CHAPTER 3

SELECTION OF KEY RADIONUCLIDES FOR SOURCE TERM STUDIES

ABSTRACT

This chapter describes the screening process we used to determine the key radionuclides released from the Savannah River Site (SRS) that are most important to public health. The screening process is an objective and efficient way to identify the radionuclides that are potentially important contributors to offsite radiation dose to local residents and for which detailed source term or release estimates will be done. We used the National Council on Radiation Protection and Measurements (NCRP) screening methods that have been used extensively in similar projects. The NCRP screening techniques are based on documented and well-known radiological assessment principles that combine environmental transport mechanisms, exposure pathways, and dosimetry components into a few calculational steps that require a minimum of site-specific data for the initial screening approach. This method does not eliminate any radionuclide from further consideration; rather, it helps focus resources first on those radionuclides that are most important for public health. The result of the screening process is reported as a screening value for each radionuclide. We summed the screening values and calculated the relative contribution of each radionuclide to the total screening value for all pathways of exposure. We established our screening criterion at a level of 0.1% of the total screening value. The screening method involved two steps. In the first step of screening, the results showed that the important contributors to the total screening value are somewhat different for the air and water pathways. For the air pathways, the radionuclides from the SRS contributing greater than 0.1% to the screening value for all potential pathways of exposure are ^{241}Am, ^{41}Ar, ^{14}C, ^{137}Cs, ^{3}H, ^{129}I, ^{131}I, ^{238}Pu, ^{239,240}Pu, ^{103,106}Ru, ^{89,90}Sr and uranium. For releases to surface water, the radionuclides that contributed 0.1% or more to the total screening value are ^{137}Cs, ^{60}Co, ^{3}H, ^{129}I, ^{131}I, ^{32}P, ^{238}Pu, ^{239,240}Pu, ^{89,90}Sr, ^{35}S, ^{99}Tc, uranium, ^{91}Y, ^{65}Zn, and ^{95}Zr,Nb. In the second step of screening, we further ranked the radionuclides identified in the first step by determining the relative importance of these radionuclides by exposure pathway. The percent contribution of each radionuclide to the total screening value exposure pathway for each exposure pathway was the basis for ranking the radionuclides. The radionuclides that ranked among the top three for at least two of the seven exposure pathways were selected for detailed source term development. Based on this second screening step, detailed source term estimates were developed for ^{131}I, ^{3}H, ^{41}Ar, ^{129}I, and ^{239,240}Pu released to air. For surface water pathways, detailed source terms for ^{137}Cs, ^{3}H, ^{90}Sr, ^{60}Co, ^{32}P, and ^{131}I were developed. Release estimates for uranium were also determined.

INTRODUCTION

Dose reconstruction is a staged process involving important steps where very detailed work must be done. Some initial, critical steps must be taken early in a dose reconstruction study if scientific and public credibility is to be achieved. One of these critical steps is the use of screening methods to focus later work on the important contaminants released from the facility to the environment. Screening is a method for ranking the radionuclides and chemicals released to the environment in terms of their importance to human health. Because there are numerous materials potentially released from a facility like the SRS to the environment, screening calculations provide an objective basis for making decisions about priorities. It is important to carry out a screening process before beginning in-depth dose reconstruction because it is essential to allocate resources for and focus efforts on those that were most important to public health. For radionuclides, for example, there are differences in amounts released to air and water, half-life, behavior in the environment and biological uptake. It is impossible, under common operating constraints, to give equal attention to each radionuclide in the early stages of dose reconstruction.

The screening process helps to focus our research efforts and provides a relative ranking of the radionuclides released to air and water in terms of their importance to human health. We used the National Council on Radiation Protection and Measurements (NCRP) screening methods that have been revised and updated over the years and used extensively in similar projects. The NCRP screening techniques are based on documented and well-known radiological assessment principles that combine environmental transport mechanisms, exposure pathways, and dosimetry components into a few calculation steps that require a minimum of site-specific data for the initial screening approach. The first step in applying the screening methods to atmospheric or surface water releases from the SRS was assessing the releases of particular radionuclides during their operational history.

The output from this screening is a list of the radionuclides and their relative contribution to the screening values[1] from all pathways (or for individual pathways) of exposure to a nearby individual. We compiled the release estimates and results of the NCRP screening methodology in Excel spreadsheets. The result of the calculational steps is reported as a screening value, and provides a basis for comparing and ranking the radionuclides by their contribution to the total screening value. While the screening value is reported in units of dose (millirem or sievert), this value does not represent a "true dose" because the many conservative assumptions used in the screening analysis tend to maximize the screening value. It is reasonable to assume that the true dose under more realistic situations would be lower than the screening value.

Only Site personnel monitored effluents at the points of release onsite at the SRS. Because the majority of historic monitoring and record keeping came from the Site, we must rely on available Site records for the input release estimates for our screening analysis because onsite effluent monitoring at the points of release has been performed only by Site personnel. In addition to Site monitoring and process records, however, we can also rely on the basic chemistry and nuclear physics of the reactor and reprocessing operations the SRS. The process engineering for the separations areas and the nuclear reactors are quite well understood. Therefore, it is possible to understand the types and relative quantities of materials that might be expected from a particular process or reactor

The purpose of screening is to identify and focus resources on radionuclides released to air and water that are the most important contributors to radiation dose to those living offsite.

[1] The screening value is reported in units of dose, but does not represent a "true dose" because of many conservative assumptions used in the screening analysis for both routine and episodic releases.

operation run. For this reason, we tried to locate, compile, and evaluate the historic production and reactor power operations because these data can provide the foundation for other types of analysis during this project. This chapter describes the methods we used to focus on the key radionuclides of concern. The selection of key chemicals of concern is presented in Chapter 16.

RADIONUCLIDE RELEASE SUMMARY

During the early stages of this project, we thoroughly evaluated the process history, unplanned releases, and effluent monitoring programs, reviewed numerous documents, and conducted interviews and workshops (Meyer et al. 1995). We compiled information on radionuclides using a variety of early monthly reports and memoranda (Du Pont 1954, Du Pont 1958, Du Pont 1965, Du Pont 1966, Du Pont 1973), as well as series of reports such as *Radioactive Releases at the Savannah River Site 1954–1989 (U)*, (Ashley and Zeigler 1982, Cummins et al. 1991), annual *Audit of SRP Radioactive Waste* reports (e.g., Ashley 1962), and environmental impact statements for the reactors, which list inventory of materials generated during reactor operation (DOE 1984, DOE 1990). Recently, SRS published a series of reports describing the use and releases of key radionuclides at SRS, including tritium (Murphy et al. 1991, Murphy and Carlton 1991), radioiodine (Kantelo et al. 1993), cesium (Carlton et al. 1992a), plutonium (Carlton et al. 1992b), technetium (Carlton et al. 1993), and uranium (Evans et al. 1992). The initial focus of the document review was on radionuclides documented in SRS environmental reports (e.g. Ashley 1966; Cummins et al. 1990), periodic radionuclide release reports (e.g., Ashley and Zeigler 1974; Cummins et al. 1991), and early Site survey and monitoring reports (Albenesius 1954, Horton and Mealing 1956) described special monitoring techniques or problems that existed. While radionuclides potentially released at SRS were generally created onsite in the production reactors and processing areas, most chemicals were initially shipped to the Site from various sources.

