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UCID- 18935

Analysis of Core "Soil" and "Water" Samples from the Cactus Crater Disposal Site at Enewetak Atoll

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February 18, 1981

Lawrence Livermore Laboratory

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Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore Laboratory under Contract W-7405-Eng-48.

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ANALYSIS OF CORE "SOIL" AND "WATER" SAMPLES FROM THE CACTUS CRATER DISPOSAL SITE AT ENEWETAK ATOLL.

Introduction

Core "soil" samples and water samples were collected from the Cactus Crater Disposal site at Enewetak for the National Acadamey of Sciences (NAS) review team. The samples were sent to Lawrence Livermore National Laboratory (LLNL) for analysis of ^{137}Cs, ^{90}Sr, $^{239+240}Pu$ and ^{241}Am.

We have analyzed the samples by both gamma spectroscopy and, through a contractor laboratory,* by wet chemistry procedures. The samples processing methods, the analytical methods and the analytical quality control are all procedures we have developed for our continuing Marshall Island radioecology and dose assessment work.

* LFE Environmental Analysis Laboratory - Richmond, Ca.

Sample Processing and Analytical Methods

The core "soil" samples collected as part of the NAS review project from the Enewetak Cactus Crater Disposal Site, were ball-milled into a fine powder, packed in aluminum cans (231.38 Cm^3) and analyzed for gamma emitting radionuclides using high resolution, solid state germanium diodes at LLNL. This is the standard procedure we have developed for coral soils for our Marshall Island program.

Blind duplicates for three selected samples were included for analysis. The duplicates are identified in Tables 1 and 4 where the concentrations in pCi/g dry weight is listed for ^{137}Cs, ^{60}Co, ^{152}Eu, ^{155}Eu and ^{241}Am for each sample.

After the core samples were analyzed by gamma spectroscopy they were sent to our contractor laboratory for wet chemistry analysis for ^{90}Sr, $^{239+240}Pu$ and ^{241}Am. Again blind duplicates were included. The results are listed in Table 2. Wet chemistry analysis for ^{137}Cs was performed for a few selected samples. Comparison of the analytical results for specific samples between gamma spectroscopy and wet chemistry are listed in Table 5.

The water samples were filtered through a 0.45 µm filter and the soluble and collected particulate fractions were both analyzed. The gamma emitting radionuclides were quantified using the high resolution, solid state germanium diode systems at LLNL. The ^{238}Pu, and $^{239+240}Pu$ and ^{241}Am concentrations were determined by wet chemistry procedures at both LLNL and the contractor laboratory. The data for the water and particulate fractions are listed in Table 3.

Results

The results from the duplicate analysis listed in Table 1, 2 and 4 indicate very reproducible results for the collected samples. Comparison of the gamma spectroscopy and wet chemistry analytical methods listed in Table 5 show excellent agreement on ^{137}Cs. The results for ^{241}Am indicate that gamma spectroscopy results are consistently a bit lower than the wet chemistry results.

The general conclusion for all of the data is certainly that the concentrations of all radionuclides in the core "soil" and "water" samples are quite low, especially relative to soil and sediment concentrations at the atoll.

Table 1. Concentration in pCi/g dry weight of Gamma Emitting Radionuclides in Samples from the Cactus Crater Disposal Site at Enewetak Atoll.

