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SCOPING ASSESSMENT OF RADIOLOGICAL DOSES TO AQUATIC ORGANISMS AND WILDLIFE - N SPRINGS

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SUMMARY

Estimated does rates were determined for endemic biota inhabiting the N Springs area based primarily on spring water data collected from the first 6 months of 1991. Radiological dose estimates were computed from measured values of specific radionuclides and modeled levels of radionuclides using established computer codes. The highest doses were predicted in hypothetical populations of clams, fish-eating ducks, and rabbits. The calculated dose estimates did not exceed 1 rad/d, an administrative dose rate established by the U.S. Department of Energy for the protection of native aquatic biota. An administrative dose rate has not been established for terrestrial wildlife.

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INTRODUCTION

The Washington State Department of Ecology (Ecology) has requested that the U.S. Department of Energy (DOE) perform an expedited response to abate the offsite discharge of radionuclides from the N Springs into the Columbia River. In response to this request, Westinghouse Hanford Company (WHC) has requested from Pacific Northwest Laboratory (PNL) a scoping assessment to estimate potential radiological doses to wildlife and aquatic life that may have access to the area near the N Springs.

The assumptions used in this analysis are very conservative (i.e., hypothetical exposure conditions were defined that would give the highest potential radiation exposure and dose estimates). It is extremely unlikely that these actual exposure conditions could exist, and therefore the calculated doses overestimate the potential for exposure of the natural biota. This preliminary scoping assessment distinguishes between those pathways and animals that do not receive significant doses, even under conservative assumptions, and those that warrant further assessment under more realistic scenarios. Dose rates are evaluated against a 1-rad/d guideline for aquatic organisms established by DOE Order 5400.5. All data reported in this report are considered provisional. However, the authors believe that refinement of the calculations based on additional pertinent data would lead to lower radiation dose estimates. For example, doses were calculated on the assumption that the organisms were exposed for long enough periods of time for their body burdens to come to equilibrium with their environment. In some instances, these times involve years of constant exposure.

Dose rates (rad/d) were determined for deer, cottontail rabbits, fish-eating ducks, carp, freshwater clams, crayfish, and water plants. The source terms used for determining exposure were 100% and 10% spring water and measured levels of radioactivity in aquatic organisms and terrestrial vegetation. Food-chain transfer was also evaluated using terrestrial and aquatic biota in a simple food chain. Estimates of radionuclide burdens were obtained using organisms collected from the 100-N Area for which measured concentrations of radionuclides have been reported or from modeled tissue concentrations based on concentration ratios (CR) and concentrations of radionuclides in N Springs water.

Doses were calculated by two methods: 1) hand calculations using parameters specific to the organisms under investigation, and 2) application of the GENII (Napier et al. 1988) and CRITR (Baker and Soldat 1992) computer software systems. The CRITR model produces considerably higher doses than the hand calculations because of conservative factors used in the absence of data applicable to fish or wildlife. The doses from ingestion (feeding, drinking) and external exposure (immersion) were combined to determine the total estimated dose rates to the organisms.

METHODS

The following sections describe the development of source terms, selection of endemic biota, and exposure scenarios used in the assessment.

SOURCE TERMS

Source terms were developed for N springs water, aquatic foodstuffs, and terrestrial vegetation.

N Springs Water

The radionuclide concentrations in the spring water source were based on the 95% upper confidence limit of measured concentrations of ^{3}H and ^{137}Cs from January to July 1991 and the 95% upper confidence limit of measured concentrations of ^{90}Sr from April to July 1990 (Table 1, see also Appendix). Other radionuclides identified in the data, supplied by Westinghouse Hanford Company, were below detection limits or had only a few results above detection. For some dose calculations, the water concentrations were taken to be 10% of those measured in the spring water to account for dilution by river water.

