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Environmental Radiation Program

100-D ISLAND RADIOLOGICAL SURVEY

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Environmental Radiation Program

100 D ISLAND RADIOLOGICAL SURVEY

R. Allan Danielson
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November 1996

Washington State Department of Health

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EXECUTIVE SUMMARY

This report summarizes results from a radiological survey of a sandy downstream section of 100-D Island. It was conducted in September 1995 by staff from the Washington State Departments of Health and Ecology with logistical support from the Pacific Northwest National Laboratory and U.S. Department of Energy.

Historical data characterizing the distribution of discrete ^{60}Co contaminated particles in this sandy downstream section was questionable. Signs that this section of the island was frequented by fishermen was evident, and the potential for public radiation exposure warranted the survey.

A walking survey of exposed island shoreline was conducted when river levels were at their lowest. All surveys were performed using micro-R meters suspended approximately 2-4 centimeters above the ground. Background exposure rates along the river shore ranging from 7-8 μR/hr. were measured. A pressurized ion chamber (PIC) was used to measure variations in background at three island locations. Ambient background measurements recorded by the PIC varied from 8.8 - 9.5 μR/hr. Three discrete particles were detected and contact measurements ranged from 85 - 2000 μR/hr.

Analytical results for radioactive and non-radioactive constituents are provided in the report.

The survey of the downstream end of 100-D Island produced results that were consistent with previous radiological surveys. The net results support a conclusion that ^{60}Co contaminated particles do not pose significant human health risks. Radiological posting should be consistent with Hanford Contractor protocols since ownership of the island is retained by the U.S. Department of Energy.

INTRODUCTION

There have been several field surveys focused on characterization of radioactivity in D-Island sediments. Collectively, these surveys confirm a distribution of discrete ^{60}Co contaminated particles in the upper 15 centimeters of island sediments. Particle density estimates range from 0.04 to 0.07 particles per cubic meter and contact exposure rates of several hundred micro-R/h are not uncommon. Ambient exposure rates range from 6 to 8 μR/h.

In July 1995, the reliability and lack of data for a sandy downstream section of the island was being debated within the Tri-Party Agreement. As a result, the Washington Department of Ecology requested that the Department of Health conduct a radiological survey of this section of the island. The survey was conducted by staff from the Departments of Health and Ecology on September 18, 1995.

HISTORICAL OVERVIEW

The 100-D Island is located in the Columbia River approximately 250 meters offshore of 100-D Area (See Figure 1). It is a low-lying island that becomes partially submerged due to daily fluctuations in the river level. Most of the 25-acre island is covered by a layer of sediments predominated by cobbles, 1 to 6 inches in diameter, and coarse sandy gravel. Sediments grade to coarse sands where slack-water condition exists as evidenced by a coarse sandy beach located on the downstream end of the island. Vegetation, present on the higher elevations of the island, consists of grass, small bushes and a few small trees.

The D-Reactor cooling water discharge line extends from an outfall on the south bank of the Columbia River and runs underneath the upstream end of D-Island. As designed, water was held in a retention basin to allow thermal cooling and decay of short-lived radioactivity before it was discharged to the center of the river.

The D-Island discharge line was physically and radiologically characterized in 1984 as part of the decommissioning process (UNC, 1986). In 1990, as part of a site cleanup and surveillance effort, the D-Reactor effluent line vents became an issue. The vents, which became exposed during low river flow, are a potential source of contamination. A decision was made to remove and plug the vent pipes to prevent potential public exposure and/or release of contamination. Part of the vent pipe removal project was to survey the area to find any contamination