These reports helped (1) identify those radionuclides that were generated during processing, and potentially released from the Site, and (2) provide an historical perspective on process history and radionuclide effluent monitoring at SRS. Based upon this broad range of documents, we compiled a “master list” of ~ 100 radionuclides (Table 3A-1, Addendum 3A) which had been:

- Present in SRS reactor fuel assemblies,
- Estimated to have been released, either to air or water, from the SRS,
- Measured in high-level sludge, supernate or reconstituted waste, or
- Present in low-level radioactive waste.

Several report series provided summaries of effluent data collected over the history of operations at the Site for the radionuclides in our list (e.g., Ashley 1959–1967). The Site compiled data for radioactive releases to water and to air from both routine and special monitoring at effluent sampling locations (Stephens and Ross 1984). Each year a compilation of the release data gathered from 1954 through the current year was published for the Site (e.g., Ashley and Zeigler 1982; Cummins et al. 1991). Periodically, the radiochemical separation of selected samples was used to determine quantities of a specific radionuclide of interest. For the annual radioactive release reports, releases of the long-lived radionuclides ^{60}Co, ^{90}Sr, ^{106}Ru, ^{137}Cs, and ^{147}Pm were quantified in the early years using isotopic distributions (Cummins et al. 1991). Special studies reports or historic memoranda provided information on other specific radionuclides (Johnson 1957; Marter 1965; Smith 1965; Johnson 1968; Fowler and Simmons 1985). Understanding the way in which radionuclides were produced and released from specific processes provided information when direct effluent measurements were not made or were not available (Du Pont 1966, 1973, 1980; Fisk and Durant 1987). For example, during the 1960s and 1970s, the Site developed and used more advanced counting instrumentation that allowed for the routine detection of radionuclides at lower levels. In July 1974, the Health Physics Environmental Monitoring Group assumed responsibility for making "official release calculations for radioiodine and radioactive particulates" so that the Site would have independent release estimates made by a single group using the same techniques and equipment (McClearen 1975).

We compiled estimates for releases of radionuclides to air and water in Excel spreadsheets associated with the electronic version of this report. The spreadsheet identifies the references used in determining release estimates for the radionuclides. For release estimates for the surface water screening, we combined reported releases to streams and to seepage basins to ensure that no radionuclide of potential importance would be missed. In some cases, where releases were not reported, we assumed releases based on those reported for other years.

RADIONUCLIDE SCREENING

The relative importance of releases of radionuclides to the environment depends upon the quantities released, differences in the potential for nuclide concentration in the environment, and the relative toxicity of the radionuclides, as measured by their dose conversion factors. The method used to screen radioactive contaminants potentially released from the Site to the environment is one developed by the NCRP. It was initially developed for evaluating releases to the atmosphere (NCRP 1989) in terms of their relative importance as potential contributors to radiation dose. The methods were reviewed and revised over the years and, in 1996, the NCRP revised and expanded the methods to cover releases to surface water and to the ground (NCRP 1996). The NCRP screening methodology is a valuable tool because it provides a compilation of effective dose factors and screening factors for exposure pathways of more than 800 radionuclides and generic environmental transport parameters, including uptake, bioaccumulation, and environmental transfer factors. The information for each radionuclide is encapsulated in the total screening factor, which is the sum of committed effective doses received from inhalation; plume immersion; external irradiation from ground contamination; and ingestion of soil, vegetables, milk, or meat assumed to be locally produced during 1 year for a unit concentration of radioactivity in air. Screening factors for a radionuclide are also provided by pathway so the dominant exposure pathway for that radionuclide can be evaluated. The screening factors assume an average annual air concentration and a 30-year buildup time to account for accumulation in the environment. The resulting screening value applies to a period of 50 years following the release.

The results of the calculations are reported as screening values. Cautious or conservative calculations that overestimate the importance of radionuclides produce a ranking of radionuclides in terms of the screening value, a measure of the potential impact on local public health. While the radionuclides ranked low on the basis of the first screening calculation are not likely to be important in terms of public health, no radionuclides are completely eliminated. In a subsequent step, more realistic calculations focus on better estimates of releases and give a better measure of the priorities for the most highly ranked contaminants, based on the various exposure pathways.

The NCRP screening methodology is a valuable tool because it provides a compilation of effective dose factors and screening factors for exposure pathways for more than 800 radionuclides, along with generic environmental transport parameters, uptake and bioaccumulation factors, and environmental transfer factors. Human consumption rates and usage factors that are used in the screening methods are quite cautious or conservative and tend to overestimate the parameters used in the screening calculations. Table 3-1 provides examples of some individual usage factors in the screening and illustrates the use of conservative values. For example, the NCRP methods assume an individual consumes 20 kg y^{-1} of fish, a value that represents the 99th percentile of adult fish consumption in the U.S. Although this consumption rate is the 95th percentile for adults for freshwater fish, fishing represents an important potential exposure pathway for a portion of the SRS population. Another example of conservatism in the screening approach is milk consumption, assumed as 0.87 quarts per day, while the EPA reports that average milk consumption in the U.S. is about 0.26 quarts per day.

Table 3-1. Annual Individual Values Used in the NCRP Screening Models

Exposure pathway	Selected parameters	NCRP value
Inhalation pathway	Breathing rate	8000 m^3 y^{-1}
	Resuspension factor	2 x 10^{-8} m^{-1}
External exposure	To contaminated ground surface (Assume exposed most of the year)	8000 h y^{-1}
Ingestion pathway	Vegetable, fruits, grains (Assume root uptake and soil adhesion)	100 kg y^{-1}
	Water (Assume drinking water from area)	800 L y^{-1}, or 2.5 qt d^{-1}
	Fish (Consumption of fish flesh only)	20 kg y^{-1}
	Milk (Assume no milk is imported from other areas)	300 L y^{-1}, or 0.82 qt d^{-1}
	Soil	0.25 g d^{-1}

Screening SRS Releases: Step 1

The NCRP approach considers environmental transport mechanisms, exposure pathways, and radiation dosimetry in a few simple steps. In the first step, the concentration of the radionuclide in the environment is calculated by using environmental transport screening models with the release quantity from the facility. The environmental concentration is then multiplied by a *screening factor*(*SF*) for that particular radionuclide to obtain a *screening value (SV)* that can be compared with screening values for other radionuclides. The screening factors are based on effective dose factors. In our first screening step, we used the most cautious screening approach for both air and water pathways, which considered the combined effects of all significant potential pathways of exposure. The results of the preliminary screening done in the first step showed that the important contributors to the screening value are somewhat different for the air and water pathways. For the initial, most conservative approach to screening air releases, the atmospheric concentration, C_a, is calculated as follows:

$$C_a = fQ/V \tag{3-1}$$

where

C_a is the atmospheric concentration of the radionuclide (Bq m^{-3})
Q is the release rate from the facility (Bq s^{-1})
V is the volumetric flow rate of the exhaust vent (m^3 s^{-1})
f is the fraction of time the wind blows toward the receptor (dimensionless).

