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Sequim Marine Research Laboratory Routine Environmental Measurements During CY-1977

by
J. J. Fix
P. J. Blumer

June 1978

Pacific Northwest Laboratory
Richland, Washington 99352
Operated for the
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SEQUIM MARINE RESEARCH LABORATORY ROUTINE ENVIRONMENTAL MEASUREMENTS DURING CY-1977

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SEQUIM MARINE RESEARCH LABORATORY ROUTINE ENVIRONMENTAL MEASUREMENTS DURING CY-1977

INTRODUCTION

Beginning in 1976, a routine environmental program was established at the Marine Research Laboratory (MRL) at Sequim, Washington. The program is intended to demonstrate the negligible impact of current MRL operations on the surrounding environs and to provide baseline data through which any cumulative impact could be detected. The sampling frequency of the program is shown in Table 1. The frequency is greater during the first 2 years of the program to provide sufficient initial information to allow reliable estimates of observed radionuclide concentrations and to construct a long-term sampling program.

The program is designed, primarily, to determine levels of radioactivity present in selected biota in Sequim Bay. The biota were selected because of their presence near the laboratory and their capacity to concentrate trace elements. Other samples were obtained to determine the radionuclides in Sequim Bay and laboratory drinking water, as well as the ambient radiation exposure levels and surface deposition of fallout radionuclides for the laboratory area. Appendix A provides a summary of the analytical methods used.

The present document includes data obtained during CY 1977 in addition to CY-1976 data published previously.[1] It is intended that a document be written each year providing a summary of the data collected and an evaluation of the data based on either historical data or regulatory requirements promulgated by the State of Washington or the U.S. Environmental Protection Agency.

SAMPLE COLLECTION AND ANALYSIS

Several environmental samples have been collected from the MRL environs. The results of all analyses are included herein. The program is primarily intended to measure concentrations of several radionuclides, although a few non-radiological analyses are also done. Specific details for all measurements follow.

DRINKING WATER

Results of radiological analyses for gross beta activity, gross alpha activity, ^{3}H and gamma-emitting radionuclides are shown in Table 2. All of the results are less than detectable with the exception of an occasional result for gross beta, gross alpha, and ^{3}H. These few positive results are very near the detection level and may simply be due to counting statistics or to low level activity from naturally occurring or fallout radiation. There is no indication that MRL activities have contributed to the observed levels.

Table 3 presents the results of total coliform analyses of MRL drinking water. The results are all <2 per 100 ml or within the standard of no detectable coliform organisms in drinking water.

BAY WATER

Results of radiochemical analyses of Sequim Bay water samples are shown in Table 4. All of the results are generally below the detection level with the exception of gross beta activity, gross alpha, and ^{40}K. Occasionally a positive tritium result is obtained. The ^{40}K activity is responsible for the positive gross beta counts. The positive gross alpha activity is attributable to naturally occurring uranium as shown by the specific U analysis during February 1977. The tritium results are attributable to

either the low level tritium concentrations in the environment because of worldwide fallout or the statistical uncertainty of measuring radionuclide levels near or below the detection level of the technique.

Table 5 is a summary of the copper as well as oil and grease analyses of Sequim Bay water. Additional data regarding Cu concentrations in Pacific Northwest coastal sea water using an extremely sensitive technique have been published. In general, these results are about a factor of 10 lower than the results included here.[2]

CLAMS

Three varieties of clams have been collected to date. Results of analyses for gamma-emitting radionuclides, ^{90}Sr and total plutonium are shown in Table 6. Potassium-40 from natural causes and ^{90}Sr and Pu from worldwide fallout have been observed. All other results are below the detection limit. There is no detectable radioactivity attributable to MRL operations.

SEAWEED

Samples of kelp and eelgrass were collected from Sequim Bay near the MRL dock. With the exception of ^{40}K, ^{90}Sr, and total plutonium, all of the results shown in Table 7 were less than detectable. Again, the ^{40}K is attributable to natural causes, and the ^{90}Sr and Pu to worldwide fallout.

AMBIENT RADIATION EXPOSURE

Table 8 is a summary of the external radiation level measured by thermoluminescent dosimeters placed 1 meter above ground level. The locations of the dosimeters are shown in Figure 1. Each dosimeter includes five chips of CaF_2:Mn (Harshaw TLD-400) encased in an opaque capsule lined with 2 mils of lead and 10 mils of tantalum.