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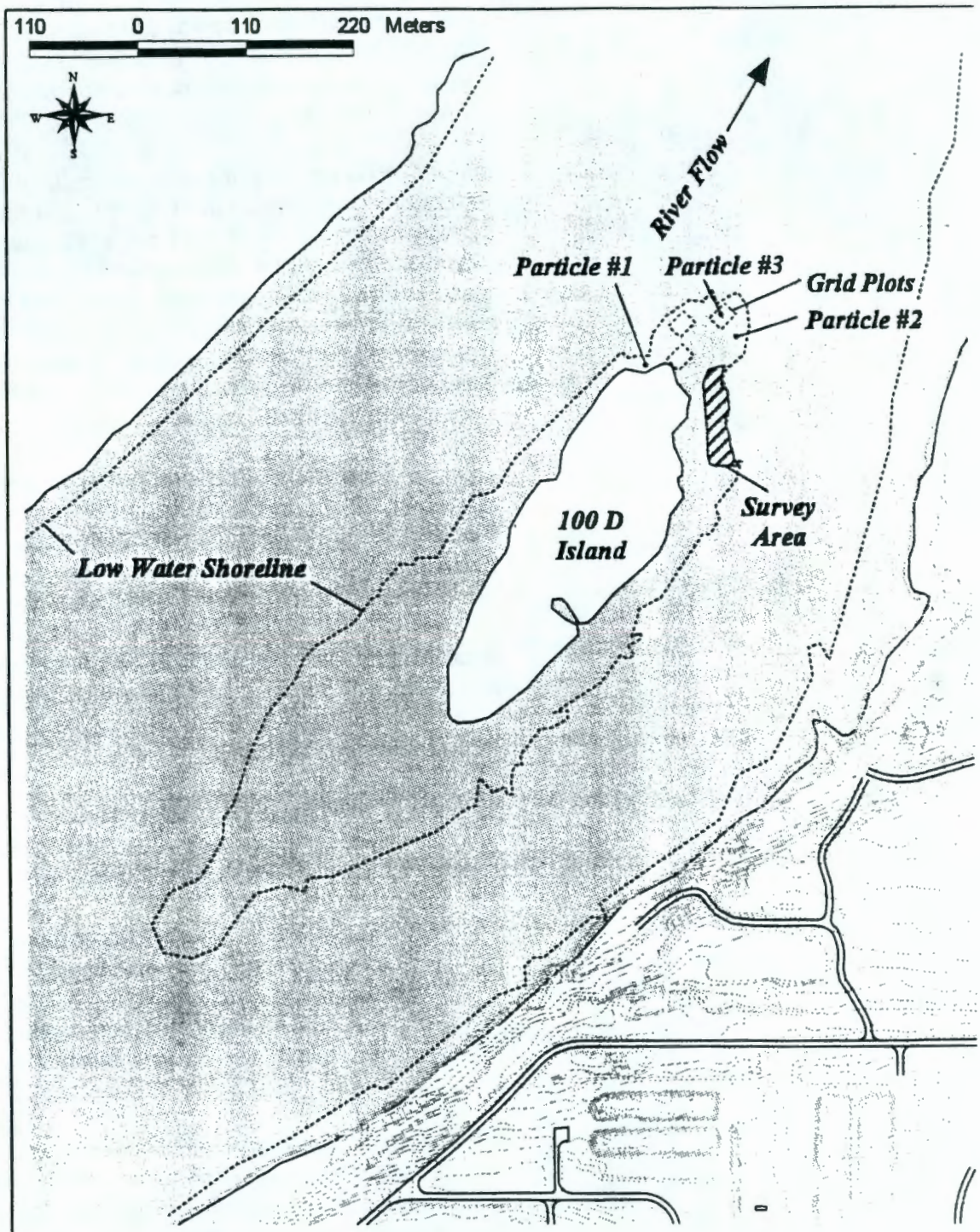

Figure 1. Map of 100-D Island and Survey Area

which had escaped through the vents. Approximately 1/2 of the upstream end of the island was surveyed in 1993 using the USRADs system (Wade and Wendling 1994). Contamination consisted almost exclusively of discrete radioactive particles of ^{60}Co.