Sample No.			^{137}Cs		^{60}Co		^{152}Eu		^{155}Eu		^{241}Am	
SPR24E028	CD-1	7.8-9.3	1.4	(2.3)*	0.95	(2.8)*	1.2	(2.5)*	0.33	(7.7)*	1.4	(9.1)*
SPR24E029	CD-1	17.0-22.0	5.6	(1.3)	0.11	(10)	0.24	(10)	<0.037	(-)	0.24	(17)
SPR24E030	CD-1	24.0-25.5	18	(0.9)	1.2	(2.3)	0.63	(5.1)	1.0	(8.1)	4.0	(8.4)
SPR24E031	CD-1	27.0-0-31.6	27	(1.4)	0.95	(11)	0.63	(24)	1.4	(15)	6.3	(16)
SPR24E032	CD-1	42.0-43.5	2.1	(1.7)	0.90	(2.2)	0.32	(6.1)	1.1	(3.8)	1.2	(9.6)
SPR24E033	CD-1	1.6-5.8	3.1	(1.7)	2.5	(1.4)	1.2	(2.5)	1.5	(3.2)	5.2	(6.6)
SPR24E034	CD-12	4.6-6.1	8.3	(1.1)	4.0	(1.1)	2.6	(1.8)	2.3	(2.7)	4.3	(5.9)
SPR24E035	CD-12	10.0-11.5	9.4	(1.1)	8.1	(0.8)	0.41	(9.2)	2.1	(5.2)	4.7	(16)
SPR24E036	CD-12	20.0-21.5	0.81	(7.4)	0.63	(7.4)	0.25	(26)	0.50	(20)	<0.20	(-)
SPR24E037	CD-12	25.0-26.5	1.4	(6.2)	0.81	(9)	0.50	(16)	0.77	(11)	0.45	(43)
SPR24E038	CD-12	30.0-31.5	0.90	(8.6)	0.63	(8.6)	<0.14	(-)	0.95	(15)	<0.23	(-)
SPR24E039	CD-12	35.0-36.5	<0.10+	(-)	<0.11	(-)	<0.17	(-)	<0.25	(-)	<0.19	(-)
SPR24E040	CD-12	40.0-41.5	0.24	(17)	0.17	(32)	<0.081	(-)	<0.095	(-)	<0.11	(-)
SPR24E041	CD-12	45.0-46.5	<0.026	(-)	0.10	(49)	<0.059	(-)	<0.063	(-)	<0.081	(-)
SPR24E042	CD-17	5.0-6.5	7.2	(1.1)	2.2	(1.6)	1.5	(2.3)	1.4	(3.3)	5.6	(5.3)
SPR24E043	CD-17	10.0-11.5	19	(1.4)	1.04	(7.4)	<0.17	(-)	0.86	(19)	3.8	(16)
SPR24E044	CD-17	25.0-26.5	16	(0.9)	0.95	(2.5)	<0.040	(-)	0.68	(7.5)	4.1	(6.3)
SPR24E045	CD-17	30.0-31.5	8.8	(1.6)	1.7	(5.7)	1.2	(6)	0.77	(15)	1.9	(11)
SPR24E046	CD-17	35.0-36.5	3.0	(3.7)	0.90	(5.9)	0.59	(13)	0.77	(13)	0.99	(22)
SPR24E047	CD-17	50.0-51.5	0.068	(25)	0.045	(29)	<0.032	(-)	<0.041	(-)	<0.043	(-)
SPR24E100	(Dup. E033)		3.1	(1.6)	2.5	(1.8)	1.2	(2.6)	1.5	(27)	5.4	(4.5)
SPR24E101	(Dup. E030)		18	(0.9)	1.2	(2.0)	0.63	(4.7)	0.86	(6.3)	4.1	(7.3)
SPR24E102	(Dup. E032)		1.9	(1.5)	0.86	(2.0)	0.30	(6.3)	1.08	(4.1)	1.04	(8.8)

* Values in parentheses are the one sigma counting errors in percent.

\+ Less than number (i.e. <) indicate the radionuclide was non-detectable at the listed decision limit.

Table 2. Radionuclide Concentration in pCi/g Determined by Wet-Chemistry Analysis for Cactus Crater Disposal Site Core "Soil" Samples.

