modeled radioiodine dispersal and radiological doses. The wide range in the lower (2.5^{th} percentile) and upper (97.5^{th} percentile) values of the dose reconstruction of radioactive iodine exposures and doses provides evidence of much uncertainty in these values, many of which span two orders of magnitude (i.e., vary by a factor of more than 100).

- ATSDR's review of recently found continuous air monitoring data during the RaLa processing, coupled with thyroid iodine content in deer harvested on ORNL grounds and off-site locations, strongly suggests that the releases of radioactive iodines did not extend past the ORNL site boundaries at levels sufficient to cause harmful health effects. Rather, the historical monitoring data from the 1950s suggest that the effect of RaLa releases defined by the Task 1 dose reconstruction effort may have overestimated the extent of the contamination, both in area impacted and in radiological dose, by perhaps a factor of 10. Despite these findings, historical monitoring data used in the air analyses are limited; they were reported as gross beta and gamma measurements of long-lived activity, and do not indicate that the activity was from iodine or any other radioisotope specific to the RaLa releases.

- ATSDR further evaluated potential public health hazards associated with Task 1 modeled doses and information from historical beta and gamma activity monitoring data and deer thyroid studies. In assessing potential hazards, ATSDR reviewed the most recent data related to thyroid-induced diseases from the Chernobyl reactor accident in 1986 and other reports concerning the noncancerous and cancerous effects on the thyroid. Using this review:

- ATSDR concludes—even using the exposure and dose estimates from the Task 1 report—that persons who were at least 21years of age during the 1944–1956 RaLa release years and who were possibly exposed to radioactive iodines did not receive a radiation dose to the thyroid likely to induce thyroid disease or cancer.
- ATSDR believes that persons under the age of 18 during the 1944–1956 RaLa release years who received a thyroid radiation dose in excess of 10 rads should be considered the critical, sensitive population. Yet because of insufficient data about the actual areas affected by the RaLa releases, ATSDR cannot identify which communities surrounding X-10 may have been affected in the past.

- ATSDR believes that soil sampling data for I-129—as a surrogate for the chemically similar but short-lived I-131—in the ORR and within the prevailing wind directions of ORNL are needed to define those areas affected by the historical X-10 releases of radioactive iodines. ATSDR also believes that for I-129 in selected areas off the ORR, soil sampling is warranted.

VI.B. Current and future exposure

ATSDR has categorized current (1991–present) and future situations as posing *no public health hazard*. No significant air releases of radioactive iodines are occurring from ORNL. Therefore, ATSDR does not expect any current or future exposures to radioactive iodines from this site. Any I-131 released from X-10 from the 1940s through 2005 has, because of its short half-life, decayed completely. On the other hand I-129 from the X-10 releases may still exist in the environment because of its long half-life. That said, ATSDR scientists believe that the levels are not of public health concern because iodines, including I-129 and I-131, are removed from the body in about 12 days and from the thyroid in 80 days. Moreover, the amount of nonradioactive iodine common in contemporary diets offers sufficient protection against uptake of radioactive iodines, including radioactive iodines occurring at environmental levels.

> ATSDR uses the ***no public health hazard*** category where there is no potential for human exposure to harmful levels of contaminated media.

VII. Recommendations

Having evaluated past, current, and future public health activities and the available environmental information, ATSDR offers the following recommendations:

1. I-131 released during RaLa activities behaves chemically the same as I-129 but, because of its long half-life, persists in the environment. Thus, sampling soil for I-129 can indicate areas where I-131 was deposited during the RaLa years. ATSDR will use the results of soil sampling to refine its public health actions. Regulatory agencies should, therefore, sample I-129 concentrations in surface soils in the ORR area and within the central areas of ORNL, as well as in the prevailing wind directions associated with ORNL. Sample locations should include the approximate areas of the air monitoring stations in ORR and should correlate I-129 levels to air monitoring station results. ATSDR also recommends sampling in selected off-site locations to account for I-129 produced during weapons testing. These locations should be determined through discussions with air dispersion experts. These locations could possibly include areas where the dose reconstruction predicted the highest doses to have occurred, as well as selected background locations. The background locations can also be used for comparison with on-site analyses.
2. ATSDR cannot predict whether this proposed soil sampling will reduce the uncertainty associated with the thyroid doses resulting from the intake of I-131. ATSDR believes, however, that sampling results will better delineate the area affected by X-10 releases and thereby allow for more accurate identification of the exposed population.
3. As a prudent public health practice, especially in the light of uncertainty about exposures to I-131, ATSDR recommends that residents who lived in the potentially affected communities and were 18 years of age or younger between 1944 and 1957 discuss their concerns with their local physician for the need of thyroid exams or other thyroid-related procedures in accordance with the American Thyroid Association recommendations.

VIII. Public health actions

The Public Health Action Plan for radioactive iodine releases from X-10 describes actions to be taken after the completion of this public health assessment by ATSDR and other government agencies at and near the site. The purpose of this Public Health Action Plan is to ensure that this public health assessment not only identifies public health hazards, but also provides a plan of action to mitigate and to prevent adverse human health effects resulting from exposure to hazardous substances in the environment. If additional information about X-10 radioactive iodine releases becomes available may change some or all of this public health assessment's conclusions; in that event, human exposure pathways should be reevaluated and these conclusions and recommendations should be amended as necessary to protect public health.

- ORR staff will notify ATSDR if environmental monitoring data indicate that statistically significant radioactive iodine levels are found to be present in soils. Upon such notification, ATSDR will determine appropriate public health actions.
- ATSDR will develop and implement additional environmental health education materials, as necessary, to help community members understand the findings and implications of this public health assessment.

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Appendix A. ATSDR glossary of environmental health terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA)—the federal agency that develops and enforces environmental laws to protect the environment and human health.

This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-800-CDC-INFO.

Absorption

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

Activity
The number of radioactive nuclear transformations occurring in a material per unit time. The term for activity per unit mass is specific activity.

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

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

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

Ambient
Surrounding (for example, the ambient air).

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

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

Background radiation
The amount of radiation to which a member of the general population is exposed from natural sources, such as terrestrial radiation from naturally occurring radionuclides in the soil, cosmic radiation originating from outer space, and naturally occurring radionuclides deposited in the human body.

Biota
All of the organisms (plants, animals, fungi, protists, and microorganisms) in a habitat, region, or environment. Some of these organisms might be sources of food, clothing, or medicines for people.

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

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

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

Carcinogen
A substance that causes cancer.

Case-control study
A study that compares exposures of people who have a disease or condition (cases) with people who do not have the disease or condition (controls). Exposures that are more common among the cases may be considered as possible risk factors for the disease.

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

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

Chronic
Occurring over a long time (more than 1 year) [compare with acute].

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

Committed Effective Dose Equivalent (CEDE)
The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to the organs or tissues. The committed effective dose equivalent is used in radiation safety because it implicitly includes the relative carcinogenic sensitivity of the various tissues. The unit of dose for the CEDE is the rem (or, in SI units, the sievert:1 sievert equals 100 rems).

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs do not necessarily pose a health hazard, but might be selected for further evaluation in the public health assessment process.

Completed exposure pathway
[See exposure pathway.]

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

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

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

Curie (Ci)
A unit of radioactivity. One curie is that quantity of radioactive material in which 3.7×10^{10} nuclear transformations occur per second. The activity of 1 gram of radium is approximately 1 Ci; the activity of 1.46 million grams of natural uranium is approximately 1 Ci.