The release rate, Q, for each radionuclide is based on estimates of the amount released in a 1-year period from the facility. For the first step in the screening process, we calculated an average annual release for each radionuclide based on compilations of the release data that the Site published (e.g., Ashley and Zeigler 1982; Cummins et al. 1991). For, V , the volumetric flow rate of the exhaust vent, the default value (0.3 m^3 s^{-1}) was assumed as a conservative estimate in place of detailed knowledge of vent flow rates for all main stacks. For f, the most conservative screening approach assumes that the wind blows only 25% of the time toward the potentially exposed individual, a conservative estimate because as the frequency of wind increases, the air concentration decreases.

For the initial, most conservative approach to screening surface water releases, the radionuclide concentration, C_w, is:

$$C_w = W_O/ Q_O \tag{3-2}$$

where

C_w is the radionuclide concentration in the receiving surface water (Bq m^{-3})
Q_O is the flow rate of an effluent discharge at the point of release (m^3 s^{-1})
W_O is the radionuclide release rate at the point of release (Bq s^{-1}).

After the concentration of radionuclide, i, in air or water ($C_{a\ or\ w}$) is determined for each radionuclide, , I, then the screening value (SV_i) for each radionuclide is:

$$SV_i = C_{i(a\ or\ w)} \times SF_{i(a\ or\ w)} \tag{3-3}$$

where

SV_i is the screening value for the radionuclide, I (Sv or mrem)
$C_{i(a\ or\ w)}$ is the radionuclide concentration of radionuclide, i, in the air or water (Bq m^{-3})
$SF_{i(a\ or\ w)}$ is the screening factor for the radionuclide, i, in air or water (Sv per Bq m^{-3}).

The output from the first screening step was a list of the radionuclides and their relative contribution to the screening value considering all pathways of exposure for those living nearby. We summed the screening values and calculated the relative contribution of each radionuclide to the total screening value for that year for all pathways of exposure. We established our screening criterion at a level of 0.1% of the total screening value. This criterion means that radionuclides that contributed 0.1% or more to the total screening value were considered further in the second screening step. The input release estimates and results of the NCRP screening methodology have been compiled in the Rad-Screening workbook. In the electronic version, double-clicking on the following hyperlink provides access to this workbook: Rad-Screening.xls.

For the air pathways, the radionuclides that contribute 0.1% or higher to the total screening value are ^{241}Am, ^{41}Ar, ^{14}C, ^{137}Cs, ^{3}H, ^{129}I, ^{131}I, ^{238}Pu, ^{239,240}Pu, ^{103,106}Ru, ^{89,90}Sr and uranium. For surface water pathways, the radionuclides that contribute 0.1% of the total screening value are ^{137}Cs, ^{60}Co, ^{3}H, ^{129}I, ^{131}I, ^{32}P, ^{238}Pu, ^{239,240}Pu, ^{89}Sr, ^{90}Sr, ^{35}S, ^{99}Tc, uranium, ^{91}Y, ^{65}Zn, and ^{95}Zr,Nb. Figures 3-1 and 3-2 display the relative contribution to the screening value by each radionuclide for the air and water pathways. This first step in the NCRP screening for radionuclides released to air showed that ^{131}I and ^{3}H were the major contributors to the screening value (~50% and 35%, respectively) with ^{41}Ar contributing about 7%. Two other radionuclides released to air (^{129}I and ^{239,240}Pu) each contributed less than 5% each to the total screening value. The other radionuclides released to air that met our screening criteria of contributing at least 0.1% to the screening value (^{241}Am, ^{14}C, ^{137}Cs, ^{238}Pu, ^{103,106}Ru, ^{89,90}Sr and uranium) jointly contributed about 5% (Figure 3-1).

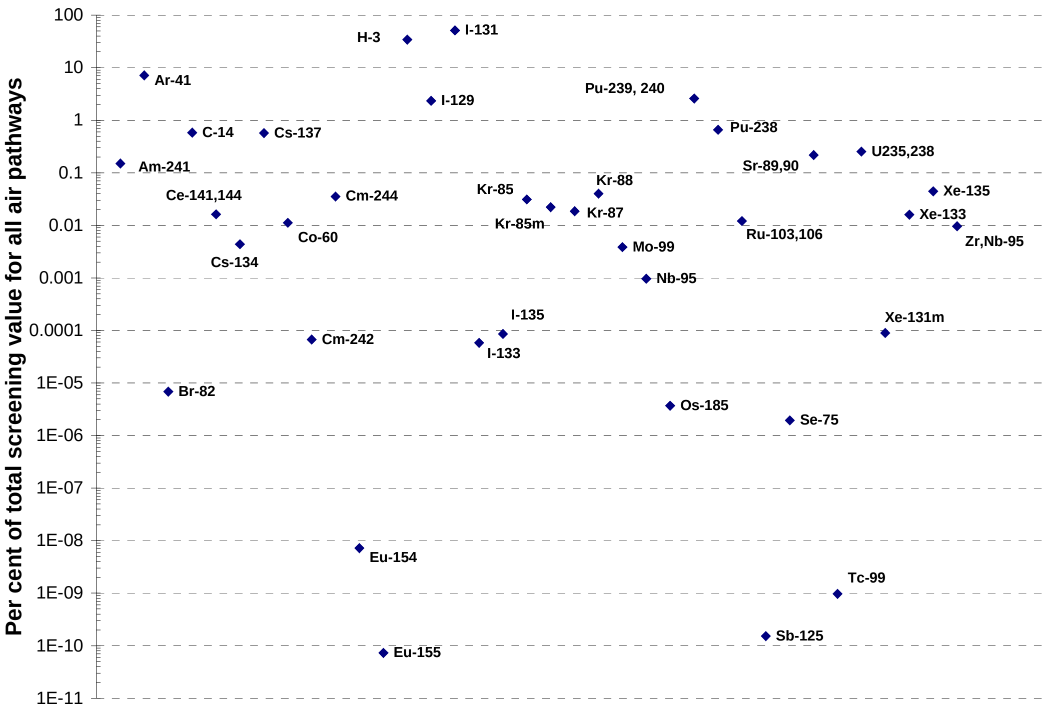

Figure 3-1. Relative importance of airborne radionuclides released from the SRS as potential contributors to the total screening value for all air pathways. For example, ^{131}I and tritium contribute about 50% and 30% of the total screening value, respectively, and ^{239,240}Pu contributes about 2% to the total screening value. The screening analysis used NCRP methods and helped to identify the radionuclides for detailed source term development.

The first step in the NCRP screening for radionuclides in surface water showed that ^{137}Cs would be a major contributor to offsite dose via the surface water pathways (~75% of the screening value), with ^{60}Co, tritium, ^{131}I, ^{32}P, and ^{90}Sr also important contributors (jointly contributing about 20% to the screening value) (Figure 3-2). Sulfur-35 and ^{65}Zn together contributed less than 4% to the screening value via the surface water pathway, and all other radionuclides meeting our screening criteria (^{129}I, $^{239,240}Pu$, ^{99}Tc, uranium, and ^{95}Zr,Nb) jointly contributed less than 2% to the screening value.