In June 1995, the issue of radioactive contamination on D-Island was being debated within the Tri-Party Agreement (D-Island DQO Process Summary, 1995). At issue was the adequacy of existing data to characterize the distribution of discrete radioactive particles on a sandy downstream section of the island. This sandy section is submerged during periods of normal river flow and is exposed during periods of low flow. Evidence confirms this section is frequented by fishermen. Although access is not controlled, it is closed to the public.

Due to a potential for public exposure, the Department of Health was asked to perform a radiological survey of this section of the island. The purpose of the survey was to determine the distribution of radioactive particles to justify radiological posting, thus minimizing the probability of human exposure.

A radiological survey plan for the exposed sandy downstream shoreline was prepared by the Department of Health and distributed to all participants. A conceptual summary of the Department's plan follows:

> A walking survey of exposed shoreline will be conducted when river levels are at the lowest. Surveys would be conducted along two paths parallel to the water line.
>
> Three five-by-five meter survey plots would be established and directly surveyed for discrete particles. Results would be compared with particle density measurements made by previous surveys. Several 20 to 40 centimeter deep excavations in the sandy area would be made to look for buried discrete particles.
>
> All surveys would be performed using calibrated micro-roentgen meters (μR meter) and micro-rem meters (μRem meter) held approximately 2-4 centimeters above the ground. A calibrated count rate meter (GM meter) would be used to help locate a discrete particle in the sediment

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matrix. Instrument readings along survey lines would be visually averaged over 100 meters and recorded.

A pressurized ionization chamber (PIC) would be utilized to provide an accurate measurement of the external gamma exposure rates at several island locations. The PIC can measure external gamma radiation at normal background levels with a precision in the range of ± 1μR/h.

A global positioning device would be used to document the location of all samples and surveys.

Variations in field conditions would justify plan revision.

INSTRUMENTS

Instruments, such as micro-R meters, micro-rem meters and the pressurized ion chambers (PIC), were selected on the basis of their reliability, ability to detect small amounts of radioactivity, and operational convenience in field situations. The PIC, an integrating instrument, measures the total dose over a given time span. It is a heavy, bulky instrument comprised of two main components: the electronics and a pressurized gamma ion chamber capable of measuring ambient radiation levels with a precision of ± 1μR/h. Portable instruments, like the micro-R and micro-Rem, are rate meters that continuously measure fluctuations in exposure and dose per unit time.

The relative sensitivities of each instrument to various gamma energies are illustrated in Figure 2 (Thatcher 1995). The NaI (sodium iodide) detector in the micro-R meter is very efficient and most sensitive to gamma energies of approximately 50 keV to 700 keV. This property makes it an ideal instrument for conducting walking surface scans and taking environmental grid point measurements. In general, the micro-rem meter is the portable equivalent of the pressurized ion chamber (PIC) and provides accurate dose rate measurements over a wide range of gamma ray energies. The under response of the PIC, below 70 kev, is attributable to the attenuation of low energy gamma radiation by the metal casing surrounding the ion chamber.