Decay product/daughter product/progeny
A new nuclide formed as a result of radioactive decay. It involves the radioactive transformation of a radionuclide into its decay product(s), either directly, or as the result of successive transformations in a radioactive series. A decay product can be either radioactive or stable.

Depleted uranium (DU)
Uranium having a percentage of U 235 smaller than the 0.7% found in natural uranium. It is obtained as a byproduct of U 235 enrichment.

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

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

Descriptive epidemiology
The study of the amount and distribution of a disease in a specified population by person, place, and time.

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

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

DOE
The United States Department of Energy.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligrams (a measure of quantity) per kilogram (a measure of body mass) per day (a measure of time), or mg/kg/day, when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually gets into the body through the eyes, skin, stomach, intestines, or lungs.

Dose (for radioactive chemicals)
The radiation dose is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

Dose-response relationship
The relationship between the amount of exposure [dose] to a substance and the resulting changes in body function or health (response).

Effective Dose Equivalent (H_E)
The sum of the products of the dose equivalent to the organ or tissue (H_T) and the weighting factors (W_T) applicable to each of the body organs or tissues that are irradiated ($H_E = \Sigma W_T H_T$). The effective dose equivalent recognizes the carcinogenic radiosensitivity of the several different tissues of the body.

EMEG
Environmental Media Evaluation Guide, a media-specific comparison value that is used to select contaminants of concern. Levels below the EMEG are not expected to cause adverse noncarcinogenic health effects.

Enriched uranium
Uranium in which the abundance of the U 235 isotope is increased above normal.

Environmental media
Soil, water, air, the biota, or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism(s)
Environmental media include water, air, soil, and biota. Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism(s) are the second part of an exposure pathway.

EPA
The United States Environmental Protection Agency.

Epidemiological surveillance
The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the information and its use for public health programs.

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Equilibrium, radioactive
In a radioactive series, the state that prevails when the ratios between the activities of two or more successive members of the series remain constant.

Equivalent dose

The dose to a specific organ or tissue that is received from an intake of radioactive material by an individual over a specified time after the intake.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure can be short-term [see acute exposure], of intermediate duration [see intermediate-duration exposure], or long-term [see chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction
A method of estimating the amount of past exposure of individuals or populations to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure investigation
The collection and analysis of site-specific information and biological tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with or are exposed to it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental medium and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Exposure registry
A system of ongoing follow up of people who have had documented environmental exposures.

Feasibility study
A study by EPA to determine the best way to clean up environmental contamination. A number of factors are considered, including health risk, costs, and what methods will work well.

Grand rounds
Training sessions for physicians and other health care providers about health topics.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Half-life ($t_{½}$)
The time it takes for half the original amount of a substance to disappear. In the environment, the half-life is the time it takes for half the original amount of a substance to disappear when it is changed to another chemical by bacteria, fungi, sunlight, or other chemical processes. In the human body, the half-life is the time it takes for half the original amount of the substance to disappear either by being changed to another substance or by leaving the body. In the case of radioactive material, the half-life is the amount of time necessary for one half the initial number of radioactive atoms to change or transform into other atoms that are normally not radioactive. After two half-lives, 25% of the original number of radioactive atoms remain.

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations focus on a specific exposure issue. They are therefore more limited than public health assessments, which review the exposure potential of each pathway and chemical [compare with public health assessment].

Health education
Programs designed for a community to educate it about health risks and how to reduce them.

Health investigation
The collection and evaluation of information about the health of community residents. This information is used to describe or document the occurrence of a disease, symptom, or clinical measure and to estimate the possible association between the occurrence and exposure to hazardous substances.

Health statistics review
The analysis of existing health information (e.g., from death certificates, birth defect registries, and cancer registries) to determine if there is excess disease in a specific population, geographic area, and time period. A *health statistics review* is a descriptive epidemiological study.

Indeterminate public health hazard
The category used in ATSDR public health assessment documents when a professional judgment about the level of health hazard cannot be made because critical information is lacking.

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate-duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

Ionizing radiation
Any radiation capable of knocking electrons out of atoms and producing ions. Examples: alpha, beta, and gamma radiation, x-rays, and neutrons.

Isotopes
Nuclides having the same number of protons in their nuclei, and hence the same atomic number, but differing in the number of neutrons, and therefore in mass number. Identical chemical properties exist in different isotopes of a particular element. The term should not be used as a synonym for "nuclide," because the term "isotopes" refers specifically to different nuclei of the same element.

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Metabolism
The conversion or breakdown of a substance from one form to another by a living organism.

mg/kg
Milligrams per kilogram

mg/m^3
Milligrams per cubic meter (or per 1000 liters): a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration
Movement of materials from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

Mortality
Death rate; the cause (a specific disease, condition, or injury) is usually stated.

Mutagen
A substance that causes mutations (genetic damage).

Mutation
A change (damage) to DNA, genes, or chromosomes of living organisms.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

No apparent public health hazard
A category used in ATSDR public health assessments for sites where human exposure to contaminated media may be occurring, might have occurred in the past, or may occur in the future, but is not expected to cause any harmful health effects.

No-observed-adverse-effect level (NOAEL)
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard
A category used in ATSDR public health assessment documents for sites where people never have and never will come into contact with harmful amounts of site-related substances.

NPL
[See National Priorities List for Uncontrolled Hazardous Waste Sites.]

Parent
A radionuclide which, upon disintegration, yields a new nuclide, either directly or as a later member of a radioactive series.

Plume
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction in which they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

ppb
Parts per billion

ppm
Parts per million

Prevalence
The number of existing disease cases in a defined population during a specific time period [contrast with incidence].

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action plan
A list of steps to protect public health.

Public health advisory
A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed by coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health hazard
A category used in ATSDR public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public health hazard categories
Statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are: no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

Public health statement
The first chapter of an ATSDR toxicological profile. The public health statement is a summary written in words that are easy to understand. It explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public meeting
A public forum with community members for communication about a site.

Quality factor (radiation weighting factor)
The linear-energy-transfer-dependent factor by which absorbed doses are multiplied to obtain (for radiation protection purposes) a quantity that expresses—on a common scale for all ionizing radiation—the approximate biological effectiveness of the absorbed dose.

Rad
The unit of absorbed radiation dose equal to 100 ergs per gram, or 0.01 joule per kilogram (J/kg) (= 0.01 gray, or 1 cGy) in any medium [see dose].

Radiation
The emission and propagation of energy through space or through a material medium in the form of waves (e.g., the emission and propagation of electromagnetic waves, or of sound and elastic waves). The term “radiation” (or “radiant energy”), when unqualified, usually refers to electromagnetic radiation. Such radiation commonly is classified according to frequency: microwaves, infrared, visible (light), ultraviolet, x-rays, and gamma rays and, by extension, corpuscular emission, such as alpha particles (helium nuclei), beta particles (electrons), neutrons, or rays of mixed or unknown type, such as cosmic radiation.

Radioactive material
Material containing radioactive atoms.

Radioactivity
Spontaneous nuclear transformations that result in the formation of new elements. These transformations are accomplished by emission of alpha or beta particles from the nucleus or by the capture of an orbital electron. These reactions may or may not be accompanied by a gamma photon.

Radioisotope
An unstable or radioactive isotope (form) of an element that can change into another element by giving off radiation.

Radionuclide
Any radioactive isotope (form) of any element.

RBC
Risk-based Concentration, a contaminant concentration that is not expected to cause adverse health effects over long-term exposure.

RCRA
[See Resource Conservation and Recovery Act (1976, 1984).]