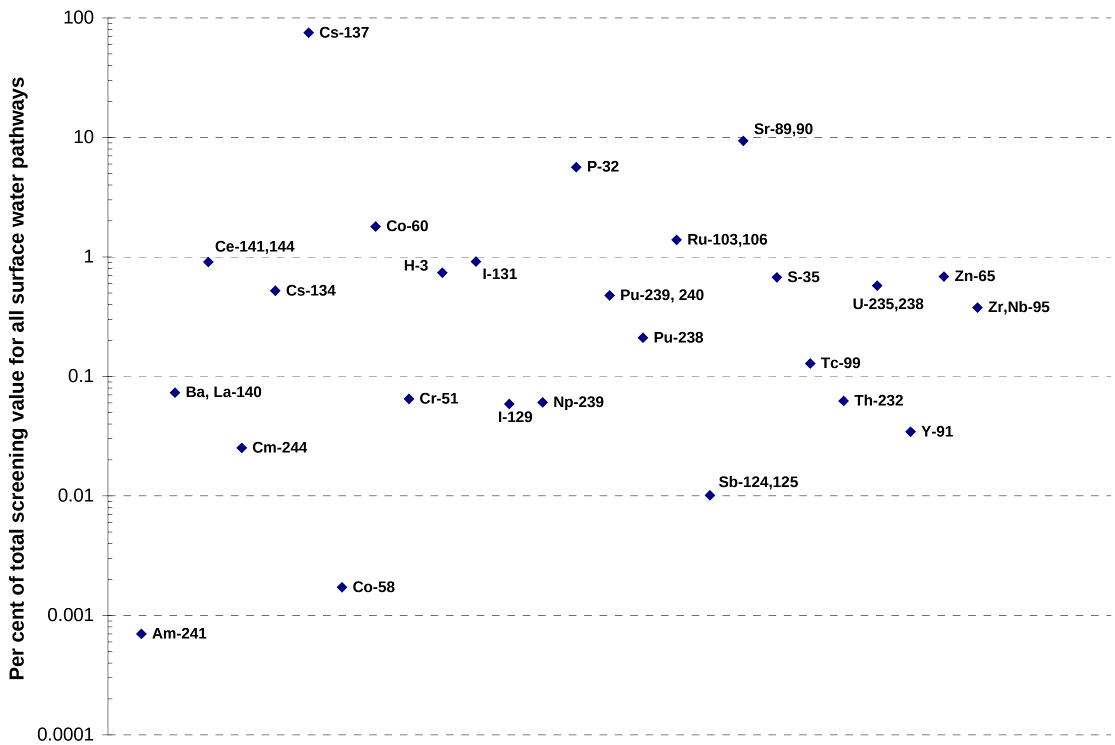

Figure 3-2. Relative importance of waterborne radionuclides released from the SRS as potential contributors to the total screening value, a measure of the potential public health impact. The results show the relative contribution to the screening value for all water pathways. For example, ^{137}Cs and ^{90}Sr contribute about 75% and 5% of the total screening value, respectively. This screening, using the NCRP methods, helped to identify the radionuclides for detailed source term development.

Screening SRS Releases: Step 2

Next, additional screening was carried out to provide a more realistic ranking of the radionuclides that were identified in the first step. This second step of screening evaluated the importance of the exposure pathway for the radionuclides meeting our screening criteria. The NCRP screening models consider the following pathways for radionuclides released to air: inhalation of contaminated air, direct radiation exposure from immersion in the airborne plume, direct radiation exposure from ground contamination and deposition of radionuclides on vegetation and ground. Radionuclides in air deposit on soil, pasture land, and vegetation and can lead to further potential exposure pathways: ingestion of contaminated vegetables, and pasture and soil consumption by cows lead to ingestion of contaminated milk and meat. From releases of radionuclides in liquid effluent, two modes of radiation exposures can occur: external and internal. External exposure can occur from ground contamination, shoreline activities or swimming. Internal exposures can occur when the radionuclides are ingested into the body, either directly in water, or indirectly through ingestion of fish, agricultural or garden produce, animal products or through inadvertent ingestion of soil. River or stream water used for irrigation or for watering animals may introduce radionuclides into food crops and animal products such as milk or eggs that people ultimately consume. For surface water pathways, the NCRP screening includes ingestion of water, vegetables, fish, milk, meat, soil, and the contribution from both swimming and boating, and ground irradiation from garden soil and shoreline deposits.

Exposure pathways are the ways by which humans are exposed to radionuclides or other toxic substances. The key exposure pathways are air and water, with most exposures via inhalation, drinking water, ingestion of crops and other foods, and by direct radiation. The relative importance of a pathway depends on the particular radionuclide and how it was released from the facility.

In the second step of screening, we further ranked the radionuclides identified in the first step (those contributing greater than 0.1% to the total screening value) (Figures 3-1 and 3-2) by determining the relative importance of these radionuclides by exposure pathway. The percent contribution of each radionuclide to the total screening value for each exposure pathway was the basis for ranking the radionuclides. The radionuclides that ranked among the top three for at least two of the seven exposure pathways were selected for detailed source term development. For the air pathway, those radionuclides are ^{241}Am, ^{41}Ar, ^{14}C, ^{137}Cs, ^{3}H, ^{129}I, ^{131}I, ^{238}Pu, ^{239,240}Pu, ^{103,106}Ru, ^{89,90}Sr and uranium. For the water pathway, those radionuclides are ^{137}Cs, ^{60}Co, ^{3}H, ^{129}I, ^{131}I, ^{32}P, ^{238}Pu, ^{239,240}Pu, ^{89}Sr, ^{90}Sr, ^{35}S, ^{99}Tc, uranium, ^{91}Y, ^{65}Zn, and ^{95}Zr,Nb. For the air pathways, exposure could occur through inhalation, immersion in the plume of radioactivity, and eating produce, drinking milk from local dairy cows, or eating meat after deposition of radionuclides on vegetation and ground.

The results of the second step screening calculations are summarized in Table 3A-2 and Table 3A-3 in Addendum 3A for the air and water pathways, respectively. Tables 3-2 and 3-3 summarize the results of that assessment for air and water, respectively, and identify the radionuclides that ranked among the top three for at least two of the seven exposure pathways. Detailed source term development was undertaken for those radionuclides, shown in bold in the first column of each table. For radionuclides released to air from the SRS, the screening shows that ^{3}H and ^{131}I are ranked high in at least 5 of the 7 exposure pathways. Argon-41 contributes almost 100% of the screening value from the plume immersion pathway. Based on this second screening step, detailed source term estimates were developed for ^{131}I, ^{3}H, ^{41}Ar, ^{129}I, ^{239,240}Pu and uranium released to air. More detailed assessments of release estimates for ^{3}H, ^{131}I, ^{129}I ^{41}Ar, plutonium, and uranium can be found in Chapters 4.1, 4.2, 4.3, and 4.4.

Screening shows that tritium and iodine are the major contributors to dose from all airborne pathways.