Aquatic Foodstuffs

Analytical data on concentrations of specific radionuclides measured in aquatic biota collected near the 100-N Area in the Columbia River were used to model doses to animals

TABLE 1. Measured Concentrations of Radionuclides in N Springs Water (pCi/L), 1991 Data

Radionuclide	Dates Sampled	Mean	95% UCL[a]	Maximum	Minimum	n[b]
^{3}H	Jan.-July	32,000	41,000	94,000	4,000	24
^{60}Co	Jan.-July	0.7	0.8	1.4	<0.03	24
^{90}Sr	Jan.-July	5,400	6,200	7,900	2,900	25
^{90}Sr	Jan.-Mar.[c]	3,600	4,000	5,400	2,900	11
^{90}Sr	Mar.-July[c]	6,800	7,400	7,900	5,100	14

(a) Upper confidence limit.
(b) Number of samples.
(c) ^{90}Sr concentrations are reported for 2 time frames, see Figure 1, Appendix A.

that consume these biota. Doses to clams were calculated based on ^{60}Co, ^{90}Sr and ^{137}Cs as reported in clams. Doses to fish-eating ducks were estimated with the CRITR computer code using undiluted spring water concentrations and concentration ratios, and assuming long enough exposure times for both the forage fish and the waterfowl to come to equilibrium with their diet.

Fish (Carp)

Carp was used as a representative species because it was collected in the river near the 100-N Area and is known to consume clams. Asiatic clams found in the mud and gravel near N Springs are immobile and likely to accumulate higher concentrations of radionuclides than most other organisms. The concentrations of key radionuclides determined by analysis of clam samples collected near the N Springs area are reported in Table 2. A concentration ratio of 1620 between the level of ^{90}Sr in clam shells and the level in 100% spring water was used to estimate the dose to the clam (Vanderploeg et al. 1975).

Fish-Eating Duck

The CRITR code was used to estimate the potential radiation dose to a hypothetical fish-eating duck. This duck eats fish that have come to equilibrium with the exposure conditions near the N Springs. The fish-eating duck consumes 200 g of these fish daily, which contain ^{3}H, ^{60}Co, and ^{90}Sr (Table 3). The fish-eating duck is assumed to reside in the area for 9 months and feed in the shoreline area 50% of the time it resides there. A nesting pair of fish-eating ducks probably would leave the area after its brood had left the nest, a period of time estimated to be no longer than 6 months.

TABLE 2. Maximum Measured Radionuclide Concentrations in Clam Flesh Collected Near the N Springs (1990 data, Woodruff and Hanf 1991)

Radionuclide	Concentration, pCi/g
^{60}Co	0.06
^{90}Sr	0.05
^{137}Cs	0.02

TABLE 3. Maximum Radionuclide Concentrations in Fish Flesh Collected Near N Springs, Estimated from the CRITR Model

Radionuclide	Concentration, pCi/g
^{3}H	41
^{60}Co	0.4
^{90}Sr	370

Terrestrial Vegetation

Analytical results from several species of vegetation collected from the 100-N Springs shoreline were used to generate a hypothetical "worst case" plant that was assumed to be consumed by deer or rabbits (Table 4).

EXTERNAL DOSES TO AQUATIC BIOTA

Dose estimates were made for fish and water plants exposed to 100% spring water and for water plants exposed to 10% spring water. The external dose to a clam buried in the sediment contaminated by spring water was also calculated. External dose calculations for ducks assume that the duck remains in N Spring water 100% of the time, 50% of the time floating on the surface, and 50% of the time immersed diving for fish. However, we assume for internal dose calculations that the duck obtained only half of its food fish from the N Springs area.

TABLE 4. Maximum Concentrations Observed in N Springs Area Vegetation Used to Generate "Worst Case" Plant (1990 data)

Radionuclide	Concentration, pCi/g	Species
^{3}H	3.7	Dogbane vegetation
^{90}Sr	437	Mulberry twigs/leaves
^{60}Co	0.161	Mulberry twigs/leaves
^{137}Cs	0.244	Mulberry twigs/leaves
^{234}U	0.168	Chicory vegetation
^{235}U	0.006	Chicory vegetation
^{238}U	0.031	Chicory vegetation
^{238}Pu	0.00032	Chicory vegetation
$^{239/240}Pu$	0.001	Chicory vegetation

WILDLIFE EXPOSURE SCENARIOS

The exposure scenarios assume 100% consumption of undiluted spring water and hypothetical vegetation (Table 4). We assume a 50 kg deer consumes 11 L/d of undiluted spring water and 3.7 kg/d of N Springs shoreline vegetation. A hypothetical 1-kg cottontail rabbit was assumed to drink 0.2 L/d 100% spring water and eat 75 g/d of N Springs hypothetical shoreline vegetation.

