A.7.0 Human Receptors

A.7.1 Description

The human receptor is the person whose exposure to radionuclides is being modeled. The receptor is assumed to be a hypothetical subsistence user who has a diet of marine animals and plants from the Bering Sea and/or Pacific Ocean near Amchitka Island, or a consumer of commercially harvested fish from the Bering Sea and/or Pacific Ocean. The receptor is assumed to be exposed for 70 years to the entire diet from the diet option chosen. Therefore, the exposure calculation includes both children and adults.

A.7.2 Current Knowledge

Subsistence users include those family and village members who hunt and fish in the Bering Sea and the Pacific Ocean waters along with those family or village members who share the catch. The model makes the conservative assumption that the immediate surroundings of Amchitka Island are used for subsistence hunting and fishing although the exact patterns of this use are undocumented to date. The receptor is exposed to any radionuclides that may be in the diet for a period of 70 years. It is unlikely that the majority of people eat exclusively a subsistence diet for an entire lifetime. By using the assumption that the receptor is a subsistence user for 70 years, the model makes a conservative estimate of exposure (that is, higher than expected to occur).

The commercial fishery in the Bering Sea and the northern Pacific Ocean provides large amounts of fish to the United States, Canada, Russia, Japan, and other countries. The receptor in this scenario is exposed to any radionuclides that may be in the diet for a period of 70 years. It is assumed that Bering Sea fish and shellfish comprise only a small fraction of the total diet of these receptors. Table A-6 provides for more information about other items in the total diet.

The exposure calculation (see Section A.13.0) assumes that the receptor is exposed to the radionuclides for a lifetime.

A.7.3 Discussion of Uncertainties

The receptors modeled as consuming a subsistence diet eating food harvested within the Aleut culture and communication area. It is not likely that subsistence fishers fish equally everywhere in that area.

Table A-6
Subsistence Diet and Commercial Catch Diet Distribution Scenarios for Amchitka Screening Risk Assessment

Food Item	Percent of Item in Diet		
	Mainly Fish Diet	Mainly Mammal Diet	Commercial Catch
Marine fish	90	5	3.2
Marine mammals	5	90	0
Crustaceans	1	1	0.8
Mollusks	1	1	0.4
Plants (including kelp)	1	1	0
Other (nonmarine) foods	2	2	95.6

For example, subsistence fishers from Nikolski in the eastern Bering Sea are more likely to fish in the eastern part of the culture and communication area than to go several hundred miles to its western boundaries. However, the risk assessment model assumes that there is a fishing zone around Amchitka Island where exposed fish can be harvested. The fishing zone surrounds Amchitka and is bounded by the 200-m isobath. It assumed to have an area of 2,000 km^2 (Section A.10.2.3). The Aleut culture and communication area is approximately 1.8×106 km^2 (1,800-km long by 1,000-km wide). This means that the fishing zone is 2,000/1,800,000 = 0.1 percent of the Aleut culture and communication area.

The risk assessment model also assumes that fishing is done 10 percent of the time in the fishing zone around Amchitka. The model is not sensitive to the location of fishing the other 90 percent of the time. That is, in the mathematical structure of the model it does not matter where the remaining 90 percent of fishing occurs, so the location does not have to be defined. Because not all subsistence fishers harvest fish at Amchitka, the model overstates the likely exposure of subsistence consumers and is, therefore, conservative.

The demographics of consumers of commercially caught fish are uncertain. These receptors are assumed to be distributed among the world's population, but data were not available to estimate what fraction of the population of any country or other geographic or cultural unit consumes fish caught in the Bering Sea and northern Pacific Ocean. It is important to note that the exposure calculations are specifically for people who eat fish harvested in the Bering Sea and northern Pacific Ocean, and many or most of any population may not eat such fish at all. Therefore, the exposure estimated for consumption of commercially caught fish is overstated for any given population.

A.7.4 Implementation

The receptors are a subsistence consumer and a consumer of commercial catch who receive a 70-year exposure to radionuclides in food.

A.8.0 Distribution of Diet

A.8.1 Description

The dose to which consumers are exposed depends on the type and amount of contaminated food they eat. Different types of food (e.g., fish, seals, and crabs) have different BCFs; therefore, have different concentrations of radionuclides in their tissues. Therefore, the model contains a breakdown of diet. The food types considered separately are marine fish, marine mammals, crustaceans, mollusks, and plants. Other refers to nonmarine foods that would not be expected to contain radionuclides that are of marine origin. A more detailed breakdown is not appropriate because there are not different BCFs for subgroups of these food types.