Table 3-2. Results of Screening Radionuclides by Air Pathways[a]

Radionuclide[b]	All Pathways	Inhalation	Ingestion: Milk	Ingestion: Produce	Ingestion: Meat	Ground contam.	Plume immersion	No. of pathways[c]
^{241}Am								0
^{41}Ar	✓						✓	2
^{14}C								0
^{137}Cs						✓		1
^{3}H	✓	✓	✓	✓	✓			5
^{129}I	✓		✓		✓			3
^{131}I	✓	✓	✓	✓	✓	✓		6
^{239,240}Pu	✓	✓		✓				3
^{238}Pu		✓						1
^{103,106}Ru						✓		1
^{89,90}Sr								0
uranium						✓		1[d]

[a] Results of the second step in the screening process; the radionuclides that ranked among the top for at least two of the seven exposure pathways were selected for detailed source term development. See Table 3A-2 for details.

[b] The radionuclides identified in the first screening step that contribute greater than 0.1% to the screening value for all potential pathways of exposure.

[c] The number of times a particular radionuclide ranked high in at least two air exposure pathways. These radionuclides are shown in bold and source terms were developed for them (see Chapter 4).

[d] Uranium was included in the final source term development because of its concentrated use in the M-Area and its potential chemical toxicity (see Chapter 16). Understanding the kidney toxicity of uranium may be an important step in future SRS studies if health risks are calculated

For surface water pathways, ^{137}Cs dominates all pathways except the ingestion of drinking water, where tritium is equally important. Strontium-90 also emerges as an important radionuclide for exposure through surface water pathways. Phosphorus-32 is important when the ingestion of fish is a key exposure pathway, while ^{131}I should be considered when the ingestion of drinking water and meat are major pathways of exposure. When ground contamination is a major exposure pathway, then ^{60}Co and uranium should be considered. More detailed assessments of release estimates for ^{3}H, ^{137}Cs, ^{90}Sr, ^{60}Co, ^{32}P, ^{131}I, and uranium can be found in Chapter 5, *Releases Of Radionuclides To Surface Water*. Uranium was included in the final source term development because of its potential chemical toxicity (see Chapter 16). Understanding the kidney toxicity of uranium may be an important step in future SRS studies if health risks are calculated.

Table 3-3. Results of Screening Radionuclides by Surface Water Pathways[a]

	All	Ingestion					Ground	No. of
Radionuclide[b]	Pathways	Water	Fish	Milk	Produce	Meat	contamination	pathways[c]
^{137}Cs	✓	✓	✓	✓	✓	✓	✓	7
^{60}Co	✓						✓	2
^{3}H	✓	✓						2
^{129}I								0
^{131}I	✓			✓				2
^{32}P	✓	✓	✓					3
^{239,240}Pu								0
^{238}Pu								0
^{89,90}Sr	✓	✓	✓	✓	✓	✓		6
^{35}S						✓		1
^{99}Tc					✓			1
uranium							✓	1[d]
^{91}Y								0
^{65}Zn	✓							1
^{95}Zr,Nb								0

[a] Results of the second step in the screening process; the radionuclides that ranked among the top for at least two of the seven exposure pathways were selected for detailed source term development. See Table 3A-2 for details.

[b] The radionuclides identified in the first screening step that contribute greater than 0.1% to the screening value for all potential pathways of exposure.

[c] The number of times a particular radionuclide ranked high in at least two surface water exposure pathways. These radionuclides are shown in bold and source terms were developed for them (see Chapter 5).

[d] Uranium was included in the final source term development because of its concentrated use in the M-Area and its potential chemical toxicity (see Chapter 16). Understanding the kidney toxicity of uranium may be an important step in future SRS studies if health risks are calculated

SUMMARY

This chapter describes the screening process we used to focus our efforts and resources most effectively on the radionuclides important to public health. The first step in the NCRP screening process showed that the radionuclides released to air and contributing greater than 0.1% to the total screening value are ^{241}Am, ^{41}Ar, ^{14}C, ^{137}Cs, ^{3}H, ^{129}I, ^{131}I, ^{238}Pu, ^{239,240}Pu, ^{103,106}Ru, ^{89,90}Sr and uranium. For releases to surface water, the important contributors emerging from the first screening step are ^{137}Cs, ^{60}Co, ^{3}H, ^{129}I, ^{131}I, ^{32}P, ^{238}Pu, ^{239,240}Pu, ^{89,90}Sr, ^{35}S, ^{99}Tc, uranium, ^{91}Y, ^{65}Zn, and ^{95}Zr/Nb. The second step of screening evaluated the importance of exposure pathway for each of these radionuclides. For radionuclides released to air from the SRS, the screening shows that tritium and iodine are the major potential contributors to radiation dose from all airborne pathways except plume immersion. Detailed assessments of release estimates to air for

^{3}H, ^{131}I, ^{41}Ar, ^{129}I, plutonium, and uranium can be found in Chapters 4.1, 4.2, 4.3, and 4.4. For surface water pathways, ^{137}Cs dominates all pathways except the ingestion of drinking water, where tritium is most important. Strontium-90 is relatively important when considering the ingestion of vegetables and meat as major exposure pathways, and ^{32}P is important when considering the ingestion of fish from local streams. Detailed assessments of release estimates to water for ^{3}H, ^{137}Cs, ^{90}Sr, ^{60}Co, ^{131}I, ^{32}P, ^{35}S, and uranium can be found in Chapter 5.

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ADDENDUM 3A

ADDITIONAL RADIONUCLIDE DATA FOR SCREENING CALCULATIONS

Addendum 3A—Tables

Table 3A-1. Comprehensive List of Radionuclides Associated with Fuel, Releases or Waste at SRS

Symbol	Half-life	Present in SRS fuel assembly [a]	SRS releases estimates [b]	High level sludge [c]	High level supernate [c]	Reconstit. Waste [c]	Low-level waste [d]
Am-241,243			X				
Am-241	432.y	X		X	X	X	
Ar-41	1.83 h		X				
Ba-140	12.8d	X					X
Ba,La-140			X				
Br-82	35.3 h		X				
C-14	5730 y		X				
Ce-141	32.6 d	X	X	X	X		X
Ce-141,144			X				
Ce-143	33.0h	X					
Ce-144	284.d	X	X				X
Ce,Pr-144				X	X	X	
Cm-242	163.d	X	X				
Cm-244	18.1y	X	X	X	X	X	
Co-58	70.8d	X	X				
Co-60	5.27y	X	X				X
Cr-51	27.7 d		X				X
Cs-134	2.06y	X	X	X	X		X
Cs-135	2.3E7 y			X	X		
Cs-136	13.0d	X	X				
Cs-137	30.1y	X	X	X	X	X	X
Eu-152	13.3 y			X	X		
Eu-154	8.8 y			X	X		
Fe-59	44.5 d						X
H-3	12.35 y		X				X
I-129	1.57E7 y		X	X	X		
I-131	8.04d	X	X				X
I-132	2.28h	X					
I-133	20.9h	X	X				
I-134	52.5m	X					
I-135	6.61h	X	X				
Kr-85	10.7y	X	X				
Kr-85m	4.48h	X	X				
Kr-87	1.27h	X	X				
Kr-88	2.86h	X	X				
La-140	40.3h	X					X
Mn-54	312.5 d		X				X
Mo-99	2.75d	X	X				