Receptor population
People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Rem
A unit of dose equivalent that is used in the regulatory, administrative, and engineering design aspects of radiation safety practice. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor (1 rem is equal to 0.01 sievert).

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Resource Conservation and Recovery Act (1976, 1984) (RCRA)
This act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RfD
[See reference dose.]

Risk
The probability that something will cause injury or harm.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], and contact with the skin [dermal contact].

Safety factor
[See uncertainty factor.]

Sample
A portion or piece of a whole; a selected subset of a population or subset of whatever is being studied. For example, in a study of people, the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sievert (Sv)
The SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose, in gray, multiplied by the quality factor (1 sievert equals 100 rems).

Solvent
A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination
The place where a hazardous substance originates, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Special populations
People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behavior (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Specific activity
Radioactivity per unit mass of material containing a radionuclide, expressed, for example, as Ci/gram or Bq/gram.

Stakeholder
A person, group, or community who has an interest in activities at a hazardous waste site.

Statistics
A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Substance
A chemical compound or element; a material.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Surveillance
[see epidemiological surveillance]

Survey
A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people.

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge about the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances to humans or animals.

Uncertainty factor
A mathematical adjustment for reasons of safety when knowledge is incomplete—for example, a factor used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for

variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

Units, Radiological

Units	*Equivalents*
Becquerel* (Bq)	1 disintegration per second = 2.7×10^{-11} Ci
Curie (Ci)	3.7×10^{10} disintegrations per second = 3.7×10^{10} Bq
Gray* (Gy)	1 joule/kilogram (J/kg) = 100 rads
Rad (rad)	100 erg/g = 0.01 Gy
Rem (rem)	0.01 Sv
Sievert* (Sv)	100 rems

*International Units, designated (SI)

Urgent public health hazard
A category used in ATSDR public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Watershed
A watershed is a region of land that is crisscrossed by smaller waterways that drain into a larger body of water.

Other Glossaries and Dictionaries
Environmental Protection Agency http://www.epa.gov/ocepaterms/
Centers for Disease Control and Prevention (CDC) http://www.bt.cdc.gov/radiation/glossary.asp
National Library of Medicine http://www.nlm.nih.gov/medlineplus/mplusdictionary.html

Appendix B. A conservative approach to radiation dose assessment

Issues associated with being protective or overestimating radiation doses

Research has been inconclusive about the effects or lack thereof of very low doses of ionizing radiation at or below the limits recommended by the International Commission on Radiological Protection (ICRP). A recent review by the National Council on Radiation Protection and Measurement (NCRP) of a large number of studies noted that the linear no-threshold hypothesis (LNT) could not be verified because cancer induced by low levels of radiation could not be distinguished from its many other causes. However, the report also stated that considerable support exists for this hypothesis and there is no reason not to believe that there is a threshold dose below which no effects would occur. Nonetheless, the NCRP also noted that such effects may not be observed because of experimental design, experimental subjects, or a number of other factors included in a study (NCRP 2001). More recently, the French Academy of Science (FAS 2005) questioned the validity of using LNT for evaluating the carcinogenic risk as a result of low doses (less than 10,000 millirem, mrem). The FAS was even more concerned of the use of LNT when doses were considered very low doses (< 1000 mrem).

Most of the data showing adverse health effects related to radiation exposure come from high-dose and high-dose-rate exposures. Therefore, ICRP's initial goal in setting dose limits was to prevent the directly observable, nonmalignant, and not necessarily cancerous effects of such exposures. As the science of radiation protection advanced, the ICRP modified its dose limits to reduce the incidence of cancer and detrimental heredity effects resulting from exposure to radiation (ICRP 1991).

Estimation of radiation dose

Radiation dose is a function of the energy from the radiation, the amount of energy absorbed by the organism, and the mass of the material absorbing the radiation. The energy of radiation is well known, being derived from first principles of atomic physics. The amount of radiation absorbed is based either on estimated measurements of energy transfer or, in the case of human exposures, on models called phantoms that are used to estimate the shapes, sizes, and masses of organs. Using mathematical models called transport models, one estimates the amount of radiation absorbed by these phantoms. These estimates are then applied to modeled human data. The ICRP has reviewed and prepared publications discussing tissue masses, ethnicity issues, composition, age, and sex based on medical information. The masses of human organs used, therefore, are best estimates. Because of these uncertainties, the ICRP established a standardized human, the "reference man."

ICRP dose coefficients

In its earlier publications, the ICRP only concerned itself with radiation exposure to workers. Following the events associated with the nuclear reactor accident at Chernobyl, the ICRP expanded its role to include the public. ICRP noted that to characterize exposure to the public, one must have a good understanding of age dependency, biokinetics, anatomical, and physiological data (ICRP 1991).

The ICRP has developed dose coefficients, or dose conversion factors (DCF), which can be used for dose assessment. These DCF values are a combination of factors containing much uncertainty. To compensate for this, the ICRP added conservative assumptions to the DCF values; thus, they may overestimate radiation doses. As radioactive materials decay and emit particles and/or waves the energy emitted can interact with matter. This interaction has been assigned a weighting factor called the radiation weighting factor (W_R). The ICRP selected the W_R to be representative of values that are broadly compatible with the dosimetric quantity of linear energy transfer. Linear energy transfer estimates the number of ionizations produced by radioactive emissions along their paths as they traverse matter. ICRP selected one specific value (1) for beta particles and gamma radiation on the basis of the energy of the particular particle and another value (20) for alpha particles on the basis of energy distribution curves.

For radiation effects on tissues, the ICRP also established a tissue weighting factor (W_T), which is based on the organ and tissue contribution to overall health and the incidence of cancers; it is also based on their "reference man" concept and rates of disease in the population. The weighting factors range from 1% for bone surfaces and skin to 20% for the gonads (genetic effects only). Except in the case of radiation effects to the breast, the sexes differ little in response to ionizing radiation. The factors are also used to establish probabilities based on latency periods of fatal cancers and nonfatal or hereditary effects in the whole population and in workers. This is a concept of detriment that the ICRP defines as a "measure of the total harm that would eventually be experienced by an exposed group and its descendants as a result of the group's exposure to a radiation source."

Accordingly, the ICRP established whole body coefficients for detriment following exposure to ionizing radiation as shown in Table B-1.

Table B-1. ICRP detriment coefficients

Population	*Fatal cancers*	*Non-fatal*	*Hereditary effects*	*Total*
Adult workers	0.0004 per rem	0.00008 per rem	0.00008 per rem	0.00056 per rem
Public	0.0005 per rem	0.0001 per rem	0.00013 per rem	0.00073 per rem

Biokinetic models

After radioactive materials are ingested or inhaled, they are absorbed and distributed throughout the body. The degree of absorption depends on the chemical form of the material; the ICRP has grouped the compounds into general categories based on their solubilities in water or body fluids. ICRP further divided the human body into compartments into or from which the materials are transported or where they are stored for extended periods. The models describing the movement of radioactive materials relative to compartments are based on autopsies, human volunteers, and animal studies, with adjustments for the reference man. After reviewing these studies, the ICRP selected coefficients for rates of absorption, transit times, and storage times in the organs of interest. In many cases, the variables selected are an overestimation of the true but uncertain biological function.

Summary

The establishment of a series of dose coefficients, or dose conversion factors, involves much uncertainty in the parameters for calculating the coefficient. Because of human variability, a standardized reference man and dose coefficients are used to estimate the radiation dose to a given population. Many of these assessments do not use site-specific information such as demographics or inhalation and ingestion rates. In its evaluation of the radiation doses associated with the Oak Ridge Reservation, ATSDR has used site-specific parameters and variables more relevant to southern communities than to the rest of the United States population. These parameters and variables were derived from the U.S. Environmental Protection Agency's Exposure Factors Handbook (EPA 1997)

References

[EPA] U.S. Environmental Protection Agency. 1997. Exposure Factors Handbook CD-ROM.