Sample No.			^{137}Cs		^{90}Sr		$^{239+240}Pu$		^{241}Am	
SPR24E028	CD-1	7.8-9.3			6	(10)*	10	(2.2)*		
SPR24E029	CD-1	17.0-22.0			5.5	(1.8)	1.6	(2.1)		
SPR24E030	CD-1	24.0-25.5	18	(3.1)*	36	(1.5)	12	(2.1)	6.4	(2.1)
SPR24E031	CD-1	27.0-31.6	31	(1.7)	52	(3.0)	21	(2.9)	11	(2.2)
SPR24E032	CD-1	42.0-43.5			13	(3.2)	11	(2.2)	1.7	(2.0)
SPR24E033	CD-1	1.6-5.8	3.1	(2.6)	16	(3.7)	38	(2.3)	8.1	(1.8)
SPR24E034	CD-12	4.6-6.1			14	(5.0)	33	(2.5)		
SPR24E035	CD-12	10.0-11.5			29	(5.0)	37	(2.3)		
SPR24E036	CD-12	20.0-21.5			5.8	(2.9)	5.2	(2.4)	0.8	(5.5)
SPR24E037	CD-12	25.0-26.5			19	(5.0)	6.3	(2.3)		
SPR24E038	CD-12	30.0-31.5			10	(3.2)	7.5	(3.0)	1.2	(1.9)
SPR24E039	CD-12	35.0-36.5			0.63	(6.0)	0.13	(4.6)	0.069	(3.9)
SPR24E040	CD-12	40.0-41.5			1.2	(4.6)	1.5	(2.3)	0.22	(2.6)
SPR24E041	CD-12	45.0-46.5			0.41	(9.9)	0.21	(4.3)	0.016	(7.2)
SPR24E042	CD-17	5.0-6.5			12	(10)	46	(2.9)		
SPR24E043	CD-17	10.0-11.5			35	(5.0)	20	(3.1)		
SPR24E044	CD-17	25.0-26.5			33	(5.0)	15	(3.0)		
SPR24E045	CD-17	30.0-31.5			26	(5.0)	11	(3.9)		
SPR24E046	CD-17	35.0-36.5			10	(5.0)	16	(3.0)		
SPR24E047	CD-17	50.0-51.5			0.44	(8.7)	0.22	(4.8)	0.047	(2.3)
SPR24E100	(Dup. E033)		3.0	(3.0)	14	(5.2)	36	(3.0)	8.1	(1.9)
SPR24E101	(Dup. E030)		17	(3.2)	35	(5.5)	11	(3.4)	6.3	(1.2)
SPR24E102	(Dup. E032)				13	(6.6)	12	(2.9)	1.9	(2.1)

* Values in parentheses are the one Sigma counting errors in percent.

Table 3. Cactus Crypt Water Samples Filtrate and Particles.

	I.D.	pCi/l (%σ)[j]							
		$^{239+240}Pu$	^{238}Pu	^{137}Cs	^{60}Co	^{125}Sb	^{155}Eu	^{241}Am	^{90}Sr
	CD-1 25.0-27.0[a]	.056 (4)	.006 (17)	269 (3)	d	d	d	.007 (40)	302 (5)
e	CD-1 25.0-27.0[b]	42.6 (2)	4.2 (4)	77 (1)	23.5 (1)	2.4 (9)	5.7 (5)	43.7 (8)	80.9 (3)
	CD-1 27.0-32.0[a]	.041 (5)	.003 (25)	227 (3)	d	d	d	<.003	359 (5)
f	CD-1 27.0-32.0[b]	113 (1)	5.4 (6)	215 (2)	19.8 (2)	2.3 (33)	12.7 (4)	90.3 (5)	229 (10)
	NRU-1 20' below surf[a]	.109 (3)	.024 (6)	28 (3)	d	d	d	.003	142 (5)
g	NRU-1 20' below surf[b]	271 (1)	75.4 (7)	153 (1)	60 (1)	3.5 (19)	29.8 (3)	107 (6)	203 (10)
	NRU-1 40' below surf[a]	.083 (3)	.020 (6)	25 (3)	d	d	d	.008	176 (5)
h	NRU-1 40' below surf[b]	746 (2)	190 (7)	325 (1)	153 (2)	8.2 (20)	69 (7)	213 (12)	555 (10)
	NRU-2 20' below surf[a]	.173 (2)	.044 (4)	26 (8)	d	d	d	<.002	309 (5)
i	NRU-2 20' below surf[b]	58 (2)	14.3 (3)	42 (2)	36 (2)	4.7 (10)	11.7 (5)	12.3 (15)	109 (10)

[a] soluble fraction (<0.45 micron)