Table 3A-1. Comprehensive List of Radionuclides Associated with Fuel, Releases or Waste at SRS (cont'd)

Symbol	Half-life	Present in SRS fuel assembly [a]	SRS releases estimates [b]	High level sludge [c]	High level supernate [c]	Reconstit. waste [c]	Low level waste [d]
Na-24	15 h						X
Nb-95	35.0d	X	X	X			X
Nb-98	51.5 m				X		
Nd-147	11 d	X					
P-32	14.3 d		X				X
Pd-107	6.5E6 y			X	X		
Pr-143	13.6 d	X					
Pr-144	17.28 m						X
Pm-147	13.6 m		X	X	X	X	X
Pu-238	87.7y	X	X	X	X	X	X
Pu-239, 240			X			X	
Pu-239	2.4 E4y	X		X	X		X
Pu-240	6.6 E3y	X		X	X		
Pu-241	14.4y	X		X	X		
Pu-242	3.76E5 y			X	X		
Rb-86	18.8d	X					
Ru-103	39.4d	X	X	X	X		X
Ru-105	4.44h	X					
Ru-106	1.00y	X	X	X	X	X	X
Rh-106	29.9 s						X
Rh-105	1.48d	X					
S-35	87.4 d		X				X
Sb-124	60.2 d		X				
Sb-124,125			X				
Sb-125	2.77 y		X				
Sn,Sb-126	3.91 h	X		X	X		
Sb-129	4.41 h	X					
Se-75	119.8 d		X				
Se-79	6.5E4 y			X	X		
Sm-151	90 y			X	X	X	
Sr-89	50.6d	X	X	X	X		X
Sr-90	28.8 y	X	X	X	X	X	X
Sr-91	9.48 h	X					
Tb-158	150 y			X	X		
Te-127	9.35 h	X		X	X		
Te-127m	109. d	X					
Te-129	1.16 h	X		X	X		
Te-129m	33.5 d	X					

Table 3A-1. Comprehensive List of Radionuclides Associated with Fuel, Releases or Waste at SRS (cont'd)

Symbol	Half-life	Present in SRS fuel assembly [a]	SRS Releases estimates [b]	High level sludge [c]	Hi-Level supernate [c]	Reconstit. waste [c]	Low level waste [d]
Te-131m	1.25 d	X					
Te-132	3.26 d	X					
Tc-99	2.13E5 y			X	X		
Tc-99m	6.01 h	X					
Th-232	405E10 y		X				
U			X				
U-233	1.59E5 y			X	X		
U-235	703E6 y			X	X		
U-238	4.47E9 y		X	X	X		
Un-ID-alpha			X				
Un-ID-B+G			X				
Xe-131m	11.9 d		X				
Xe-133	5.25d	X	X				
Xe-135	9.10h	X	X				
Y-90	2.67d	X					X
Y-91	58.5d	X	X	X	X		
Zn-65	243.9 d		X				X
Zr,Nb-95			X				
Zr-93	1.53E6 y			X	X		
Zr-95	64.0d	X	X	X	X		X
Zr-97	16.9h	X					

[a] From Bauer et al. 1986, DOE 1984, DOE 1990
[b] From Cummins et al, 1991, Ashley and Zeigler 1982
[c] From DOE 1979, Looney et al. 1989
[d] From Stone and Christensen 1983

Table 3A-2a. Ranking Radionuclides by Air Exposure Pathway Based on their Contribution to the Total Screening Value: All Pathways

Radionuclide[e]	Atmospheric release rate[a] (Bq y^{-1})	Atmospheric concentration[b] (Bq m^{-3})	All paths Screening Factor[c] (Sv per Bq m^{-3})	Screening value[d] (Sv y^{-1})	Percentage of total screening value
I-131	2.6E+12	6.8E+04	2.80E-02	1.9E+03	50
H-3	2.5E+16	6.7E+08	1.90E-06	1.3E+03	35
Ar-41	6.6E+15	1.7E+08	1.50E-06	2.6E+02	7
I-129	5.9E+09	1.5E+02	5.60E-01	8.7E+01	2
Pu-239, 240	3.1E+09	8.2E+01	1.00E+00	8.2E+01	2
Ru-103,106	1.6E+11	4.3E+03	9.60E-03	4.1E+01	1
Pu-238	1.0E+09	2.7E+01	8.90E-01	2.4E+01	1
C-14	3.1E+12	8.1E+04	2.60E-04	2.1E+01	1
Cs-137	3.6E+09	9.5E+01	2.20E-01	2.1E+01	1
U235,238	9.3E+08	2.4E+01	3.40E-01	8.3E+00	0.2
Sr-89,90	2.1E+09	4.1E+01	1.90E-01	7.8E+00	0.2
Am-241	2.1E+09	5.5E+00	1.00E+00	5.5E+00	0.1
Total screening value from radionuclides released to air				3.7E+03	100

a The atmospheric release rate and atmospheric concentraton in the next column are the input values for the assessment of each exposure pathway (inhalation, ingestion of milk, vegetables, meat, and ground contamination) in subsequent portions of this table.
b Concentration at the point of release from the facility
c From Table B.1, NCRP 1996
d Product of the screening factor times the atmospheric concentration.
e The radionuclides that are the main contriubotrs to the screening value are shaded.

Table 3A-2b. Ranking Radionuclides by Air Exposure Pathway Based on their Contribution to the Total Screening Value: Inhalation Pathway

Radionuclide	Inhalation Screening Factor (Sv per Bq m^{-3})	Screening value[d] (Sv y^{-1})	Percent of inhalation scrn value
H-3	1.40E-07	9.3E+01	53
Pu-239, 240	5.50E-01	4.5E+01	26
Pu-238	5.00E-01	1.4E+01	8
I-131	1.20E-04	8.1E+00	5
U235,238	2.60E-01	6.3E+00	4
Ru-103,106	1.00E-03	4.3E+00	2
Am-241	5.70E-01	3.1E+00	2
C-14	4.50E-06	3.7E-01	0.2
Sr-89,90	2.80E-03	1.1E-01	0.07
I-129	6.20E-04	9.6E-02	0.06
Cs-137	6.80E-05	6.5E-03	0.004
Ar-41	a		
Total screening value for inhalation		1.7E+02	100

[a] No screening factor for this radionuclide for this pathway.

Table 3A-2c. Ranking Radionuclides by Air Exposure Pathway Based on their Contribution to the Total Screening Value: Milk Ingestion Pathway

Radionuclide	Milk Screening Factor (Sv per Bq m^{-3})	Screening value (Sv y^{-1})	Percent of milk ingestion screening value
I-131	1.50E-02	1.0E+03	62
H-3	8.60E-07	5.7E+02	35
I-129	2.20E-01	3.4E+01	2
C-14	6.30E-05	5.1E+00	0.3
Cs-137	4.10E-02	3.9E+00	0.2
Sr-89,90	4.60E-02	1.9E+00	0.1
U235,238	1.80E-03	4.4E-02	0.003
Ru-103,106	2.50E-06	1.1E-02	0.0007
Pu-239, 240	9.90E-05	8.1E-03	0.0005
Pu-238	8.90E-05	2.4E-03	0.0001
Am-241	2.00E-04	1.1E-03	0.0001
Ar-41	a		
Total screening value for milk		1.6E+03	100

[a] No screening factor for this radionuclide for this pathway.