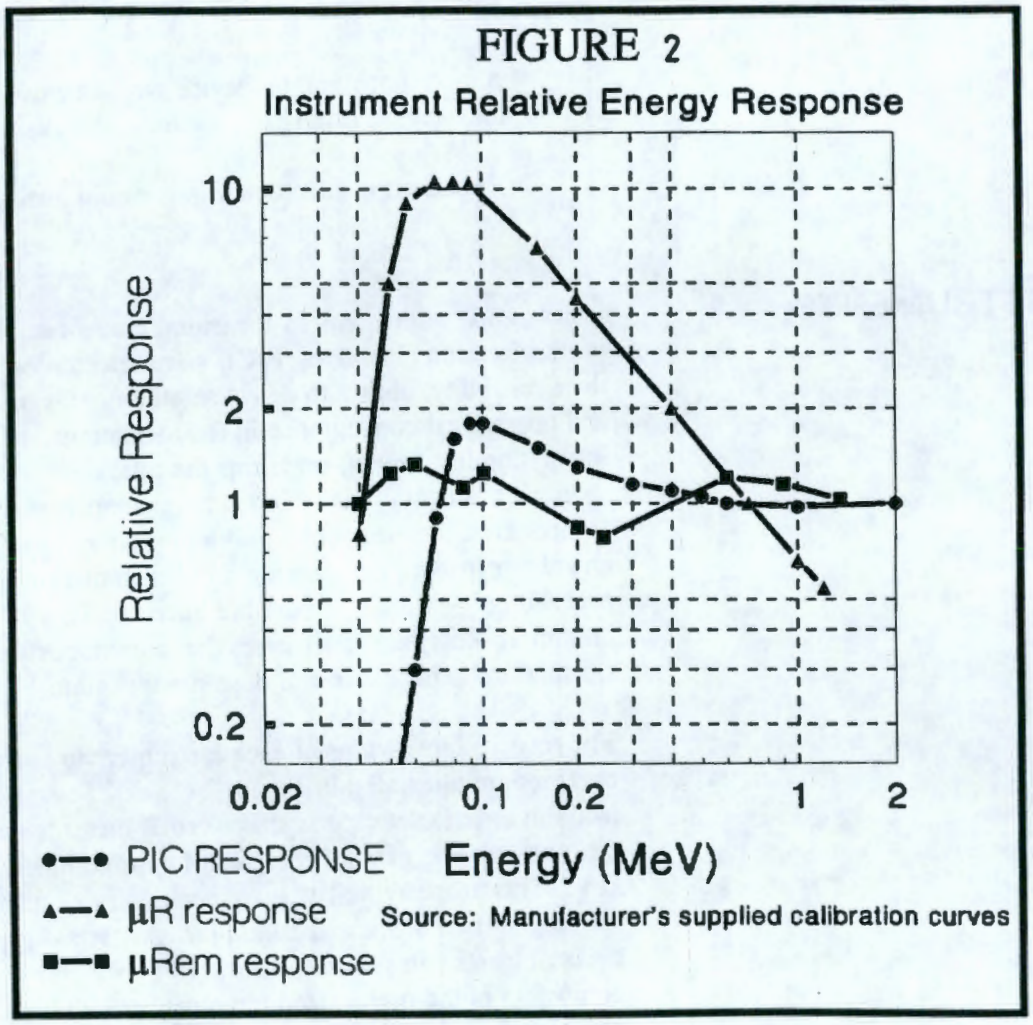
FIGURE 2
Instrument Relative Energy Response
Relative Response
10
2
1
0.2
0.02
0.1
0.2
1
2
Energy (MeV)
PIC RESPONSE
µR response
µRem response
Source: Manufacturer's supplied calibration curves

RESULTS AND DISCUSSION

The PNNL *Surface Environmental Surveillance Project* provided a boat and driver to transport the survey team to the northeast (downstream Hanford side) side of 100-D island. The river flow was very low, exposing a small area of eurasian milfoil. A sizable section of sandy beach and low-lying gravel bar on the downstream end of the island was revealed.

The micro-R meter survey was conducted by two surveyors walking parallel paths along the water line perimeter of the downstream end of the island. Instruments were suspended at a height of 2-4 centimeters above the ground surface and two passes were made while the river was at its lowest level. The second pass was made at 2-5 meters inland from the waters edge. As the water level in the river began rising, the survey continued inland from the shore until all of the low-lying area was surveyed (See shaded area on map). Special attention was given to the sandy beach (approximately 20 by 100 meters) and was surveyed in detail using a 1 meter grid pattern.

Measurements were recorded by averaging exposure rate fluctuations over each 100 meters surveyed. Instruments were operated in the "audio mode" enhancing the surveyors ability to detect subtle changes in the exposure rate. The micro-R survey results were quite consistent, ranging from 8.5 - 9.5 μR/h and no areas of elevated exposure rates were detected, except where discrete particles were located. Typical background exposure rates along the river shore range from 7-8 μR/h.