A.8.2 Current Knowledge

Current information concerning diet distributions for native Alaskan communities has been published by the ONR (1997). The communities listed in that document are Emmonak, Kotzebue, Kivalina, Point Hope, Point Lay, Barrow, and Diomede. However, none of these communities is in the Aleutian chain, so these diet distributions were not used. A quote from the A/PIA trustee (2000) indicates that Aleut diets contain a large portion of marine mammals (e.g., seals). However, detailed dietary information about quantities of native marine and nonmarine foods for other populations is not available. Therefore, diets will be defined that emphasize the consumption of fish or the consumption of marine mammals as the major sources of food.

The value that is used for daily food consumption by subsistence consumers was taken from the Community Profile Database (ADFG, 2002). The average daily consumption rate used in the risk model (1.25 kg/d) is the 95th percentile upper bound estimate of per capita consumption for the community of Nikolski, Alaska (ADFG, 2002). This is the highest consumption rate among several communities (Akutan, Atka, False Pass, Nikolski, St. Paul, and Unalaska) listed in the database. The mean reported per capita consumption for these communities for what is designated in the database as the most representative year is 0.53 kg/d, and the mean consumption rates of fish and marine mammals are 0.28 kg/d and 0.12 kg/d, respectively. For comparison, annual consumption rates of food from marine sources were reported for Arctic Seas communities (ONR, 1997). The mean consumption rate was 0.71 kg/d, and the mean consumption rates of fish and marine mammals were

0.16 kg/d and 0.48 kg/d, respectively. Therefore, the consumption rates used in the model (1.25 kg/d total and a maximum of 1.125 kg/d fish and marine mammals) are conservative.

Consumers of commercial catch are assumed to eat 0.86 kilograms (kg) of food daily, which is presented in the EPA Exposure Factors Handbook (EPA, 1997). The modeled consumption rate for commercially caught fish is 0.0275 kg/d, a value between the mean (approximately 0.015 kg/d) and the 95th percentile upper confidence limit (between 0.040 and 0.045 kg/d) (EPA, 1997) for the general U.S. population. Therefore, fish consumption rates for the modeled consumers of commercially caught fish are also conservative. The diet distributions are presented in Table A-6.

A.8.3 Discussion of Uncertainties

There is uncertainty in the exact distribution of foods of marine origin in the receptors' diets. The risk results (Section 5.8) show that the scenario in which marine fish make up 95 percent of the diet gave the highest exposure, suggesting that the quantity of fish consumed is the most sensitive diet variable. The distribution of fish and marine mammals in the diets of the six A/PIA communities used for reference (ADFG, 2000b) ranged from 40.5 percent to 69 percent fish and 5 percent to 48 percent marine mammals, but in the screening risk assessment the consumption rates are assumed to be 95 percent fish in the fish subsistence diet and 95 percent marine mammals in the marine mammal subsistence diet. Land mammals accounted for 3 percent to 27 percent of the diet, but in the screening risk assessment they are included in the 2 percent "Other (non-marine) foods" category (Table A-6). Therefore, the risk assessment model's assumption that 95 percent of the diet consists of fish or marine mammals is conservative.

The daily consumption rate and diet distributions used in the model are higher than the mean consumption rate and upper bound of the distributions reported for the six reference communities in the A/PIA database by three-fold or more in the scenarios with 95 percent fish consumption (maximum risk of 9.7×10^{-11} for mean discharge) and four-fold or more in the scenarios with 95 percent marine mammal consumption (maximum risk of 5.3×10^{-11} for mean discharge).

The rate of fish consumption in the scenarios for consumption of commercial catch is also conservative. The value, 3.4 percent of 0.86 kg per day, is approximately 27.5 g/day. This is nearly double EPA's reported value of approximately 14 g/day (EPA, 1997) for the average rate of fish consumption by the general population. In addition, it is unlikely that any population consuming commercially caught fish gets all of its fish from the Bering Sea and northern Pacific Ocean (Scenario 9), and certainly not from the zone immediately surrounding Amchitka Island (Scenarios 3 and 6). Therefore, the risk assessment model overestimates the risk from consumption of commercial catch for the mean discharge rates or base case (4.2×10^{-11}) by many-fold.

A.8.4 Implementation

This risk assessment conservatively assumed one diet that was high in fish and one diet that was high in marine mammals, as denoted in Table A-6. This assumption resulted in an overestimate of exposure when it is compared to dietary distributions for Aleuts and quantities of native marine foods eaten by the native Alaskan consumers in Aleutian communities as shown in the A/PIA Community Profile Database (ADFG, 2002). For consumers of commercial catch, the diet is assumed to be mainly of nonmarine origin. The dietary fraction was used in the calculation of the radionuclide risk factor (see Table 1 in the main text).