The data have been relatively consistent from month to month as shown in Table 8. The low rate of exposure observed was somewhat surprising. The estimated annual external exposure rate would be about 40 mR or about 50% of the exposure observed near the Hanford Site in southeastern Washington State. However, a series of 12-hour measurements using a Reuter-Stokes ionization chamber at each of the TLD locations indicated an average external exposure rate of about 9 μR/hr. These results are summarized in Table 9.

SOIL

Results of radiochemical analyses of soil samples collected from two locations during 1976 and 1977 in the immediate vicinity of the MRL are shown in Table 10. The sample locations are shown in Figure 1. The low concentrations of naturally occurring ^{40}K, ^{224}Ra, and ^{226}Ra further confirm the relatively low exposure rates measured in the environs of the MRL. These concentrations are about 50% of the concentrations observed in the Hanford environs in the southeastern region of Washington State.

Statistically-positive measurement of artificially produced radionuclides was made for ^{90}Sr, $^{95}ZrNb$, ^{137}Cs, ^{238}Pu, and $^{239-240}Pu$. All of the observed activity is attributed to worldwide fallout. The large variability in results of soil samples is typical and accumulation of additional data will allow a better estimate of the expected range of activity in soil for the MRL environs.

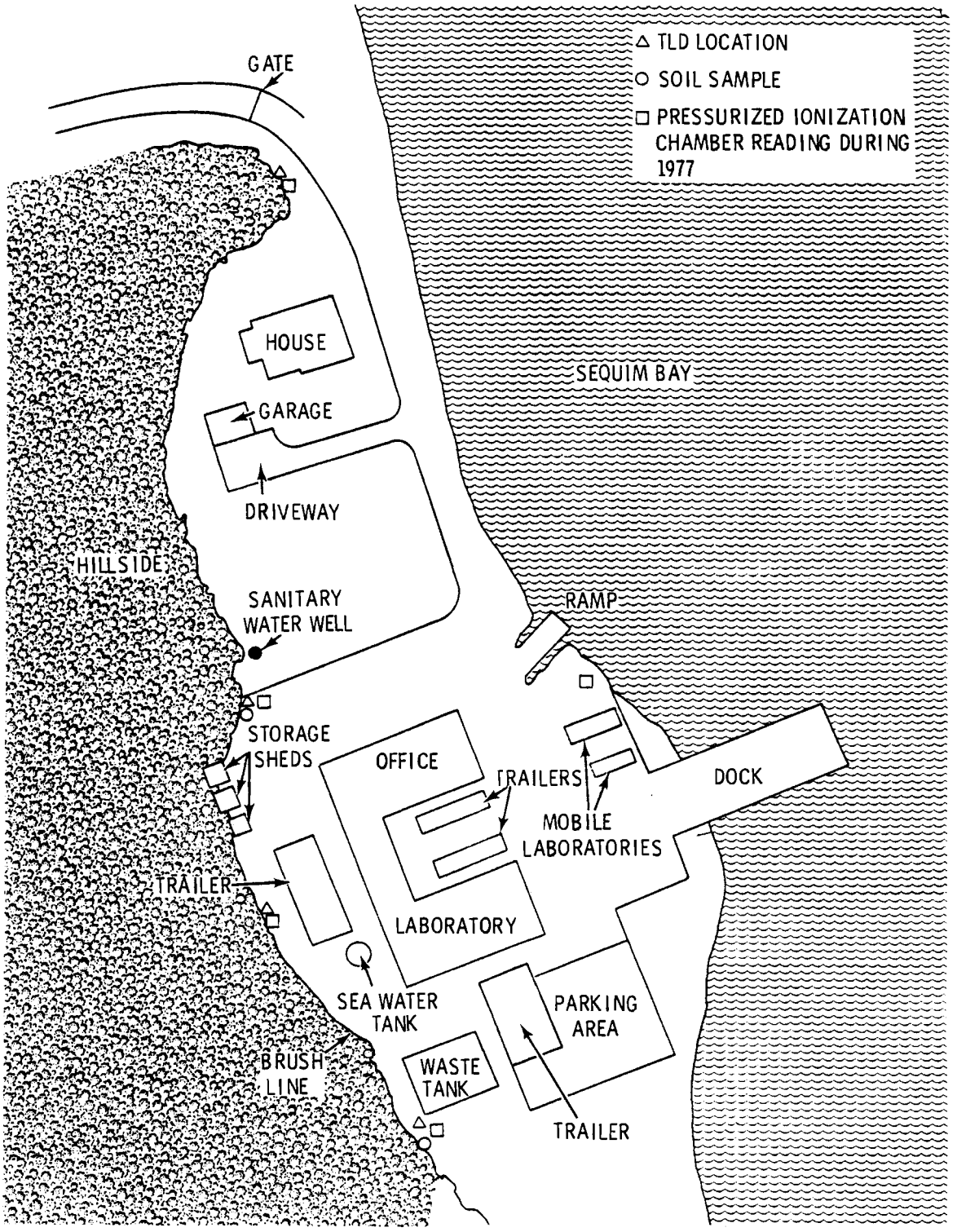

FIGURE 1. Sample Collection Locations at the Sequim MRL

TABLE 1. Sequim Marine Research Laboratory Sampling Schedule

Sample Type	Locations	Frequency		Amount Sampled	Analyses	
		First 2 Years	Thereafter		Radiological	Other