A pressurized ion chamber (PIC), mounted on a tripod approximately 1 meter above the terrain, was used to measure variations in exposure rate at three island locations (Reference Map for Locations). It was set to collect a data point every 15 seconds, internally average data points and, generate an average exposure rate. Data collected for 1.5 hours on the sandy beach section of the island averaged 9.5 μR/h. Measurements generated in the middle of an area dominated by coarse gravel and cobble sediments averaged 9.0 μR/h over a 1.2 hour time span. A third location, on the north shore of the island, averaged 8.8 μR/h over the same interval.

In addition, three 5 by 5 meter plots were selected at the downstream end of the island. These were surveyed for discrete particles using a tight grid pattern to compare with particle densities measured by previous surveys.

Three discrete particles were detected during the survey. A micro-R meter and GM pancake probe were used to define the general location of each particle in the sediments and a trowel was used to separate the particle from the cobbles and gravel. All particles were isolated in the coarse sand fraction of island sediments and collected in individual sample containers.

Particle #1: This particle was found on the north side of the island. The shoreline in this area is comparatively sloped and appears to be at or near the high water mark. A surface exposure rate of 30 μR/h was measured and the particle was found about 10 to 15 centimeters below grade. A contact reading of 700 μR/h on the isolated particle was indicated.

Particle #2: This particle was found in a relatively flat area, just north of the sandy beach, and is intermittently exposed by fluctuations in the river level. A surface exposure rate of 20 μR/h was measured and the particle was found about 5 to 10 centimeters below grade. A contact reading of 2000 μR/h on the isolated particle was indicated.

Particle #3: This particle was found in one of the 5 by 5 meter plots, near the center of an intermittently exposed flat area on the downstream end of the island. A surface exposure rate of 20 μR/h was measured and the particle was found about 5 centimeters below grade. A contact reading of approximately 85 μR/h was indicated on the isolated particle.

All of the discrete particles recovered were sent to the Department of Health office in Olympia to be analyzed by gamma spectroscopy. The gamma spectrum indicated only the presence of ^{60}Co. A micro-rem meter was used to provide a measure of the dose rate on the discrete particles recovered. Quantitative measurements were not performed.

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Two shallow pits were excavated to a depth of 30 to 40 centimeters to search for particles at depth and measure sub-surface radiation levels. The first, in an area near the location of particle #2, a maximum exposure rate of 11μR/h was measured. The second, excavated in the sandy beach area, indicated a radiation level of 20 μR/h and a soil sample was collected for analysis. This sample was split and fractions sent to the Department of Health Radiation Laboratory in Seattle and the Department of Ecology contract laboratory.

SAMPLE RESULTS

Analytical results for radioactive and nonradioactive constituents are summarized in the tables below. Average background concentrations for various constituents are presented for purposes of comparison. Radiological and non-radiological values reported are consistent with typical concentrations measured in offsite soil. Zinc (230 mg/kg) was the only metal reported that was higher than mean background. The zinc value reported is less than the maximum value (366 mg/kg) used to calculate the mean and is within the range of observed background values seen in the Yakima Basin.

Concentration of Radionuclides in 100-D Island Soil
(pCi/g ± 2 sigma counting error)

Nuclide	Health Lab	Ecology Lab	PNNL Lab[1]
Co-60	1.6 E-01 ± 0.16-01	1.57 E-01 ± 0.37 E-01	NR
Cs-137	6.61 E-01 ± 0.39 E-01	ND	3.9 E-01 ± 1.3 E-01
Eu-152	2.75 E-01 ± 0.45 E-01	ND	NR
Eu-154	3.2 E-02 ± 2.4 E-02	ND	NR
Gross Beta	1.93 E+01 ± 0.25 E+01	2.62 E+00 ± 0.51 E+00	NR
Sr-89	NA	< 1.5 E-00	NR
Sr-90	5.0 E-03 ± 3.0 E-03	< 7.1 E-01	7.9 E-02 ± 1.9 E-02
Tc-99	3.8 E-01 ± 1.4 E-01	NA	NR
Gross Alpha	NA	2.45 E+00 ± 0.45 E+00	NR
Pu-238	8.9 E-03 ± 3.2 E-03	NA	NR