The dose from external radiation exposure (9E-4 rad/d) was based on measurements obtained from a thermoluminescent dosimetry (TLD) monitoring station located 3 feet above ground at the N Springs shoreline (0.04 mrem/hr, Woodruff and Hanf 1991).

RESULTS

The majority of the calculated dose rates come from ^{90}Sr and its ^{90}Y progeny. Cobalt-60 contributions to the calculated dose rates were a small fraction of the ^{90}Sr dose. Contribution to dose rates by ^{3}H were negligible. The calculated dose rates for several aquatic organisms and wildlife are summarized in Table 5.

AQUATIC ORGANISMS AND PATHWAYS

This section covers doses from external and internal sources to Columbia River plants and animals found around the N Springs shoreline.

Water Plants

The external dose rate for water plants in 10% spring water was calculated to be 3E-7 rad/d. Because of the small diameter of these water plants, much of the radiation from internally deposited radionuclides would escape to the surrounding water without being

TABLE 5. Summary of Potential Dose Rates (rad/d) Estimated for Aquatic and Terrestrial Biota from the N Springs

Species	Dose Rate (rad/d) Internal	External	Total	Comments
Water plant	3E-7	3E-7	6E-7	10% spring water
Clam	4E-2	4E-1[(a)]	4E-1	By CRITR model
	4E-6	---	---	By analysis of clam tissue and shell
Crayfish	4E-2	1E-2	5E-2	External dose estimated at sediment surface
Fish (carp)	2E-2	3E-6	2E-2	CRITR model; 100% spring water
	7E-5	3E-6	7E-5	Diet of clams
Fish-eating duck	5E-1	2E-6	5E-1	Half of diett was N Springs forage fish
Deer	8E-2	9E-4	8E-2	
Rabbit	6E-1	9E-4	6E-1	

(a) Includes 3.5E-1 rad/d from ^{90}Sr in shell and 5E-2 rad/d from sediment.

adsorbed by the plant. As an order of magnitude estimate, the internal dose was assumed equal to the external dose from water immersion. Therefore, the total dose was estimated to be 6E-7 rad/d.

Clams

Under the 100% spring water exposure scenario, the external dose to the clam is 5E-2 rad/d. The CRITR dose rate estimate (based on bioaccumulation factors and concentrations of radionuclides in the undiluted spring water) is 5E-2 rad/d. The potential dose to the clam from ^{90}Sr in the shell was estimated at 3.5E-1 rad/d and was based on a CR of 1620 for ^{90}Sr in the shell. The combined internal and external dose rate was 0.4 rad/d as calculated by the CRITR model. Based on measured concentrations of radionuclides in whole clam flesh, the internal dose is 4E-6 rad/d.

Crayfish

The CRITR model uses the same concentration ratios for clams and crayfish, therefore the internal dose rates for these two organisms were identical. However, the external dose rate was based on the crayfish spending 50% of the time on the sediment surface and 50% immersed in 100% spring water. The total external dose is estimated to be 1E-2 rad/d. Consequently, the combined dose rate (internal and external) was calculated to be 5E-2 rad/d.

Carp

The carp that feeds exclusively on clams would have an internal dose rate of 7E-5 rad/d based on the measured concentration of radionuclides in clams (Table 2). The estimated internal dose rate based on concentration ratios in the CRITR model was 2E-2 rad/d. The potential external dose rate from immersion in 100% spring water was 3E-6 rad/d based on measured concentrations of ^{3}H, ^{60}Co, and ^{90}Sr (Appendix A). The combined internal and external estimated dose rate for carp based on measured radionuclides in clams potentially consumed by carp was 7E-5 rad/d; the CRITR model predicts a dose rate of 2E-2 rad/d. At a dilution of 10% spring water, the dose rate was 2E-3 rad/d.

Fish-Eating Duck

The external dose for the fish-eating duck was based on exposure to surface water 50% of the time and exposure by immersion in the water 50% of the time. The resulting combined external dose rate was 2E-6 rad/d. The calculated internal dose rate for the fish-eating duck from ingestion of 100-N Area fish was 0.6 rad/d.