[FAS] French Academy of Sciences. 2005. Dose-effect relationships and estimation of the carcinogenic effects of low doses of ionizing radiation.

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

[NCRP] National Council on Radiation Protection and Measurements. 2001. Evaluation of the linear-nonthreshold dose-response model for ionizing radiation. Bethesda: National Council on Radiation Protection and Measurements Report 136.

Appendix C. Implications of exposure to radioactive iodines from ORNL

In the Reports of the Oak Ridge Dose Reconstruction, ChemRisk (1993) identified iodine-131 (I-131) as needing further evaluation. ATSDR provides information that describes the relationship between I-131 and the ORNL site in this appendix. Because it is important to understand the meaning of ionizing radiation to comprehend the properties and characteristics of I-131, ATSDR provides a description of ionizing radiation in this appendix.

ATSDR's toxicological profiles for ionizing radiation and I-131 identify and review the key peer-reviewed literature describing the toxicological and/or radiological properties of specific hazardous substances. They also present other relevant literature, but in less detail than in the key studies. These toxicological profiles are not intended to be exhaustive documents, but they do reference fairly comprehensive sources of specialty information. ATSDR also conducted internet searches for available data on I-131.

What is ionizing radiation?

Ionizing radiation is energy that is carried by rays and particles emitted from radioactive material, fuel components in nuclear reactors, and radiation-producing machines. Ionizing radiation consists of alpha particles, beta particles, gamma rays, and X-rays. Basically, alpha and beta particles are small pieces of atoms that move quickly. Gamma rays and X-rays are forms of electromagnetic radiation. These radioactive particles and rays have enough energy to knock electrons out of atoms or molecules during an interaction. This process is referred to as ionization, hence the term "ionizing radiation." Because people cannot sense ionizing radiation, special instruments have to be used to see if someone has been exposed to it and to calculate the person's level of exposure (ATSDR 1999).

How does an atom become radioactive?

An atom is either stable (nonradioactive) or unstable (radioactive). Whether an atom is stable depends on the ratio of neutrons to protons within the nucleus. When the nucleus has too many or too few neutrons, then the nucleus becomes unstable and the atom is considered to be radioactive. An atom can become radioactive naturally, by natural processes in the environment, or by human intervention (ATSDR 1999).

How does a radioactive atom give off ionizing radiation?

Because a radioactive atom is unstable, it will eventually transform into a different element by changing the number of protons in the nucleus. This occurs after one of several possible reactions takes place in the nucleus that stabilizes the neutron-to-proton ratio. The following are some of the possible reactions. If an atom has too many neutrons, then a neutron will change into a proton and emit a negative beta particle (an electron). Typically, if an atom has too many protons, then a proton will change into a neutron and emit a positive beta particle (a positron). Some massive atoms transform by emitting an alpha particle (the nucleus of a helium atom). Any excess energy that remains can be emitted as gamma rays. There are additional reactions that could occur, but the end result is the same—to turn a radioactive atom into a stable atom of a different element (ATSDR 1999).

How long can radioactive material give off ionizing radiation?

In theory, radioactive material can eternally emit ionizing radiation. However, realistically less than 0.1% of the original radioactivity will remain after 10 half-lives (ATSDR 2001b). The half-life can be as brief as a fraction of a second or as long as several billions of years. Each radionuclide has its own unique half-life. For example, I-131 has an 8-day half-life, whereas uranium-235 has a 700 million-year half-life (ATSDR 1999). Thus after 80 days, only 0.1% of the original amount of I-131 remains; whereas, for uranium-235, 7 billion years would be required to reduce its activity to 0.1% of the original amount.

What are the three types of radiation?

Alpha, beta, and gamma radiation are the three primary types of radiation. Alpha radiation, also known as alpha particles, is the nuclei of helium atoms consisting of particles with two protons and two neutrons; alpha particles travel extremely fast. Because of the protons, alpha particles have a large positive charge that pulls hard at the electrons of other atoms. When alpha particles travel close to an atom, they excite its electrons and can draw them from the atom; thus, ionizing the atom. Following each ionization, the alpha particle loses some of its energy and it begins to slow down. You can only be exposed to alpha radiation if you absorb radioactive material that produces alpha radiation in your body (e.g., if you swallowed or inhaled the radioactive material); you cannot be exposed to alpha radiation in radioactive material that is outside of your body and not on your skin. After this radioactive material has entered your body, it can be combined with the contents in your intestines and stomach, absorbed by your blood, integrated into a molecule, and eventually deposited into living tissue (e.g., bone matrix) where the material continues to undergo radioactive decay. Thus, the alpha particles from absorbed radioactive material can result in damage to your tissues (ATSDR 1999).

Beta radiation, also known as beta particles, consists of electrons that are emitted by certain radioactive materials during nuclear transformation. These particles are much lighter and more penetrating than alpha particles, and the majority of them have enough energy to move through the skin to enter the underlying, living tissue. You can also be exposed to beta radiation by taking a beta-emitting radionuclide into your body. Once a negative beta particle loses its energy, it will have no more effect on your body (ATSDR 1999).

Gamma radiation, also known as gamma rays, is a highly energetic form of radiation, similar to X-rays, that travels at the speed of light. When a radioactive atom is transformed by emitting alpha or beta particles, it may also emit one or more gamma rays in order to discharge any surplus energy. These gamma rays are bundles of energy (photons) that do not have any charge or mass. As a result, gamma rays can easily travel through air, body tissue, and other materials. These rays can travel a great deal farther than alpha or beta particles, and they do not have to be inside your body or even close to your skin. When a gamma ray travels through your body, it may hit nothing or it may hit an atom. If it hits an atom, the gamma ray could give the atom all or part of its energy, which usually knocks an electron out of the atom. As a gamma ray is pure energy, it no longer exists if it loses its energy (ATSDR 1999).

How Can Ionizing Radiation Enter and Leave My Body?

You can be exposed to ionizing radiation in two ways: external radiation and internal radiation. External radiation comes from natural and manmade sources of ionizing radiation outside of your body, such as coal burning power plants, X-ray machines, industrial equipment, and natural sources of radiation. Gamma rays are the main source of external radiation. Exposure to external radiation will not make you radioactive. In the United States, the average annual dose of external radiation is approximately 100 millirem (mrem) per person (1 millisieverts per person, mSv/person) (ATSDR 1999). Internal radiation comes from natural and manmade sources of ionizing radiation that are inside of your body. Because radioactive materials occur naturally in air, food, and water, you take these substances (e.g., radium, radon) into your body everyday. Internal radiation can emit alpha particles, beta particles, or gamma rays, depending on the radionuclide's isotope. The internal dose is based on the measure of energy that is deposited by all of the ionizing radiation generated inside your body. In the United States, the average annual dose of internal radiation is approximately 260 mrem per person (2.6 mSv/person) (ATSDR 1999).

What is I-131?

I-131 was purified for medical and research purposes following the processing of irradiated reactor fuel at ORNL. This material was also discharged to the environment from ORNL during radioactive lanthanum (RaLa) separation processes. Because I-131 has a relatively short half-life (8 days), the amounts of radioiodine in wastes and effluents decrease rapidly after they are discharged (TDOH 1999).