TLD's(a)	4	Monthly	Monthly	--	External Radiation	
Bay Water	1	Monthly	Semiannually	4 ℓ	γ-scan Gross beta Gross alpha Tritium	Oil and grease Heavy metals(b)
Drinking Water	1	Quarterly	Semiannually	1 ℓ	γ-scan Gross beta Gross alpha Tritium	Coliforms Chlorides(c)
Kelp	1	Quarterly	Quarterly	2 kg	γ-scan Sr-90 Pu-Total	
Eelgrass	1	Quarterly	Quarterly	2 kg	γ-scan Sr-90 Pu-Total	
Clams	1	When Available		2 kg	γ-scan Sr-90 Pu-Total	
Soil	2	Annually	Annually	2 kg	γ-scan Sr-90 Pu-Total	

(a) Five chips of CaF_2:Mn (Harshaw type TLD-400) encased in an opaque capsule lined with 2 mils of lead and 10 mils of tantalum.

(b) Analysis for heavy metals dependent on their use in laboratory research projects. Only Cu analysis done to date.

(c) Added for CY-78.

TABLE 2. Concentrations of Radionuclides in Drinking Water Samples from Sequim (Grab Samples)[a] (Units of 10^{-9} Ci/ml of Water)

Date	Beta	Alpha	^{3}H	^{46}Sc	^{51}Cr	^{60}Co	^{65}Zn	^{137}Cs
1976								
8/2	3.9 ± 5.5	0.25 ± 0.39	-0.02 ± 140			0.93 ± 28	-0.32 ± 55	0.55 ± 31
10/6	2.4 ± 5.9	0.34 ± 0.35	-170 ± 110			2.5 ± 28	13 ± 57	4.0 ± 31
12/2	7.5 ± 6.1	0.34 ± 0.35	280 ± 200	0.09 ± 36	0.38 ± 490	0.16 ± 28	-0.003 ± 56	0.05 ± 31
1977								
1/4	2.9 ± 5.8	1.00 ± 0.52	-65 ± 230			8.9 ± 28	-4.1 ± 57	-0.12 + 31
3/3	4.0 ± 6.0	0.10 ± 0.27	56 ± 310			7.4 ± 28	-0.02 ± 60	-0.21 ± 31
6/3	3.5 ± 6.1	0.55 ± 0.42	250 ± 300			7.0 ± 28	-2.8 ± 56	-0.09 ± 31
10/5	3.8 ± 4.1	0.37 ± 0.45	-260 ± 280			-0.17 ± 28	-27 ± 58	1.4 ± 31

[a] Analytical results ± 2 sigma counting uncertainty. Negative results do not reflect a physical reality but result from the statistical uncertainty of discriminating between the sample and instrument background count rate.