A.9.0 Bioconcentration Factors

A.9.1 Description

Substances are taken up from water by marine biota, both directly and through the food web. The BCF is the ratio of concentration of a substance in receptor tissue to the concentration in the exposure medium (e.g., water, sediment). As used here, BCF includes uptake from food, so it is a composite of uptake factors from all sources of exposure and especially marine water.

A.9.2 Current Knowledge

Substances in water may be concentrated as they are taken up by primary producers and transferred up the food web to the top-level predators. At each step in the food web, a substance may be further concentrated or the predator may exclude the substance to various degrees. Therefore, it is useful to have BCFs for each trophic level in the food web.

Published data are available for concentrations of some elements in marine fish and seawater near Amchitka Island (Bloom et al., 1975; Isaakson and Seymour, 1968). These data have been used to calculate BCFs for fish species for some radionuclides (IT, 1999), and are used preferentially herein as long as the element was detected in both fish flesh and water. Some BCFs (i.e., for strontium-90, cesium-137, plutonium-239, plutonium-240, and plutonium-241) come from measurements of radionuclide concentrations in water and marine mammal tissue in arctic waters (ONR, 1997). These values were used in preference to published values for biota from other waters. BCFs have also been published by the International Atomic Energy Agency (IAEA) (1985). The IAEA data include BCFs for fish, crustaceans, mollusks, and macroalgae. Tabulated data for uptake of most of the ROPCs for this risk assessment by crustaceans, mollusks, and macroalgae were not found in other sources. All BCFs for nonmammals were derived either by direct measurement of contaminant concentrations in biota and water or by estimates of uptake based on the uptake of chemicals with similar chemical properties. Note that food preparation is assumed to be absent. Therefore, there is no allowance for selective consumption of body parts that may have higher or lower BCFs than those for flesh.

The BCFs for mammals were derived using EPA guidance (EPA, 1999). EPA presents a method to calculate the concentration of chemicals in the flesh of an animal from the concentration in food. The EPA method (EPA, 1999) states that the BCF for a mammal (kg food/kg flesh) is computed by multiplying the uptake factor for beef (Ba, mg/kg flesh per mg ingested/d) by the food ingestion rate (IR, kg food/d): BCF = Ba × IR. Published uptake factors for each radionuclide (Baes et al., 1984) were first adjusted for mammal receptors represented by sea lions by multiplying the uptake factors by the daily food ingestion rate of the receptor (EPA, 1999). For sea lions, the food consumption rate was calculated by using allometric equations provided by the EPA (1993) for placental mammals. The estimated energy requirement for a sea lion or other mammal weighing 566 kg (ADFG, 2000b) was estimated to be 38,030 kilocalories per day (kcal/d). This value was divided by the energy content of fish (1.2 kilocalories per gram) to yield the ingestion rate of 31.7 kg/d. This value is a more conservative estimate than a published estimate of up to 3 percent of body weight (ADFG, 2000b), which would be 17.0 kg/d. The result of these calculations was the ratio of contaminant concentration in flesh to the average concentration in the diet (pCi/g flesh per pCi/g food). The ratio was then multiplied by the BCF for fish (pCi/g food per pCi/L) to derive a water-to-flesh BCF (pCi/g flesh per pCi/L).

The BCFs chosen for this risk assessment are presented in Table A-7.

A.9.3 Discussion of Uncertainties

The BCFs for some radionuclides (Table A-7) were calculated from the reported concentrations of elements in marine biota found in Amchitka waters (Bloom et al., 1975; Isaakson and Seymour, 1968). There is a wide variability among different samples for the same element. This is probably partly because of individual variations in exposure and age and partly because concentrations in the flesh of biota and in seawater were so low that analytical error would have introduced a large uncertainty in the ratio. Most elements comprising the chosen radionuclides had BCFs that varied by a factor of 10 to 100 in different samples. When multiple data were presented, the highest was chosen. For example, Bloom et al. (1975) and Isaakson and Seymour (1968) observed strontium concentrations that led to BCFs from 0.01 to 0.93. The BCF used in the risk assessment model is the most conservative, 0.93. Therefore, BCFs are assumed to overstate the average concentration of most radionuclides in fish tissue.