Out of the current and former National Priorities List sites, I-131 has been detected in at least six of these sites—mostly U.S. Department of Energy (DOE) weapons-related sites. Radioactive iodine occurs naturally in the environment. Because it is a fission product of uranium, it can also enter the atmosphere as a result of nuclear power plants and nuclear bomb explosions (ATSDR 2001b). As I-131 has only an 8-day half-life, it is usually not a main concern at DOE sites (INEEL 2001). People are rarely exposed to radioactive iodine unless they work in an area where it is used or if they received medical doses of radioactive iodine. In the past, people have been exposed to I-131 as a result of nuclear bomb tests, nuclear fuel processing plants, or from accidental explosions and fires at nuclear power plants (ATSDR 2001b). Exposures to the public have also occurred as a result of planned releases from DOE sites, most notably Hanford and Oak Ridge Reservation as discussed in this public health assessment.

Once iodine has entered your body, it is quickly taken up by the thyroid gland (ATSDR 2001b). Given that this substance is preferentially stored in the thyroid, the main health concern for I-131 exposures is thyroid tumors. In the past, the primary pathway for radioactive iodine exposure has been through the consumption of milk from cows that grazed on contaminated vegetation. Additional pathways include consumption of fruits and vegetables and inhalation of contaminated air (INEEL 2001). Because infants and children consume large amounts of milk, they are the most susceptible populations to harmful I-131 exposures (ATSDR 2001b).

People are almost never exposed to I-131. The exceptions are those who work where radioactive iodine is used or who were given radioactive iodine by their doctors. Because the body quickly eliminates radioactive iodine, any medical tests to measure I-131 levels need to be performed quickly following exposure. The U.S. Environmental Protection Agency has established limits for specific forms of radioactive iodine; these limits reduce the releases of radioactive iodine into the environment and require industries to report their releases. The National Institute for Occupational Safety and Health (NIOSH) has established recommendations that limit worker exposure. In addition, the U.S. Nuclear Regulatory Commission, the National Council on Radiation Protection and Measurements, and the International Commission on Radiological

Protection have set recommended limits for worker exposure and releases of radioactive iodine to the environment (ATSDR 2001b).

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[ATSDR] Agency for Toxic Substances and Disease Registry. 2001b. Toxicological profile for iodine. Atlanta: US Department of Health and Human Services. 2001 September; accessed October 2005. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp158.html.

ChemRisk. 1993. Oak Ridge health studies Phase I report. Volume II- Part B-Dose Reconstruction Feasibility Study. Tasks 3 & 4. Identification of important environmental pathways for materials released from the Oak Ridge Reservations. 1993 September.

[INEEL] Idaho National Engineering and Environmental Laboratory, Environmental Surveillance, Education and Research (ESER) Program. 2001. Human health fact sheet—iodine. 2001 October. Available at: http://www.stoller-eser.com/FactSheet/Iodine.pdf.

[TDOH] Tennessee Department of Health. 1999. Iodine-131 releases from radioactive lanthanum processing at the X-10 site in Oak Ridge, Tennessee (1944–1956) — an assessment of quantities released, off-site radiation doses, and potential excess risks of thyroid cancer. Oak Ridge Dose Reconstruction, Task 1 Report.

Appendix D. Responses to peer reviewer comments on iodine 131 releases public health assessment

The Agency for Toxic Substances and Disease Registry (ATSDR) received the following comments from independent peer reviewers for the Iodine 131 Releases from the Oak Ridge Reservation (ORR) Public Health Assessment (March 2006). For comments that questioned the validity of statements made in the public health assessment, ATSDR verified or corrected the statements.

	Peer Reviewer Comment	***ATSDR's Response***
Does the public health assessment adequately describe the nature and extent of contamination?		
1	Yes, within the limits of the available data and uncertainties in the modeling of the dispersion to the environment (e.g., page 72, lines 15–17).	Thank you for your comment.
2	I concur that the data from the deer thyroid is suggestive, but far from conclusive, that significant off-site I-131 contamination did not extend far beyond the ORNL site boundaries (page 2, line 4; page 26; and page 72, line 30).	Thank you for your comment.
3	I found the assessment to adequately address the nature and extent of the contamination. The assessment points out that there were other possible hazardous and radioactive contaminants that are not treated in the report.	Thank you for your comment.
4	There is no mention of the higher radioiodines (i.e. I-132 through I-135) which are produced by fission and which persist for several days afterward. The implication that short-lived radioiodines may have contributed to dose is contained in the final paragraph on page 9. However, it is likely that processing of Oak Ridge produced slugs was not carried out until these short lived higher radioiodines had decayed away, if for no other reason than completeness and perhaps by only a few brief words, this issue should be addressed in the text.	Additional text was added to indicate that other forms of radioactive iodine were produced besides I-131 and I-129. The other radioisotopes produced generally had a half-life of less than 24 hours and would not have any significant effect on public health.
Does the public health assessment adequately describe the existence of potential pathways of human exposure?		
5	Yes. Very thorough and complete discussion of potential pathways (and conclusion on the highest important pathways: goat's and backyard cow's milk, page 24).	Thank you for your comment.

	Peer Reviewer Comment	*ATSDR's Response*
6	The pathways for human exposure are addressed in a straightforward and understandable manner. The authors of the report do a particularly effective job in delineating between "potential exposure" and "exposure" as well as between "exposure" and "harmful health effects." The air exposure pathway is very well explained. The authors point out that there are ways to improve the pathway computations such as measuring the I-129 as a function of depth in soil samples. Given the available data, the work is state-of-the-art in its approach to filling data gaps, parsing data and applying the data.	Thank you for your comment.
7	Generally, yes. However, description of the air inhalation and immersion pathways should be expanded and clarified. Also greater emphasis might be given to the delay period between time of release and ingestion, which allows for decay of the significant radioiodines.	Thank you for your comment. Additional text has been added to clarify these pathways.
Are all relevant environmental and toxicological data (i.e., hazard identification, exposure assessment) being appropriately used?		
8	Yes. Latest and best sources of data were used. Hopefully, the extent of hazard will be further refined by the additional soil sampling recommended in the ATSDR report (page 75, line 5).	Thank you for your comment.
9	The relevant data presented are used appropriately. The necessary terms are defined well and in language that most members of the general public could understand both conceptually and in their importance to public health.	Thank you for your comment.
10	There is no mention of the higher radioiodines (i.e. I-132 through I-135) which are produced by fission and which persist for several days afterward.	The comment is noted. The text was changed in the public health assessment. Please see the response in Comment 4.
Does the public health assessment accurately and clearly communicate the health threat posed by the site?		
11	Yes. Overall, the report is well written, clear, and explicit.	Thank you for your comment.