TABLE 3 Total Coliform Analyses of Sequim MRL Drinking Water

Date	Total Coliform (per 100 ml)
1976	
8/2	<2.0
10/6	<2.0
1977	
10/5	<2.0

TABLE 4. Concentrations of Radionuclides in Bay Water Samples from Sequim (Grab Samples)[a] (Units of 10^{-9} μCi/ml of Water)

Date	Beta	Alpha	^{3}H	^{14}C	^{40}K	^{46}Sc	^{51}Cr	^{60}Co	^{65}Zn	^{137}Cs	U
1976											
8/2	120 ± 28	0.35 ± 2.6	260 ± 110	19 ± 80	160 ± 240			0.06 ± 14	1.6 ± 28	-1.1 ± 15	
9/2	130 ± 29	2.4 ± 1.9	550 ± 200	-9.9 ± 2.6	210 ± 170			11 ± 11	-1.9 ± 20	-0.89 ± 10	
10/6	220 ± 34	2.7 ± 2.2	80 ± 100	7.2 ± 8.8	180 ± 170			0.06 ± 11	-0.35 ± 20	2.0 ± 10	
11/15	440 ± 44	2.3 ± 1.4	-47 ± 180	5.6 ± 6.9	190 ± 170	-0.16 ± 17	-19 ± 230	0.63 ± 11	-3.8 ± 20	-0.75 ± 10	
12/2	450 ± 45	2.5 ± 2.0	200 ± 540	3.3 ± 7.3	190 ± 170	0.03 ± 14	-12 ± 150	0.06 ± 11	-2.7 ± 19	-1.3 ± 10	
1977											
1/4	440 ± 53	1.6 ± 1.2	-160 ± 140	5.7 ± 14	260 ± 170			0.06 ± 11	-4.7 ± 20	-1.1 ± 10	
2/1	260 ± 43	3.6 ± 1.6	16 ± 120	0.45± 5.1	230 ± 170			2.4 ± 11	0.002 ± 20	-1.9 ± 10	4.8 ± 2.0
3/3	86 ± 11	2.9 ± 1.6	240 ± 380	20 ± 32	190 ± 170			0.63 ± 11	-1.7 ± 20	-1.4 ± 10	
4/4	410 ± 5.1	0.93 ± 1.3	590 ± 170	9.1 ± 13	180 ± 170			0.06 ± 11	7.3 ± 21	-1.6 ± 10	
5/4	370 ± 49	3.0 ± 1.6	970 ± 350	1.5 ± 2.2	230 ± 170			2.6 ± 11	-1.9 ± 19	1.6 ± 10	
6/3	240 ± 37	2.6 ± 2.2	23 ± 220	1.2 ± 4.4	210 ± 170			9.4 ± 11	-3.4 ± 20	4.4 ± 10	
7/2	400 ± 59	0.48 ± 0.3	81 ± 180	-15 ± 12	210 ± 170			1.7 ± 11	4.1 ± 21	-0.32 ± 10	
8/1	410 ± 90	1.5 ± 1.3	49 ± 440	-2.1 ± 10	180 ± 170			3.6 ± 11	-4.4 ± 19	-1.4 ± 10	
9/6	460 ± 57	0.76 ± 1.6	-44 ± 390	-26 ± 12	260 ± 170		5.2 ± 210	4.5 ± 11	3.6 ± 20	3.5 ± 10	
10/15	320 ± 44	1.7 ± 1.9	-97 ± 260	-7.5 ± 14	210 ± 170			1.7 ± 11	-4.7 ± 20	0.15 ± 10	
11/7	360 ± 45	2.8 ± 2.4	-350 ± 67	12 ± 51	200 ± 170			4.5 ± 11	7.8 ± 19	1.7 ± 10	
12/5	420 ± 48	2.1 ± 1.9	-47 ± 290	49 ± 77	180 ± 170	0.04 ± 15	7.1 ± 180	0.06 ± 11	2.2 ± 20	2.6 ± 10	

[a] Analytical results ± 2 sigma counting uncertainty. Negative results do not reflect a physical reality but result from the statistical uncertainty of discriminating between the sample and instrument background count rate.