Table 3A-2d. Ranking Radionuclides by Air Exposure Pathway Based on their Contribution to the Total Screening Value: Produce Ingestion Pathway

Radionuclide	Vegetable Screening Factor (Sv per Bq m^{-3})	Screening value (Sv y^{-1})	Percent of produce ingestion screening value
H-3	5.80E-07	3.9E+02	54
I-131	4.00E-03	2.7E+02	38
Pu-239, 240	2.70E-01	2.2E+01	3
I-129	8.00E-02	1.2E+01	2
C-14	1.30E-04	1.1E+01	1
Pu-238	2.50E-01	6.8E+00	1
Sr-89,90	7.30E-02	3.0E+00	0.4
Cs-137	2.30E-02	2.2E+00	0.3
Ru-103,106	3.60E-04	1.5E+00	0.2
Am-241	2.80E-01	1.5E+00	0.2
U235,238	1.40E-02	3.4E-01	0.05
Ar-41	a		
Total screening value for veg		7.2E+02	100

[a] No screening factor for this radionuclide for this pathway.

Table 3A-2e. Ranking Radionuclides by Air Exposure Pathway Based on their Contribution to the Total Screening Value: Meat Ingestion Pathway

Radionuclide	Meat Screening Factor (Sv per Bq m^{-3})	Screening value (Sv y^{-1})	Percent of meat ingestion screening value
I-131	9.50E-03	6.45E+02	73
H-3	2.90E-07	1.93E+02	22
I-129	2.20E-01	3.41E+01	4
C-14	7.20E-05	5.87E+00	0.7
Cs-137	5.10E-02	4.85E+00	0.5
Sr-89,90	5.80E-02	2.38E+00	0.3
Ru-103,106	5.70E-05	2.45E-01	0.03
Pu-239, 240	2.50E-03	2.05E-01	0.02
Pu-238	2.20E-03	5.98E-02	0.01
U235,238	9.20E-04	2.24E-02	0.003
Am-241	1.30E-03	7.12E-03	0.0008
Ar-41	a		
Total screening value for meat		8.86E+02	100

[a] No screening factor for this radionuclide for this pathway.

Table 3A-2f. Ranking Radionuclides by Air Exposure Pathway Based on their Contribution to the Total Screening Value: Plume Immersion Pathway

Radionuclide	Plume immersion Screening Factor (Sv per Bq m^{-3})	Screening value (Sv y^{-1})	Percent of plume immersion screening value
Ar-41	1.50E-06	2.61E+02	99.9
I-131	4.70E-07	3.19E-02	0.01
Am-241	2.30E-08	1.26E-07	0
U235,238	1.30E-10	3.17E-09	0
I-129	1.00E-08	1.55E-06	0
Pu-239, 240	1.10E-10	9.02E-09	0
Pu-238	1.10E-10	2.99E-09	0
Ru-103,106	6.00E-07	2.57E-03	0
C-14	a		
Cs-137	a		
H-3	a		
Sr-89,90	a		
Total screening value for plume imm		2.62E+02	100

[a] No screening factor for this radionuclide for this pathway.

Table 3A-2g. Ranking Radionuclides by Air Exposure Pathway Based on their Contribution to the Total Screening Value: Ground Contamination Pathway

Radionuclide	Ground contamination Screening Factor (Sv per Bq m^{-3})	Screening value (Sv y^{-1})	Percent of ground contamination screening value
Cs-137	9.80E-02	9.31E+00	43
I-131	1.20E-04	8.15E+00	38
Ru-103,106	7.00E-04	3.00E+00	8
U-235,238	4.60E-02	1.12E+00	5
I-129	5.10E-03	7.90E-01	4
Am-241	6.80E-03	3.73E-02	2
Pu-239, 240	1.90E-04	1.56E-02	0.07
Pu-238	1.80E-04	4.90E-03	0.05
Ar-41	a		
C-14	a		
H-3	a		
Sr-89,90	a		
Total screening value for ground cont.		2.62E+02	100

[a] No screening factor for this radionuclide for this pathway.

Table 3A-3a. Ranking Radionuclides by Water Exposure Pathway Based on their Contribution to the Total Screening Value: All Pathways

Radionuclide[e]	Half-life	Releases in liquid effluents[a] (Bq y^{-1})	Liquid effluent concentration[b] (Bq m^{-3})	All pathways Screening factor[c] (Sv per Bq m^{-3})	Screening value[d] (Sv/y)	Percent of total screening value
Cs-137	30 y	6.3E+11	8.1E+01	1.10E-06	8.96E-05	60
Sr-89,90		6.4E+11	8.3E+01	4.30E-07	3.56E-05	24
Co-60	5.271 y	6.8E+10	8.8E+00	6.10E-07	5.37E-06	4
P-32	14.29 d	3.7E+10	4.8E+00	8.20E-07	3.94E-06	3
I-131	8.04 d	3.1E+11	4.0E+01	8.60E-08	3.48E-06	2
H-3	12.35 y	1.5E+15	2.0E+05	1.40E-11	2.80E-06	2
Zn-65	243.9 d	1.4E+11	1.9E+01	1.30E-07	2.43E-06	2
S-35	87.44 d	1.5E+12	2.0E+02	1.10E-08	2.20E-06	1
Zr,Nb-95	63.98 d	1.0E+11	1.3E+01	7.40E-08	9.88E-07	1
Tc-99	2.13e5 y	1.0E+11	1.3E+01	6.90E-08	9.28E-07	1
U-235,238	4.468e9 y	3.1E+10	4.0E+00	1.80E-07	7.21E-07	0.5
Pu-239, 240	24065 y	1.2E+09	1.6E-01	1.70E-06	2.72E-07	0.2
I-129	1.57e7 y	1.2E+09	1.6E-01	1.40E-06	2.24E-07	0.2
Y-91	58.5 d	1.2E+11	1.5E+01	8.20E-09	1.27E-07	0.09
Pu-238	87.74 y	4.1E+08	5.3E-02	1.50E-06	8.01E-08	0.05
Total screening value from radionuclides released in liquid effluents					1.49E-04	100

a The release rate and liquid effluent concentraton in the next column are the input values for the assessment of each exposure pathway (drinking water, ingestion of fish, milk, vegetables, meat, and ground contamination) in subsequent portions of this table.
b Concentration at the point of release from the facility
c From Table C.1, NCRP 1996
d Product of the screening factor times the concentration in liquid effluents.
e The radionuclides that are the main contriubotrs to the screening value are shaded.