	Peer Reviewer Comment	***ATSDR's Response***
12	The public health assessment only considers the dose and possible effects of radioiodine intake on the thyroid. Other tissues also receive an exposure from an intake of radioiodines, and although this dose is very small by comparison to the thyroid dose, once again, if only for completeness, it along with its potential public health consequences (or lack thereof) should be mentioned.	Thank you for your comment. Additional text has been added to clarify the public health assessment.
13	Generally yes, insofar as available data permit. However, there are a number of points that need clarification and even some errors that need to be corrected have been identified in the handwritten comments in the margins of the draft [included within the comments in this appendix]. One area that needs clarification relates to the biokinetics of iodine in the body; for example, the discussion on page 74 incorrectly states that I-129 and I-131 are removed from the body and thyroid in 12 and 120 days, respectively. A simplified description, perhaps illustrated with a sketch, would help to illuminate this complex aspect.	Thank you for your comment. Additional text has been added where appropriate. Text changes were made on pages where the commenter had technical questions. For example, the term centigray (cGy) was replace with rads. The biological half-life of iodines were changed to 66 days on page 3. Additional text to clarify reactor production of radioiodines was added on page 6 and clarification of Figure 6 symbols was added. ATSDR also added discussions of I-129 atom ratios on page 35. In a similar manner other changes to the text were made in accordance with the reviewers hand-written notes.
14	The PHA is effectively communicated. Often the authors of the report use too many qualifiers. For example on page 2, lines 30–33 the following statement occurs: "found enough evidence to conclude … were probably not exposed." It seems that you found enough evidence to conclude that they were not exposed. Several statements throughout the document have this wishy-washy flavor.	Thank you for your comment. The document was sent through editorial services prior to distribution.
Are the conclusions and recommendations appropriate in view of the site's condition as described in the public health assessment?		
15	Yes. All conclusions presented are supported and appropriate based on the analysis in the ATSDR report. The category "no public health hazard" is appropriate based on the ATSDR analysis.	Thank you for your comment.
16	Generally, yes.	Thank you for your comment.
17	By and large, I agree with the conclusions and recommendations in the report.	Thank you for your comment.

	Peer Reviewer Comment	ATSDR's Response
Are there any other comments about the public health assessment that you would like to make?		
18	The reviewer notes that the lack of environmental monitoring data as well as dietary data coupled with the short half-life of the primary nuclide of concern and other factors made this public health assessment challenging. In general, the preparers of the assessment have responded well to this challenge. They have produced a reasonable initial draft, which, with revisions along the lines [indicated within this appendix] and a tightening up of terminology should well serve the public interest.	Thank you for your comment.
19	Internet URL addresses are given for a number of references cited in the report. If such references are not in fact available in documented hard copy format, they should be so identified as internet postings do not rise to the level of documented works and are ephemeral and potentially subject to undeclared and undocumented revision and change.	Thank you for your comment. Those internet links are from federal sources, the documents are also available as printed copies.
20	A number of questions and comments have been made in the margins of the draft report [comments included within this appendix]. The report is marked by inconsistent and sometimes confusing usage of quantities and units. For example, absorbed doses are expressed in both units of rad and cGy, even in at least one instance on the same page (see page 47). One way of resolving this is to convert all units to a preferred unit and use this exclusively, or use this preferred unit followed by the other unit in parentheses.	Comments supplied as handwritten text on a copy of the reviewer's document have been addressed by direct incorporation into the public health assessment. All of the comments have also been included within this appendix.
21	I find it very unfortunate that in the 21st century an ATSDR report would still persist in using non-SI units as the primary measures. I realize fully that these units (non-SI) were used in the period of interest, but a report for the 21st century (and beyond) should use SI units at least as the primary units. See examples: page 5, Table 1; page 9, line 6; page 16, line 11; page 17, Table 2; page 18, Table 3; page 19, line 7; page 27, line 1; page 28, Figure 8; Page 29, Figure 9; Page 30, Table 5; page 31, Figure 10; Page 32, Figure 11; Page 33, Table 6; Page 34, Figure 12; and page A-3, line 5.	Thank you for your comment. With regards to the comment that ATSDR should be using the more standard International System of Units (SI units) for the radiation parameters, we agree. The Division of Health Assessment and Consultation health physicists present both units either as a footnote or directly following in parentheses in other documents. For the Oak Ridge documents, in earlier drafts presented to the public during subcommittee meetings and to working groups, the SI units were used. However, the community requested that ATSDR use the more familiar units as given in the present document.

	Peer Reviewer Comment	***ATSDR's Response***
22	I will add a few comments about my review of PHAs, particularly ones that are retrospective. Most of them include time periods in the not-too-distant past during for which there are either missing release data or monitoring data that do not give isotope-specific data (such as gross beta monitoring data opposed to data for a specific isotope). So the assessor must fill in the missing data and/or parse radionuclide data from gross radiation measurements. To this end, all the assessor can do is use scientific judgment based on whatever available data he has available --- usually the assessor chooses the conservative approach when selecting between uncertain datasets. To that end, I looked at the report to ensure reasonableness and conservatism but not gross overestimations in the analysis present.	Thank you for your comment.
23	I assume that the two reports cited but not referenced in the reference section (Alvarez and Pritchard) will be released before this document?	Thank you for your comment. We have spoken to the authors and they are still pursuing this.

Appendix E. Responses to public comments on iodine 131 releases public health assessment

ATSDR received the following comments from the public during the public comment period (September 13, 2006 to November 13, 2006) for the Public Health Assessment: *Iodine-131 Releases, Oak Ridge Reservation (USDOE),* September 2006. For comments that questioned the validity of statements made in the document, ATSDR verified or corrected the statements.

	Public Comment	*ATSDR's Response*
1	I believe the geographic area subject to RaLa radioiodine was well described by the Tennessee Department of Health (TDOH)] study, even though the detailed wind data had to be taken for the wrong year. I recall that the methods were tested on radioiodine data from a later year for which most factors were controlled or monitored. I do not know whether the continuous air monitoring (CAM) data used by ATSDR was seen by ChemRisk. Since those monitors would have had very low efficiency for I-131, I think one should assume that these counts had little relevance. Particles containing other radionuclides would have exhibited diverse fallout patterns. (It is true that weapons test fallout of I-131 was widely estimated from particulate fallout of other isotopes; the problems that concern me here were not equally present for weapons tests.) Perhaps unmentioned details establish relevance of the CAM data.	The data reviewed by ATSDR were discovered after the completion of the state study. The data were found by another consulting company that was looking for thyroid studies on deer harvested in the Oak Ridge area and on the reservation. Once ATSDR heard of the data, the agency met with SENES of Oak Ridge to inform them of the data's discovery. ATSDR understands that the information the data represents is limited in scope; however, the consulting company and ATSDR applied an analytical approach to the data similar to that applied in the studies evaluating the iodine releases from the Nevada Test Site (NTS) and further refined by the National Cancer Institute (NCI) for its study of the iodine doses throughout the United States. The NTS studies performed by Harry Hicks and others at the Lawrence Livermore National Laboratory looked at the gamma signatures on the gummed filters. The methods were published in Health Physics, 42(5):585-600, May 1982.
2	I recall that the use of I-129 data was discussed once in an Oak Ridge Health Agreement Steering Panel (ORHASP) meeting by the panel members most expert in dose reconstruction. The argument was that most of the I-129 found would be from weapons fallout and the processing of fuel in different locations in projects that did not process briefly cooled fuel. Meeting minutes exist, but I think no written analysis was circulated. If the mix of iodine chemical forms differed from that for RaLa, dispersion would not have been the same. While the suggested I-129 studies might have some value, the writer does not recommend them now.	We agree that the combination of radioiodines produced in a weapon detonation may be different from the yield produced within a reactor and ultimately processed through RaLa. That said, however, new studies associated with the Chernobyl accident, together with improvements in mass spectroscopy capabilities and the correlation of environmental Cesium-134 levels, may be sufficient to address the question. ATSDR, believes, therefore, that the recommendation is valid, and several of the peer-reviewers concurred.