TABLE 5. Concentration of Oil and Copper in Water Samples from Sequim (Grab Samples)

Date	Bay Water		Incoming Lab Bay Water	
	Oil & Grease (mg/l)	Copper (µg/l)	Oil & Grease (mg/l)	Copper (µg/l)
1976 8/2	4.3	2.0		
1976 10/6	1.4	2.0	1.8	2.0
1977 8/1	<1.0	3.0		

TABLE 6. Concentrations of Radionuclides in Clams Collected at Sequim[a] (Units of 10^{-6} μCi/g (Wet Weight))

Date	Sample	^{40}K	^{59}Fe	^{60}Co	^{90}Sr	^{106}Ru	^{137}Cs	Total Pu
1976								
1/15	Saxidomus Giganteus	0.89 ± 0.64		0.00008 ± 0.05	0.0006 ± 0.003	0.003 ± 0.87	0.004 ± 0.04	0.0008 ± 0.001
1/15	Prototheca Staminae	1.2 ± 0.82	1.2 ± 3.0	0.002 ± 0.06	0.003 ± 0.003		-0.01 ± 0.05	0.0007 ± 0.0001
1/15	Tresus Nuttallii	0.70 ± 0.76		-0.004 ± 0.06	0.003 ± 0.003		-0.003 ± 0.05	0.001 ± 0.0001
7/30	Saxidomus Giganteus	1.5 ± 0.68		-0.007 ± 0.05	0.007 ± 0.003		-0.02 ± 0.04	0.0009 ± 0.0001
1977								
2/1	Saxidomus Giganteus	1.8 ± 0.54		0.0002 ± 0.04	0.0006 ± 0.001		0.003 ± 0.03	0.0004 ± 0.00004
2/1	Saxidomus Giganteus	1.8 ± 0.56		0.014 ± 0.04	0.0002 ± 0.001		-0.0005 ± 0.04	0.00005 ± 0.00002
2/1	Prototheca Staminae	1.7 + 0.58		0.011 ± 0.04	0.002 ± 0.001		-0.0007 ± 0.04	0.0005 ± 0.00005
7/28	Saxidomus Giganteus	1.8 ± 0.55		0.0002 ± 0.04	0.0003 ± 0.001		0.009 ± 0.03	0.002 ± 0.0001
7/28	Saxidomus Giganteus	1.7 ± 0.53		0.0002 ± 0.04	0.001 ± 0.001		0.01 ± 0.03	0.0008 ± 0.0004

[a] Analytical results ± 2 sigma counting uncertainty. Negative results do not reflect a physical reality but result from the statistical uncertainty of discriminating between the sample and instrument background count rate.

TABLE 7. Concentrations of Radionuclides in Kelp and Eelgrass Samples from Sequim[a] Units of 10^{-6} μCi/g

Date	Sample	^{40}K	^{60}Co	^{65}Zn	^{90}Sr	^{137}Cs	Total Pu
1976							
1/19	Kelp	66 ± 2.4	0.0009 ± 0.16	0.31 ± 0.47	0.005 ± 0.004	0.09 ± 0.14	0.01 ± 0.006
7/30	Kelp	73 ± 2.3	0.020 ± 0.14	0.27 ± 0.25	0.002 ± 0.004	0.08 ± 0.13	0.006 ± 0.004
7/30	Eelgrass	9.8 ± 3.8	0.001 ± 0.26		0.002 ± 0.008	-0.07 ± 0.23	0.06 ± 0.02
1977							
5/4	Kelp	68 ± 2.1	0.08 ± 0.13	0.14 ± 0.23	0.01 ± 0.01	0.06 ± 0.12	0.002 ± 0.0003
5/4	Eelgrass	22 ± 2.9	0.001 ± 0.19	0.13 ± 0.34	0.02 ± 0.01	0.15 ± 0.18	0.002 ± 0.0003
7/28	Eelgrass	25 ± 5.9	-0.04 ± 0.16	-0.20 ± 0.30	0.01 ± 0.004	0.07 ± 0.17	0.004 ± 0.0004
7/28	Eelgrass	17 ± 4.1	0.02 ± 0.13	-0.09 ± 0.24	0.05 ± 0.005	0.10 ± 0.13	0.002 ± 0.0003
7/28	Kelp	77 ± 9.2	-0.19 ± 0.16	-0.03 ± 0.30	0.05 ± 0.005	-0.12 + 0.15	0.003 ± 0.0004
7/28	Kelp	50 ± 6.1	0.12 ± 0.14	0.02 ± 0.23	0.05 ± 0.005	-0.03 ± 0.10	0.001 ± 0.0001

[a] Analytical results ± 2 sigma counting uncertainty. Negative results do not reflect a physical reality but result from the statistical uncertainty of discriminating between the sample and instrument background count rate.