TERRESTRIAL WILDLIFE

This section discusses doses for deer and cottontail rabbits that would feed on vegetation growing in the N Springs area.

Deer

The potential dose rate to deer was calculated on the basis of dietary intake of 11 L/d of 100% spring water and 3.7 kg/d of hypothetical shoreline vegetation. The potential internal dose from drinking 100% spring water was estimated to be 4E-3 rad/d and from consumption of vegetation was 8E-2 rad/d. Consequently, the combined ingestion dose rate was 8E-2 rad/d. The dose rate estimated from TLDs located near the 100-N Area shoreline was 9E-4 rad/d. The total estimated dose to deer was 8E-2 rad/d.

Rabbit

The dose rate to the cottontail rabbit was 0.6E-1 rad/d from consumption of vegetation and 3E-3 rad/d from drinking 100% spring water. The external exposure adds 9E-4 rad/d, bringing the total estimated dose to 6E-1 rad/d.

DISCUSSION

This assessment provides a preliminary evaluation of potential doses to aquatic biota and wildlife residing at the 100 N Springs. The analysis employed conservative assumptions in the dose calculations to arrive at upper bound estimates of the dose to aquatic and terrestrial organisms: 1) use of elevated exposure concentrations, 2) fulltime residence at N Springs, and 3) restrictive feeding patterns at N Springs.

ELEVATED EXPOSURE CONCENTRATIONS

The concentrations of radionuclides used for the source terms in the analysis were upper 95% confidence limits and the use of average concentrations would reduce the estimated dose rate.

RESIDENCY

Exposure conditions for aquatic organisms, excluding fish-eating ducks, were such that the organisms reside near the N Springs 100% of the time and are exposed, where applicable, to full-strength spring water. With the exception of clams and rooted aquatic vegetation, this would not occur. Wildlife were also assumed to inhabit the N Spring area 100% of the time.

FEEDING PATTERNS

Dietary intake would not involve the scenario using 100% spring water for the prediction of concentrations in aquatic organisms entering the food chain or 100% worst-case vegetation consumed by deer and rabbits. Specific considerations by species include:

- Clam-Eating Carp--The conservative assumption was that the entire diet of the hypothetical carp consisted of 225 g/d clams from the N Springs area for its entire life. Doses were calculated assuming dietary equilibrium. This approach is conservative because carp would neither reside solely near the N Springs nor feed exclusively on clams. Modelled equilibrium between clam-tissue concentrations of radionuclides and the environment would occur only after 2 to 3 years of residence in this area.
- Fish-Eating Duck--The dose to the fish-eating duck is conservative for a number of reasons. Because of the long biological half-life of ^{90}Sr, the fish

consumed by the duck must have resided for their entire life in the N Springs to reach equilibrium. Additionally, the food fish don't grow so that they remain at an edible size for the duck. The number of unrealistic and highly conservative assumptions made at each step of this food-chain-based dose estimate are so great that no such duck could exist.

- Deer --The exposure scenario was conservative because mule deer may browse on N Springs vegetation when they enter the area, but the majority of their diet (probably >75%) consists of annuals and vegetation from perennial shrubs like rabbit brush, bitterbrush, or sagebrush. Additionally, deer in the area will not always eat or drink near the N Springs. It is also likely that some of the water they drink is taken upstream of the N Springs area or downstream after dilution by the river.

- Cottontail Rabbit --Rabbits probably do not drink proportionately as much as deer. Their home range is small and there is a likelihood that resident rabbits would consume a higher percentage of their diet near the N Springs, although not 100%.

OVERVIEW

It is our judgment that the conservative dose rates are overestimated by a factor of 10 to 100. More accurate dose estimates would require additional characterization of radionuclide levels in biota collected near the N Springs and more realistic exposure scenarios to N Spring water and contaminated food sources. Actual measured values may be obtained by reviewing additional data from Site monitoring programs. For example, a brief survey of measured levels of radionuclides in fish flesh indicates that concentrations are two to three orders of magnitude less than the concentrations predicted by the CRITR model using 100% spring water. Had actual exposure conditions been known, the CRITR model would have predicted more accurate dose estimates.