	Public Comment	*ATSDR's Response*
3	I think Table 1 and the associated text refer to quantities of I-131. The use of "radioiodine" here is confusing because of the earlier comments on possible I-129 studies.	ATSDR received a similar comment from a peer reviewer. The text has been changed to indicate the specific radionuclide.
4	The present commenter is aware of a discussion on the use of dose "comparison values" using epidemiological studies to judge whether a dose is large enough to trigger a public health action. Certainly such comparison values are inadequate to determine whether cancers were induced. (I expect such comparisons are nearly essential in studies of toxic materials for which the toxic process is not at all understood.) While an ATSDR decision not to propose a public health action does not signal the level of public safety some might expect, the conceptual difficulty with use of comparison values may not have significant consequences for the instant PHA.	ATSDR recognizes that a dose-related comparison value (CV) that relies solely on a single epidemiological study will not carry the same weight. It will also carry greater uncertainty than will CVs that are supported by multiple epidemiological studies, animal toxicity studies, or both. Yet CVs typically include a safety factor that adds an extra level of reassurance depending on how much uncertainty is associated with the underlying studies on which the CV is based. As explained in the PHA, the CVs that ATSDR uses in this PHA represent radiation doses lower than levels at which no effects were observed in studies on experimental animals or in human epidemiological studies. ATSDR's review of the peer-reviewed scientific journals provides adequate and consistent findings about the health risks associated with iodine-131 and the susceptible populations most likely to develop adverse health effects. Specifically, the data strongly suggest that the most sensitive populations to radioactive iodine intake are those persons who were younger than 18 years of age at the time of exposure. The literature also suggests that females are more likely than males to be affected by radiation exposure. Given the uncertainty associated with the modeled iodine-131 data used in the dose reconstruction, little more can be inferred about the specific health effects on a person at a given geographic location near the Oak Ridge Reservation (ORR). This would be true regardless of the uncertainties associated with applicable CVs.

	Public Comment	*ATSDR's Response*
5	The use of the word "conservative" in line 39 of page 15 is inappropriate. The words "In estimating the pattern of resulting dose to the public, …" would be preferred. In its dose reconstruction studies, the TDOH authors captured available information to develop density functions that represented the likelihood that a parameter fell in a specific range. This approach handled the uncertainties as well as possible. The use of "Monte Carlo" estimation allowed all this information to be properly combined. "Conservative" values were used in some screening studies, but not intentionally in Task 1. Some consider these density functions hard to understand, but when an average citizen is stopped for speeding, he might say that he was driving with speeds in the range of 40 to 50 mph, more likely below 45 mph. The law officer would understand. The same problem with use of the word "conservative" occurs in line 5 of page 19.	ATSDR has removed "conservative" from the sentence and modified the text to read as follows: "In estimating potential dose, ..."
6	On page 21, line 23 - Gallaher Bend refers to a big bend in the Clinch River. I think there was no town there. I think one could write "living near Gallaher Bend, an area about 3 ½ …"	Thank you for your comment. We will review the text and make the appropriate changes.

	Public Comment	*ATSDR's Response*
7	As suggested above, this reviewer discounts the usefulness of the Constant Air Monitor (CAM) data studied by ATSDR. Based on a long-ago reading of the HP manual concerning CAM use, the efficiency for detection of a radioactive gas would be small, since the instrument drew ambient air through a filter to trap and count radioactive particulates. Fallout of any other isotope would disperse in a manner different from I-131. Quantitative estimates based on CAM data would require extensive study of release patterns for each case, studies not even suggested in the text. In particular, the italics statement in lines 28-29 of page 26 is not supportable. Until such objections are resolved, it is too soon to report that the ChemRisk-SENES study of the I-131 releases missed important input data. The large uncertainties displayed in the ChemRisk results reflects the lack of appropriate monitoring data.	As you stated, the efficiency of the air filters for gaseous releases was very small, if not in fact zero. Paper filters are designed to trap particulates, and those particulates smaller than a micron are not efficiently captured. Recent studies suggest , however, that gaseous iodides may be converted to other nongaseous forms possibly more closely related to particulates. Please see *The Handbook of Environmental Chemistry - Reactive Halogen Compounds in the Atmosphere* published in 1999. ATSDR recognizes the large uncertainties in the monitoring data. the agency treated the data with these uncertainties in mind,. The data collected—beta and gamma counts of identified radioisotopes—were believed to be composed entirely of iodine compounds. This data collection approach would exceed the upper 95th percentile confidence range and be extremely conservative. A similar approach was used by NCI in its study of fallout from the NTS. The NCI discussed this approach on page 2.23 of *Estimating Exposures and Thyroid Doses Received by the American People from Iodine-131 in Fallout Following Nevada Atmospheric Nuclear Bomb Tests*. With these stipulations and realizing the most distant stations would report activities from other atmospheric sources, including iodines from NTS, the close-in stations still did not suggest the iodines released during RaLa diffused a great distance from their source. This coupled with the iodide measurements in the thyroid glands from deer collected within the DOE ORR suggested to ATSDR that the ChemRisk-SENES model may have overestimated the affected area—thus the recommendation for the iodine-129 coupled with cesium-134 sampling of the area.

	Public Comment	*ATSDR's Response*
8	It is hard to reference reports with corporate authorship. The TDOH authorship is troublesome because the Department served mostly as sponsor. What about the following as a substitute? [TDOH] ChemRisk, 1999, for the Tennessee Department of Health, Project Manager F. Owen Hoffman. Iodine-131 Release from… This is not perfect, but it discloses that authorship is with ChemRisk and its partners, and indicates the sponsorship (though funds came from DOE).	The agency editor said that according to the 5th edition of the American Psychological Association Publication Manual (2001), the government agency is listed as the author and the contractor who prepared the document is listed as the publisher. Therefore, the following is the correct method for referencing the report: [TDOH] Tennessee Department of Health. 1999. Iodine I-131 releases from radioactive lanthanum processing at the X-10 site in Oak Ridge, Tennessee (1944-1956)-an assessment of quantities released, off-site radiation doses, and potential excess risks of thyroid cancer (Reports of the Oak Ridge Dose Reconstruction, Vol. 1; July). Alameda, CA: ChemRisk. Available from: http://health.state.tn.us/CEDS/OakRidge/Iodine1.pdf.
9	The monitoring data included in the ATSDR report is insufficient to evaluate releases of elemental I-131 vapor. Iodine-131 released as a vapor of elemental iodine determines the magnitude of off-site dose estimates to individuals and populations who resided at various locations downwind of the X-10 facility.	One of the major issues addressed and not satisfactorily solved by ORHASP was the issue of iodine releases (chemical form and amounts) from the scrubber systems at X-10. From a general understanding of iodine chemistry, even the iodine vapor would become a solid at temperatures less than 77° F and, according to NCI, attach to atmospheric particulates.* The radiological dose from inhalation of either organic iodine or elemental iodines is relatively similar; the doses from particulate are about a tenth of the vapor dose. ATSDR's use of the monitoring data was not to determine the estimated thyroid dose but to estimate the potential area affected as compared to affected areas as estimated by the air dispersion model used in the Task I report. Coupled with the data obtained from deer thyroids, however, this data suggests that the dose reconstruction effort by the state may have overestimated dose distribution. *National Cancer Institute (1997). Estimating exposures and thyroid doses received by the American people from Iodine-131 in fallout following Nevada atmospheric nuclear bomb tests.