TABLE 8. Sequim Land TLD, mR/day

Date		Near Tile Field	Near Back Trailer	Near Well	N. End Near Transformer
1976					
8/2	9/16	0.12	0.12	0.12	0.11
9/2	10/7	0.11	0.11	0.12	0.11
9/29	12/6	0.11	0.11	0.11	0.11
11/4	12/6	0.12	0.11	0.12	0.12
11/29	1/18	0.11	0.10	0.11	0.11
1977					
12/28	2/8	0.15	0.14	0.15	0.13
1/28	3/4	0.13	0.13	0.13	0.13
2/28	4/8	0.13	0.12	0.12	0.13
3/30	5/5	0.14	0.13	0.13	0.14
4/28	6/6	0.12	0.12	0.12	0.12
5/30	7/27	0.10	0.10	0.09	0.10
6/28	8/2	0.15	0.13	0.14	0.14
7/27	9/13	0.11	0.11	0.11	0.11
8/29	10/14	0.12	0.12	0.12	0.12
9/28	11/10	0.13	0.12	0.13	0.12
10/27	12/7	0.12	0.12	0.13	0.12
11/28	1/17	0.12	0.12	0.12	0.11

TABLE 9. Reuter-Stokes Pressurized Ion Chamber Measurements During 1977

Location	Measurement Time[a] On	Off	Hours	Cumulative Exposure	Rate
Near Well	2:00pm	8:00am	18	161 μR	8.9 μR/hr
Near Back Trailer	8:10am	8:10pm	12	110	9.2
Near Storage Tank	8:30pm	8:20am	11.8	106	9.0
Near Gate	8:30am	8:30pm	12	107	8.9
Near Dock	8:40pm	7:40am	11	102	9.3

[a] Measurements started 2:00 pm, Friday, July 29, 1977.

TABLE 10. Concentration of Radionuclides in Sequim Soil Samples
Units of 10^{-6} μCi/g of Soil (Dry Weight)[a]

Sample Location	Naturally Occurring Radionuclides			Artificially Produced Radionuclides			
	^{40}K	^{224}Ra	^{226}Ra	^{54}Mn	^{58}Co	^{60}Co	^{90}Sr
1976							
Near Well	7.4 ± 1.1	0.36 ± 0.06	0.26 ± 0.07	-0.008 ± 0.02	0.0009 ± 0.02	0.006 ± 0.02	0.01 ± 0.004
Near Storage Basin	7.9 ± 1.1	0.33 ± 0.06	0.30 ± 0.08	-0.007 ± 0.02	0.005 ± 0.02	0.001 ± 0.02	0.004 ± 0.004
1977							
Near Storage Basin	5.6 ± 0.98	0.20 ± 0.06	0.23 ± 0.07	0.04 ± 0.03	-0.01 ± 0.02	0.004 ± 0.02	0.05 ± 0.02
Near Well	8.7 ± 1.2	0.34 ± 0.06	0.24 ± 0.07	0.008 ± 0.03	0.02 ± 0.03	-0.02 ± 0.03	0.01 ± 0.01

Sample Location	Artificially Produced Radionuclides						
	$^{95}ZrNb$	^{106}Ru	^{134}Cs	^{137}Cs	^{154}Eu	^{238}Pu	$^{239-240}Pu$
1976							
Near Well	0.008 ± 0.03	-0.04 ± 0.15	-0.02 ± 0.02	0.07 ± 0.03		0.0003 ± 0.003	0.002 ± 0.001
Near Storage Basin	0.04 ± 0.03	-0.05 ± 0.15	0.01 ± 0.02	0.04 ± 0.03	0.004 ± 0.17	0.0007 ± 0.003	0.0004 ± 0.001
1977							
Near Storage Basin	0.05 ± 0.05	0.01 ± 0.16		0.32 ± 0.05		0.05 ± 0.02	0.07 ± 0.03
Near Well	0.0007 ± 0.03	-0.03 ± 0.16		0.02 ± 0.03		0.008 ± 0.003	0.003 ± 0.002

[a] Analytical results ± 2 sigma counting uncertainty. Negative results do not reflect a physical reality but result from the statistical uncertainty of discriminating between the sample and instrument background count rate.