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APPENDIX

N SPRINGS WATER RADIONUCLIDE ANALYSIS 1991

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This appendix contains summary statistics computed for the concentrations of radionuclides measured in N Springs water during 1991. The data were provided to PNL by WHC for this scoping assessment and were used to characterized the source term of spring water for the assessment. The data are presented in summary tables and graphically. Data in the summary tables are good to 2 significant figures. The figures are plotted in Julian days and cover the period of January 1, 1991 (day 1) to July 3, 1991 (day 184) (Figure 1).

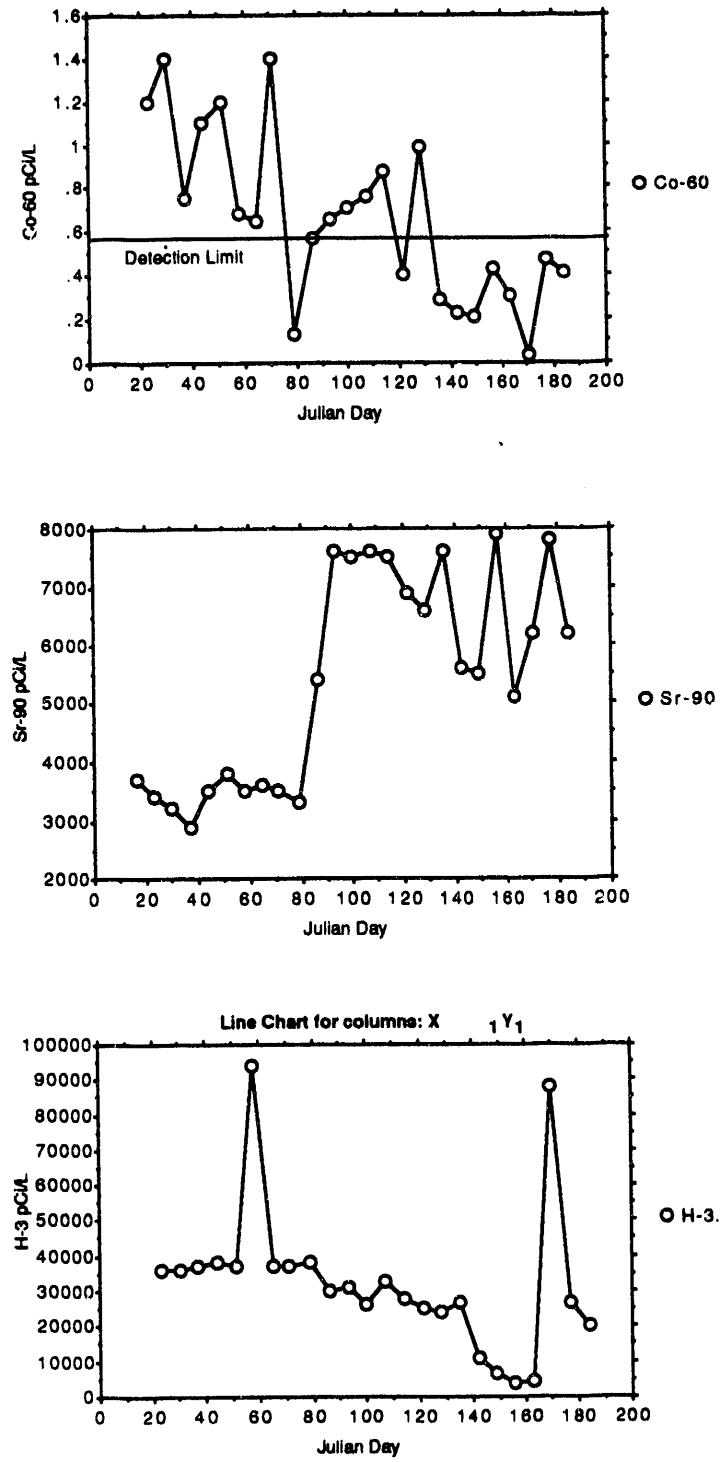

FIGURE A.1. Concentration of ^{3}H, ^{60}Co, and ^{90}Sr in N Springs Water. Sample dates were January 16, 1991 to July 3, 1991.

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