Concentration of Radionuclides in 100-D Island Soil (pCi/g ± 2 sigma counting error)			
Nuclide	**Health Lab**	**Ecology Lab**	**PNNL Lab[1]**
Pu-239	1.14 E-02 ± 0.37 E-02	NA	8.4 E-03 ± 3.0 E-03
Total Uranium	1.2 E+00 ± 0.1 E+00	5.89 E+00 ± 0.79 E+00	7.1 E-01 ± 1.4 E-01

1 Offsite averages reported in the *Hanford Site Environmental Report for Calendar Year 1993*
NA - Not Analyzed
ND - Not Detected
NR - Not Reported

METALS ANALYSIS OF 100-D ISLAND SOIL (mg/kg) Department of Ecology Contract Laboratory		
ANALYTE	**100-D ISLAND**	**YAKIMA BASIN BACKGROUND**
Aluminum	5100	37,200
Antimony	ND	-
Arsenic	3	5
Barium	40	-
Beryllium	ND	2
Cadmium	ND	1
Calcium	2800	-
Chromium	12	38
Cobalt	5	-
Copper	18	27
Iron	13,000	51,500
Lead	17	11
Magnesium	3900	-

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METALS ANALYSIS OF 100-D ISLAND SOIL (mg/kg) Department of Ecology Contract Laboratory		
ANALYTE	100-D ISLAND	YAKIMA BASIN BACKGROUND
Manganese	150	1100
Mercury	ND	0.05
Nickel	14	46
Potassium	600	-
Selenium	ND	-
Silver	ND	-
Sodium	ND	-
Thallium	ND	-
Vanadium	22	-
Zinc	230	79

ND - Not Detected

(-) - Not Measured

CONCLUSION

The survey of the downstream end of the 100-D Island produced results that were consistent with previous radiological surveys.

1978 - Pacific Northwest Laboratory (Sula, 1980) conducted a radiological survey of D-Island to determine the distribution and density of radioactive particles and measure ambient exposure levels.

Aerial surveys of Columbia River shoreline and island areas were conducted by EG&G Inc of Las Vegas in 1973-74, 1978 and 1988 (Tipton 1975, EG&G 1982, EG&G 1990).

1992 - The Pacific Northwest Laboratory (Cooper and Woodruff 1993) surveyed the islands and flood plains along the Hanford region of the Columbia River for radioactive and non-radioactive contamination.

1993 - Bechtel Hanford Company (Wade and Wendling, 1994) surveyed approximately 1/2 of the upstream end of D-Island utilizing *USRAD* equipment.

The ambient gamma radiation level measured at several island locations was near background. Burial depth and contact radiation levels of excavated discrete particles were within the range of values previously reported. No particles were found on the sandy downstream section of the island.

A rough estimate of particle density can be calculated using this survey data. For this survey, three, 5 by 5 meter plots were surveyed in which one particle was found. All particles were found at an average of 10 centimeters below grade, yielding a total of 7.5 cubic meters of sediment. Thus, the number of particles per unit volume is 1.3×10^{-1} particles per cubic meter. It should be noted, this figure is roughly double the particle density estimates of other studies and is clearly biased due to sample size.

Radiological hazards and potential health effects from exposure to ^{60}Co particles on this downstream section of D-Island are consistent with evaluations documented in previous correspondence and reports.

1994 - The Washington State Department of Health (Wells, 1994) publishes: *Special Report - Radioactivity in Columbia River Sediments and Their Health Effects*. This document summarizes previous radiological surveys and evaluates the health effects from exposure to residual radioactivity.

1994 - Letter to the Environmental Protection Agency. This letter provides a risk assessment of human exposure to ^{60}Co contaminated metallic specks in Columbia River sediments. A copy of this letter is included in Appendix A.