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1. J. J. Fix and P. J. Blumer, Sequim Marine Research Laboratory Routine Environmental Measurements During CY-1976. BNWL-2267, Battelle, Pacific Northwest Laboratories, Richland, WA 99352, May 1977.

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APPENDIX

ANALYTICAL PROCEDURES

APPENDIX

ANALYTICAL PROCEDURES

The environmental samples collected were analyzed for radionuclides by United State Testing Company of Richland, Washington and for coliforms, oil and grease, and copper by Hanford Environmental Health Foundation of Richland, Washington. The radiological data shown in Tables 2, 4, 6, 7, and 10 include the counting result plus or minus the 2-sigma counting uncertainty. Whenever the counting result is less than the uncertainty, the counting result is less than the detection limit (2-sigma uncertainty) of the analysis. Because of the statistical nature of radionuclide counting, an occasional counting result may be slightly greater than the 2-sigma uncertainty even if the radionuclide is not present. For this reason, several environmental samples must be analyzed to provide a reliable estimate of the radionuclides present. A brief description of the analytical procedures used follows.

RADIOLOGICAL ANALYSES

Water Samples

Gross Beta

Gross beta activity is measured by a direct count of the dried residue with a gas flow proportional counter. The counter is calibrated with a ^{90}Sr-Y equilibrium source.

Gross Alpha

Gross alpha activity is measured by a low level alpha counter following extraction into ether from a strong nitric acid. The ether phase is evaporated off and the residue plated on the stainless steel planchet. The planchet is counted with the gas flow proportional counter. The counter is calibrated with a ^{239}Pu source.

Gamma-Emitting Radionuclides

Gamma-emitting radionuclides are determined by the direct count of 500 ml of sample in the well of the 9 inch x 9 inch NaI(TL) well detector with the multichannel gamma ray spectrometer.

Strontium-90

Strontium-90 in water samples is precipitated with fuming nitric acid, scavenged with barium chromate, precipitated as a carbonate, transferred to a stainless steel planchet and beta counted with a low level beta proportional counter. After a 125-day period, the yttrium-90 daughter is separated and counted with a low level beta proportional counter.

Tritium

Tritium is measured in distilled water samples with a liquid scintillation spectrometer.

Clams, Eelgrass and Kelp Samples

Gamma-Emitting Radionuclides

Gamma-emitting radionuclides are determined by a direct count of the sample in the well of a 9 inch x 9 inch NaI(TL) well detector with a multichannel gamma ray spectrometer.

Plutonium

After ashing in a furnace and wet ashing with concentrated nitric acid, plutonium is extracted from the sample using cation exchange resin and thenoyl trifluoroacetone. Plutonium in the eluate is electrodeposited on a stainless steel disk, exposed to nuclear track film, and then counted.

Soil Samples

Gamma-Emitting Radionuclides

Approximately 500 grams of sample are placed into a marinelli beaker and counted on a lithium drifted germanium detector, with a multichannel pulse height analyzer.

Plutonium and Strontium-90

Soil is dried, mixed thoroughly, leached with a mixture of nitric acid and hydrochloric acids, and then passed through an ion exchange resin in 8N nitric acid. The 8N nitric acid retains strontium and other metal ions. This phase is precipitated with fuming nitric acid, scavenged with barium chromate, precipitated as a carbonate, and transferred to a stainless steel planchet. The sample is counted with a low background beta proportional counter.

The plutonium is eluted from the resin column with 0.4N HNO_3-0.01N HF and electrodeposited on a stainless steel disk for alpha spectrometric analyses.

NON-RADIOLOGICAL ANALYSES

Coliform

Standard total coliform MPN technique as described in Standard Methods, 14th edition, p. 916 is used to determine coliform counts.

Copper

Atomic Absorption Spectrophotometric following concentration and extraction using ammonium pyrrolidine dithiocarbamate (APDC) and methyl isobutyl ketone (MIBK) as given in Standard Methods, 14th ed, pp. 148-152.

Oil and Grease

Partition-Gravimetric Method as given in Standard Methods, 14th edition, p. 515.

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