Table 3A-3b. Ranking Radionuclides by Water Exposure Pathway Based on their Contribution to the Total Screening Value: Drinking Water Pathway

Radionuclide	Drinking water Screening factor (Sv per Bq m^{-3})	Drinking water screening value (Sv/y)	Percent of drinking water screening value
Cs-137	1.10E-08	2.9E-06	30
H-3	1.40E-11	2.8E-06	29
Sr-89,90	2.50E-08	2.1E-06	21
I-131	1.90E-08	7.7E-07	8
Pu-239, 240	4.50E-07	4.8E-07	5.0
Pu-238	4.10E-07	2.2E-07	2.27
U-235,238	2.20E-08	1.2E-07	1.3
Co-60	5.70E-09	6.4E-08	1
Zn-65	3.00E-09	6.0E-08	1
S-35	2.30E-10	5.4E-08	1
P-32	2.00E-09	5.2E-08	1
Y-91	3.00E-09	4.6E-08	0.48
Zr,Nb-95	9.70E-10	1.9E-08	0
I-129	9.90E-08	1.6E-08	0.2
Tc-99	5.30E-10	7.1E-09	0
Total screening value for drinking water		9.6E-06	

Table 3A-3c. Ranking Radionuclides by Water Exposure Pathway Based on their Contribution to the Total Screening Value: Fish Ingestion Pathway

Radionuclide	Fish Screening factor (Sv per Bq m^{-3})	Fish screening value (Sv/y)	Percent of fish ingestion screening value
Cs-137	5.40E-07	1.4E-04	83
P-32	8.10E-07	2.1E-05	13
Sr-89,90	3.70E-08	3.1E-06	2
Zn-65	6.60E-08	1.3E-06	1
S-35	4.20E-09	9.8E-07	1
Co-60	4.20E-08	4.7E-07	0.3
Pu-239, 240	3.40E-07	3.6E-07	0.2
Pu-238	3.10E-07	1.7E-07	0.1
I-131	4.00E-09	1.6E-07	0.1
Zr,Nb-95	4.90E-09	9.5E-08	0.06
H-3	3.40E-13	6.8E-08	0.04
U-235,238	5.50E-09	3.1E-08	0.02
Y-91	1.50E-09	2.3E-08	0.01
I-129	9.90E-08	1.6E-08	0.01
Tc-99	2.70E-10	3.6E-09	0.002
Total screening value for fish ingestion		1.7E-04	100

Table 3A-3d. Ranking Radionuclides by Water Exposure Pathway Based on their Contribution to the Total Screening Value: Produce Ingestion Pathway

Radionuclide	Vegetables Screening factor (Sv per Bq m^{-3}	Vegetables screening value (Sv/y)	Percent of vegetable screening value
Sr-89,90	1.50E-07	1.2E-05	46
Cs-137	4.60E-08	1.2E-05	45
Tc-99	5.70E-08	7.7E-07	3
Pu-239, 240	5.50E-07	5.9E-07	2.2
I-131	8.10E-09	3.3E-07	1
Pu-238	5.00E-07	2.7E-07	1.0
U-235,238	2.70E-08	1.5E-07	0.6
Co-60	9.30E-09	1.0E-07	0.4
Zn-65	4.30E-09	8.6E-08	0.3
S-35	2.70E-10	6.3E-08	0.2
Y-91	2.90E-09	4.5E-08	0.2
P-32	1.30E-09	3.4E-08	0.1
I-129	1.60E-07	2.6E-08	0.1
Zr,Nb-95	1.10E-09	2.1E-08	0.08
H-3	a		
Total screening value for produce		2.7E-05	

[a] No screening factor for this radionuclide for this pathway.

Table 3A-3e. Ranking Radionuclides by Water Exposure Pathway Based on their Contribution to the Total Screening Value: Milk Ingestion Pathway

Radionuclide	Milk Screening factor (Sv per Bq m^{-3}	Milk screening value (Sv/y)	Percent milk ingestion screening value
Cs-137	8.50E-08	2.2E-05	68
Sr-89,90	9.30E-08	7.7E-06	24
I-131	3.30E-08	1.3E-06	4
S-35	1.80E-09	4.2E-07	1
P-32	9.70E-09	2.5E-07	1
Zn-65	1.20E-08	2.4E-07	1
Tc-99	1.10E-08	1.5E-07	0.5
Co-60	7.70E-09	8.6E-08	0.3
I-129	4.60E-07	7.4E-08	0.2
U-235,238	4.00E-09	2.2E-08	0.1
Y-91	6.40E-11	9.9E-10	0.003
Pu-239, 240	2.10E-10	2.2E-10	0.001
Pu-238	1.90E-10	1.0E-10	0.0003
Zr,Nb-95	2.90E-13	5.6E-12	0.00002
H-3	a		
Total screening value for milk		3.2E-05	100

[a] No screening factor for this radionuclide for this pathway.

Table 3A-3f. Ranking Radionuclides by Water Exposure Pathway Based on their Contribution to the Total Screening Value: Meat Ingestion Pathway

Radionuclide	Meat Screening factor (Sv per Bq m^{-3}	Meat screening value (Sv/y)	Percent meat ingestion screening value
Cs-137	1.10E-07	2.9E-05	69
Sr-89,90	1.20E-07	9.9E-06	24
S-35	4.20E-09	9.8E-07	2
I-131	2.20E-08	8.9E-07	2
Zn-65	3.10E-08	6.2E-07	1
Co-60	2.90E-08	3.3E-07	1
P-32	4.80E-09	1.3E-07	0.3
I-129	4.60E-07	7.4E-08	0.2
U-235,238	2.10E-09	1.2E-08	0.03
Y-91	5.00E-10	7.7E-09	0.02
Pu-239, 240	5.20E-09	5.6E-09	0.01
Tc-99	2.70E-10	3.6E-09	0.009
Pu-238	4.70E-09	2.5E-09	0.01
Zr,Nb-95	8.60E-14	1.7E-12	0.000004
H-3	a		
Total screening value for meat ingestion		4.2E-05	100

[a] No screening factor for this radionuclide for this pathway.

Table 3A-3g. Ranking Radionuclides by Water Exposure Pathway Based on their Contribution to the Total Screening Value: Ground Contamination Pathway

Radionuclide	Ground contamination Screening factor (Sv per Bq m^{-3})	Ground contamination screening value (Sv/y)	Percent ground contamination screening value
Cs-137	3.50E-07	9.1E-05	91
Co-60	5.20E-07	5.8E-06	6
U-235,238	3.10E-07	1.7E-06	2
Zr,Nb-95	6.70E-08	1.3E-06	1
Zn-65	1.70E-08	3.4E-07	0.3
Pu-239, 240	6.90E-09	7.4E-09	0.007
Y-91	2.40E-10	3.7E-09	0.004
Pu-238	6.40E-09	3.4E-09	0.003
I-131	4.20E-11	1.7E-09	0.002
I-129	1.80E-09	2.9E-10	0.0003
Sr-89,90	5.90E-13	4.9E-11	0.00005
Tc-99	5.20E-14	7.0E-13	0.000001
H-3	a		
P-32	a		
S-35	a		
Total screening value for meat ingestion		1.0E-04	100

[a] No screening factor for this radionuclide for this pathway.