The net results from this survey support a conclusion that ^{60}Co contaminated particles in downstream D-Island sediments do not pose significant human health risks. Radiological posting should be consistent with Hanford Contractor protocols since ownership of the island is retained by the US Department of Energy.

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STATE OF WASHINGTON
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DIVISION OF RADIATION PROTECTION
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October 25, 1994

Larry Gadbois
Environmental Protection Agency
712 Swift Blvd., Suite 5
Richland, Washington 99352

Dear Mr. Gadbois:

The presence of ^{60}Co-contaminated metallic specks in the Columbia River raises several difficult regulatory questions. Among these are what are the potential health effects of these particles and what protocols should be implemented for their remediation?

Potential health effects can be separated into those that are carcinogenic and those that are non-carcinogenic. The potential non-carcinogenic, or acute, effect is tissue damage in highly localized areas of the skin or respiratory tract. The short term effect of this damage would be a lesion, while the long term effect would be a scar.

The carcinogenic potential of these specks primarily stems from two pathways. These are "ground shine", or external exposure, and ingestion. The maximum potential dose from ground shine has been estimated to be 0.04 mrem/year in a recreational scenario [We94]. This dose rate yields an annual cancer risk of 2.7×10^{-8}, using BEIR V risk estimates. Cooper and Woodruff published dose estimates for the ingestion pathway in 1993 [Co93]. Their estimate implies that an individual would receive a dose of 83 mrem if that individual were to ingest a speck with the highest recently-measured activity of 22 µCi. The Department of Health has estimated that the probability that an individual would ingest a speck is less than 0.31×10^{-6}. The product of this probability and the risk of the above maximum dose leads to a cancer risk per year of 0.23×10^{-10}.

The pathways of inhalation and direct contact with the skin are the means of the non-carcinogenic potential effects of specks. This is a deterministic, or nonstochastic, effect which will occur if the localized dose exceeds a threshold value and will not occur if the threshold value is not exceeded. The National Council on Radiation Protection has suggested that the contact exposure limit of 75 µCi-hrs [NCRP89] is the exposure threshold above which lesions will occur.

Cooper and Woodruff suggest that the maximum reasonable time a speck would remain directly on the skin is 48 hours, which implies that a speck with an activity of 1.6 µCi greater could exceed the 75 µCi-hr limit. Cooper and Woodruff also estimate that the localized dose equivalent to 75 µCi-hrs could be

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exceeded by the use of clothing containing a 1.6 μCi speck in 300 hours, and in a sleeping bag in 440 hours. These longer potential exposure times are plausible because it has been shown that specks are not easily washed out of clothing [NCRP89]. The Department of Health has conservatively estimated that the probability per year of an individual "picking up" a speck on their skin or clothing is 1.6×10^{-6} and 5.8×10^{-6} respectively.

Cooper and Woodruff also assume a 48 hour retention time for the inhalation pathway. They estimate that the dose limiting scenario for this pathway is uptake and retention of a speck in the nose. In this scenario, as in the case of direct skin exposure, specks with activities larger than 1.6 μCi will exceed the 75 μCi-hr limit. The Department of Health has estimated that the maximum probability for inhalation of a speck is 1.2×10^{-9}.

The calculations of these probabilities can be found in the Appendix, and the dose estimates are contained in the publications of Cooper and Woodruff [Co93] and the Department of Health [We94].

The maximum carcinogenic risks that have been calculated here are all several orders of magnitude below the 10^{-4} level and the maximum lesion probabilities are all approximately 10^{-6} or less. Thus the Department of Health does not believe that the human-health risks of radioactive specks in the Columbia River are sufficient to justify further surveys to locate and remove them. Nevertheless, when specks are found in the course of cleanup actions the Department recommends that they be removed. This is consistent with other environmental radiological cleanups, such as uranium mills, where "hot spots" are always remediated when they are found. This recommendation does not apply to the remediation of reactor effluent pipes in the Hanford Reach of the river because it is not clear to the Department if these pipes are a significant repository of radioactive specks.