	Public Comment	*ATSDR's Response*
10	The historic air sampling data is used with numerous uncertain assumptions to estimate the amount of I-131 attached to aerosol particles in the atmosphere. However, for the members of the public living around Oak Ridge, thyroid doses received from exposure to I-131 in aerosol (particulate) form were minor compared to doses received due to exposure to I-131 as elemental iodine vapor.	See previous comment.
11	Air monitoring data from Rogers Quarry (or Rock Quarry; HP 8; located at about 3.4 miles northeast of X-10) are inconsistent with data obtained just a few kilometers away (see Figure 10 of the draft ATSDR PHA). For instance, it should be highly unlikely for the concentration in air at the Rogers Quarry to be significantly lower than the concentration in air at Kerr Hollow Gate, which is located about one mile further downwind with respect to X-10. Yet, the air monitoring data reported in the ATSDR draft PHA indicates a major discrepancy in reported activity concentrations for these two and other locations. The discrepancy between measurements at Rogers Quarry and measurements at other locations around X-10 disappears in Table 6 of the ATSDR report. In that table, the measured concentration in air at Rogers Quarry is listed as one of the largest in the area. No explanations are provided in ATSDR's report. No indication is provided with which to evaluate the uncertainty in the reported concentration. Our own calculations do not support the conclusion that I-131 releases and subsequent doses have been substantially overestimated (even for I-131 in the particulate form). The air concentrations we calculated for the Oak Ridge Dose Reconstruction (ORDR) Task 1 report for I-131 in air as particulates are substantially lower than what is reported in the draft ATSDR PHA for specific locations and time periods for which air monitoring data are reported. However, without access to unpublished technical details we are unable to comment further on the merit of the ATSDR analysis of historic air monitoring data.	Changes in atmospheric conditions are an issue in air monitoring. The air flow patterns in Bethel Valley as compared with the Kerr Hollow Gate could be significantly different. The quarry is in somewhat of a confined area whereas the gate area opens up to wider spaces. A wider plain could decrease the air flow, allowing more contamination to settle out. Without the meteorological data associated with those sampling points, speculation is perhaps the best evaluation available. Nonetheless, ATSDR believes the use of a simplified approach, sometimes considered a conservative approach, could achieve the agency 's aims. A comparison of the Rogers Quarry data reported in Table 5 with the value reported in Table 6 indicates the values are the same. Furthermore, as can be seen when comparing Table 5 data to Table 6 data, the measurement differences do not disappear. The overall average long-term gross beta-gamma counts for locations considered on site are about 5 times higher than those locations considered off site. We believe the calculations you mentioned were used to develop the ChemRisk-SENES report. The recently identified air data reported in the PHA were initially discovered by an independent contractor and provided to ATSDR. Upon discovering the air data, ATSDR did meet with representatives of SENES in their Oak Ridge office to inform them of the data's discovery. All data used by ATSDR are considered public information.

	Public Comment	*ATSDR's Response*
12	The nature of the uncertainty associated with all assumptions regarding the analysis of air monitoring data should be taken into account before reaching definitive conclusions about estimates made in the ORDR Task 1 report of 1999. As far as we can surmise, an evaluation of uncertainty has not been carried out in the unpublished analysis performed by ATSDR and their consultants.	You are correct in your assumption that an uncertainty analysis was not performed. Evaluation of the radioactivity on a filter will have an uncertainty associated with, for example, the typical background, the counting time, and the count rate. If ATSDR were using the continuous air monitors for an estimation of the dose, then an in-depth quantitative uncertainty analysis and probability analysis would be required. ATSDR ,however, only used the data as a potential indicator of the extent of contamination.
13	ATSDR concludes that doses below 10 rads to the thyroid should not be associated with an apparent health hazard because an increased risk of thyroid cancer cannot be determined at this dose level. The risk of thyroid cancer extends well below 10 rads. The limits of epidemiological detection are also below this level. However, the limits of epidemiological detection should never be considered a surrogate for a limit of public health concern (or a conclusion of "no apparent health hazard").	The evaluation of radiation exposure using the linear-nonthreshold (LNT) approach suggests the resulting dose and that risks exist at all levels of exposure. A substantial amount of literature shows, however, that LNT is not applicable in all applications. For example, the National Academy of Sciences accepts a linear-quadratic approach for the induction of leukemia. In the case of thyroid cancer induction by radiation, ATSDR believes sufficient peer-reviewed scientific literature shows the absence of any correlation between thyroid cancer and radiation exposure below 10 rads.

	Public Comment	*ATSDR's Response*
14	In setting a dose criterion as opposed to a risk criterion to determine levels of past exposure warranting further investigation or a public health response, public exposures to concurrent sources of radiation should be taken into account. If uncertainties in releases and subsequent doses from X-10 RaLa operations were to be combined with exposures from other X-10 sources and from exposures to local fallout originating from distant testing of nuclear weapons in Nevada and in the Pacific, individual thyroid doses locally could have potentially exceeded 10 rad to the thyroid. This is especially true for individuals born between 1944 and 1952 who may have been on a diet of fresh backyard cow milk and fresh goat milk and who were exposed as infants. [See Appendix C of the ORDR Task 1 report or the SENES Oak Ridge, Inc. dose and risk calculator for public exposures to I-131 released from X-10 and to I-131 in NTS weapons fallout: <http://198.144.166.5/irad>]	Doses used in ATSDR public health documents as compared with the use of theoretical risk has been discussed in writing, in open public meetings, and through the peer-review process, both internally and externally. ATSDR recognizes the usefulness of the LNT hypothesis and its use in establishing regulatory limits. The risks received by persons who may have been exposed to releases both from Oak Ridge and the other nuclear tests may be real, but the expression of those risks has not been observed at a level where they can be conclusively related to the exposure. The observed adverse health effects versus the theoretical adverse health effects defines the difference between ATSDR public health documents and risk-based documents.

	Public Comment	*ATSDR's Response*
15	ATSDR should include a reference in its PHA for I-131 releases for the Oak Ridge Reservation that directs public attention to NCI's fallout dose and risk calculator at <http://ntsi131.nci.nih.gov/>. This has been referenced specifically on pages 1-9 in the draft ATSDR PHA for the Hanford Site released for public comment on October 16, 2006: "The largest releases of I-131 in the United States were from the Nevada Test Site. People living downwind of Hanford received radiation doses from both the Hanford Site and the Nevada Test Site. The National Cancer Institute (NCI) has developed a Web Site, <http://ntsi131.nci.nih.gov/>, to provide information on releases from the Nevada Test Site." Note that the NCI calculator provides explicit information about the uncertainty in the dose and risk from fallout for those residing in all 3,070 U.S. counties, including Anderson, Roane, Knox, and Loudon counties in Tennessee. The algorithms employed by this calculator are very similar to those employed in the ORDR Task 1 Report of 1999, the National Institutes of Health's Interactive Radioepidemiological Program (www.irep.nci.nih.gov, Land, et. al., 2003) and in the more recent BEIR VII report published in 2006 by the National Academy of Sciences. Reference: Land, C., Gilbert, E., Smith, J., Hoffman, F.O., Apostoaei, I.A., Thomas, G.A., Kocher, D.C. 2003. Report of the NCI-CDC Working Group to Revise the 1985 NIH Radioepidemiological Tables. Bethesda, MD: NIH/NCI.	The inclusion of the National Cancer Institute (NCI) Web site is not directly applicable to the iodine releases from Oak Ridge. The Nevada Test Site releases that form the basis of the NCI data are based on estimates of monitored gummed paper analyses of the fallout patterns. The doses estimated from Oak Ridge releases are not based on atmospheric dispersion models; rather, they are based mostly on estimated releases with a high degree of uncertainty from the scrubber processes. If one were to evaluate analytically the CAM data to which ATSDR refers to in the PHA, then, once the uncertainties are identified, the doses could be summed. Furthermore, the recommended sampling for I-129 would integrate the I-129 releases from all sources from ORR as well as the NTS.