When no Amchitka data were available, BCFs were the recommended numbers published by IAEA (1985). These were values calculated from observed concentrations in marine biota, but not from the Amchitka vicinity. The IAEA values (Table A-7) are intermediate values chosen by IAEA as the best values from observations that ranged over factors of about 5-fold to as much as 400-fold.

The exposure by ingestion of marine mammals is calculated by using an uptake model (EPA, 1999) for transfer of radionuclides from food to predator tissues. The model includes the rate of food ingestion by the marine predator, which was calculated for Steller sea lions weighing 566 kg (1,245 lb). The resulting food consumption rate was 31 kg/d. This value was used rather than a less conservative alternative value, which is an estimate of 3 percent of body weight, or 17 kg/d, from ADFG (2000b). If the ADFG estimate is more accurate than the number calculated by the EPA method, the BCFs for marine mammals would be slightly over half the BCFs that were used. Therefore, the risk assessment model may overstate the BCF for marine mammals by nearly two-fold on the basis of the food consumption rate.

A.9.4 Implementation

The BCFs presented in Table A-7 were used along with dietary distributions and dilution factors to calculate dietary concentration factors for radionuclides in seawater (see Table 3 in the main text). The dietary concentration factor was multiplied by conversion factors to convert it to the lifetime ingestion exposure factor (see Table 4 in the main text).

Table A-7
Bioconcentration Factors for Radionuclides by Biota Representing Groups of Food Sources for Subsistence Consumers and Commercial Catch Consumers Near Amchitka Island

Radionuclide	BCF for Fish (L/kg)	Source	BCF for Marine Mammals (L/kg)	Source	BCF for Crustaceans (L/kg)	Source	BCF for Molluscs (L/kg)	Source	BCF for Plants (L/kg)	Source
Tritium	1.00E+00	A	1.00E+00	D	1.00E+00	A	1.00E+00	A	1.00E+00	A
Carbon-14	1.79E+04	A	1.00E+00	D	2.00E+04	A	5.00E+04	A	1.00E+04	A
Chlorine-36	3.60E-01	B	9.13E-01	D	5.00E-02	A	1.00E+00	A	5.00E-02	A
Strontium-90	9.26E-01	C	1.00E+00	E	2.00E+00	A	1.00E+01	A	5.00E+00	A
Yttrium-90	2.00E+01	A	1.90E-01	D	1.00E+03	A	1.00E+03	A	1.00E+03	A
Technetium-99	3.00E+01	A	8.08E+00	D	1.00E+03	A	1.00E+03	A	1.00E+03	A
Iodine-129	1.00E+01	A	2.22E+00	D	1.00E+01	A	1.00E+01	A	1.00E+03	A
Cesium-137	1.00E+02	A	1.00E+02	E	3.00E+01	A	3.00E+01	A	5.00E+01	A
Samarium-151	5.00E+02	A	7.92E+01	D	1.00E+03	A	5.00E+03	A	3.00E+03	A
Europium-152	3.00E+02	A	4.75E+01	D	1.00E+03	A	7.00E+03	A	3.00E+03	A
Gadolinium-152	5.00E+02	A	5.55E+01	D	2.00E+03	A	5.00E+03	A	3.00E+03	A
Uranium-234	1.00E+00	A	6.34E-03	D	1.00E+01	A	3.00E+01	A	1.00E+02	A
Uranium-236	1.00E+00	A	6.34E-03	D	1.00E+01	A	3.00E+01	A	1.00E+02	A
Uranium-238	1.00E+00	A	6.34E-03	D	1.00E+01	A	3.00E+01	A	1.00E+02	A
Neptunium-237	1.00E+01	A	1.74E-02	D	1.00E+02	A	4.00E+02	A	5.00E+01	A
Plutonium-239	4.00E+01	A	3.00E+00	E	3.00E+02	A	3.00E+03	A	2.00E+03	A
Plutonium-240	4.00E+01	A	3.00E+00	E	3.00E+02	A	3.00E+03	A	2.00E+03	A
Plutonium-241	4.00E+01	A	3.00E+00	E	3.00E+02	A	3.00E+03	A	2.00E+03	A
Americium-241	5.00E+01	A	5.55E-03	D	5.00E+02	A	2.00E+04	A	8.00E+03	A

A = IAEA (1985)
B = Bloom et al. (1975)
C = Isaakson and Seymour (1968)
D = Uptake factors from Baes et al. (1984), multiplied by daily food ingestion rate (31.7 kg/d for marine mammals, represented by sea lions), as specified by EPA (1999). Those products are multiplied by the BCFs for fish (consumed by marine mammals).
E = ONR (1997)