[b] particulate fraction (>0.45 micron)

[d] no analysis

[e] also - ^{207}Bi-0.7 pCi/l; ^{152}Eu-3.3 pCi/l; ^{102m}Rh-0.9 pCi/l

[f] also - ^{207}Bi-1.9 pCi/l; ^{152}Eu-10.3 pCi/l; ^{102m}Rh-1.1 pCi/l

[g] also - ^{152}Eu-13.7 pCi/l; ^{102m}Rh-28.3 pCi/l

[h] also - ^{152}Eu-35.7 pCi/l; ^{154}Eu-3.0 pCi/l; ^{102m}Rh-67 pCi/l

[i] also - ^{152}Eu-24 pCi/l; ^{102m}Rh-3.1 pCi/l

[j] % σ - percent standard deviation of the counting error.

Table 4. Comparison in pCi/g dry weight, of duplicate analyses results for selected samples.

Sample No.	^{137}Cs	^{60}Co	^{152}Eu	^{155}Eu	^{241}Am
Gamma Spec.					
SPR24E030	18 (0.9)	1.2 (2.3)	0.63 (5.1)	1.0 (8.1)	4.0 (8.4)
SPR24E101 (Dup. E030)	18 (0.9)	1.2 (2.0)	0.63 (4.7)	0.86 (6.3)	4.1 (7.3)
Wet Chem.					
SPR24E030	18 (3.1)	-*	-	-	6.4 (2.1)
SPR24E101 (Dup. E030)	17 (3.2)	-	-	-	6.3 (1.2)
Gamma Spec.					
SPR24E032	2.1 (1.7)	0.90 (2.2)	0.32 (6.1)	1.1 (3.8)	1.2 (9.6)
SPR24E102 (Dup. E032)	1.9 (1.5)	0.86 (2.0)	0.30 (6.3)	1.1 (4.1)	1.0 (8.8)
Wet Chem.					
SPR24E032	-	-	-	-	1.7 (2.0)
SPR24E102 (Dup. E032)	-	-	-	-	1.9 (2.1)
Gamma Spec.					
SPR24E033	3.1 (1.7)	2.5 (1.4)	1.2 (2.5)	1.5 (3.2)	5.2 (6.6)
SPR24E100 (Dup. E033)	3.1 (1.6)	2.5 (1.8)	1.2 (2.6)	1.5 (2.7)	5.4 (4.5)
Wet Chem.					
SPR24E033	3.1 (2.6)	-	-	-	8.1 (1.8)
SPR24E100 (Dup. E033)	3.0 (3.0)	-	-	-	8.1 (1.9)

* (-) indicates that wet chemistry analysis was not made

+ values in parenthesis are the one sigma counting errors

Table 5. Comparison, in pCi/g dry weight, of gamma spectroscopy and wet chemistry analytical results for ^{137}Cs and ^{241}Am.

Sample I.D.		^{137}Cs Gamma Spec.		^{137}Cs Wet Chem.		^{241}Am Gamma Spec.		^{241}Am Wet Chem.	
SPR24E030	CD-1	18	(0.9)+	18	(3.1)+	4.0	(8.4)+	6.4	(2.1)+
SPR24E031	CD-1	27	(1.4)	31	(1.7)	6.3	(16)	11	(2.2)
SPR34E033	CD-1	3.1	(1.7)	3.1	(2.6)	5.2	(6.6)	8.1	(1.8)
SPR34E032	CD-1					1.2	(9.6)	1.7	(2.0)
SPR24E036	CD-12					0.45	(43)	0.8	(5.5)
SPR24E038	CD-12					<0.23*	(-)	1.2	(1.9)
SPR24E039	CD-12					<0.19	(-)	0.069	(3.9)
SPR24E040	CD-12					<0.11	(-)	0.22	(2.6)
SPR24E041	CD-12					<0.081	(-)	0.016	(7.2)
SPR24E047	CD-17					<0.043	(-)	0.047	(2.3)

*< numbers indicate no positive detection and the detection limit of the analysis

+ Values in parenthesis are the one sigma counting errors