If you have any questions, please call me at 206-586-3306 or Doug Wells at 206-586-3585.

Sincerely,

John L. Erickson, Head
Environmental Radiation Section
Division of Radiation Protection

JLE:DPW:KP
Attachments

cc: Chuck Cline, Ecology
Dave Holland, Ecology
Jerry Yokel, Ecology

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APPENDIX A CONTINUED

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Appendix - Probability Estimates

A complete risk assessment of radioactive specks in sediments includes both an estimate of the carcinogenic and non-carcinogenic effects if an individual is exposed and the probability of exposure. The Department of Health calculates this probability for each pathway by dividing the volume of sediments that the "maximally exposed individual" is exposed to each year by the minimum sediment volume that is likely to contain one speck. The latter quantity is the inverse of the maximum speck density as measured by Sula [Su80] on D-Island.

Sula found that the maximum number of specks per unit area was 5.6×10^{-3} m^{-2}. Since all of these specks were found to be in the top 15 cm, this yields a volume density of 3.7×10^{-2} m^{-3}. The inverse of this yields the minimum single-speck sediment volume of 2.7×10^{7} cm^3.

To estimate the volume of sediment ingested per year by the maximally exposed individual the Department of Health assumed a consumption rate of 200 mg/day [HSBRAM] for 63 days per year. This is a 500 hours-per-year recreational scenario[Sc93], which is approximately ten times more conservative than the Hanford Site Baseline Risk Assessment Methodology. This yields an annual consumption rate of 12.6 grams per year, or assuming a sediment density of 1.5 g/cm^3, 8.4 cm^3 per year. Thus the annual probability of consumption is 8.4 cm^3 divided by 2.7×10^{7} cm^3, or 0.31×10^{-6}.

The mass of sediment inhaled per year is given by the product of three factors: the breathing rate (approximately 1 m^3/hr), the number of hours spent recreating on the river (500 hours) and the mass-loading of suspended sediment in the air (0.0001 g/m^3)[Sc93]. The latter factor is twice as conservative as EPA's guidance [EPA91]. This yields an annual inhalation of 0.05 g, or assuming a sediment density of 1.5 g/cm^3, an annual inhalation of 0.033 cm^3 of sediment. Thus the annual probability of inhalation is given by 0.033 cm^3 divided by 2.7×10^{7} cm^3, or 1.2×10^{-9}.

The mass of sediment that annually adheres directly to the maximally exposed individual's skin is given by the product of three factors: the adherence rate (0.0002 g/cm^2 per day) [HSBRAM], the area of uncovered skin (5,000 cm^2) [HSBRAM] and the number of days per year (63 days). This yields an annual mass of 63 g, or 42 cm^3. Thus the probability of a speck adhering to the skin is 42 cm^3 divided by 2.7x107 cm^3, which yields an annual probability of 1.6×10^{-6}.

To calculate the probability of a speck adhering to clothing, the Department follows the calculation for adherence to skin, with the area of 5,000 cm^2 replaced by the area of a "reference man" [Sh92] (18,000 cm^2). This yields an annual probability of 5.8×10^{-6}.

APPENDIX A CONTINUED

These estimates utilized many conservative assumptions; however, it is important to keep several potential modifications in mind. Most of the specks are found in rocky areas where sediments are only found in the spaces between the rocks. Thus the above estimate of the density of specks in sediments available for uptake may be too low. Inclusion of this effect would reduce the minimum single-speck volume and raise the above probabilities. However, in rocky locations most of the surface area that is available for contact, ingestion or resuspension is taken by the rocks and not the sediments. Inclusion of this effect would reduce the above probabilities. Further, the density of specks is approximately three times that of a sediment "grain". This causes specks to sink below the surface, further reducing the probability of contact. The net result of these effects tends to cancel. Thus the Department of Health is confident that the probabilities calculated here are conservative estimates.