*Radionuclide Contaminant Analysis of
Small Mammals at Area G, TA-54, 1994*

*James Biggs
Kathy Bennett
Phil Fresquez*

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RADIONUCLIDE CONTAMINANT ANALYSIS OF SMALL MAMMALS AT AREA G, TA-54, 1994

by

James Biggs, Kathy Bennett, and Phil Fresquez

ABSTRACT

Small mammals were sampled at two waste burial sites (1 and 2) at Area G, TA-54 and a control site outside Area G (Site 3) to identify radionuclides that are present within surface and subsurface soils at waste burial sites, to compare the amount of radionuclide uptake by small mammals at waste burial sites to a control site, and to identify the primary mode of contamination to small mammals, either through surface contact or ingestion/inhalation. Three composite samples of at least five animals per sample were collected at each site. Pelts and carcasses of each animal were separated and analyzed independently. Samples were analyzed for ^{241}Am , ^{90}Sr , ^{238}Pu , ^{239}Pu , total U, and gamma spectroscopy (including ^{137}Cs). Significantly higher (parametric t-test at $p=0.05$) levels of total U, ^{241}Am , ^{238}Pu , ^{239}Pu , and ^{40}K were detected in pelts as compared to the carcasses of small mammals at TA-54. Concentrations of other measured radionuclides in carcasses were nearly equal to or exceeded the mean concentrations in the pelts. Our results show higher concentrations in pelts compared to carcasses which is similar to what has been found at waste burial/contaminated sites outside of Los Alamos National Laboratory. Site 1 had significantly higher ($\alpha=0.05$, $F=0.0095$) total U concentrations in carcasses than Sites 2 and 3. Site 2 had significantly higher ($\alpha=0.05$, $F=0.0195$) ^{239}Pu concentrations in carcasses than either Site 1 or Site 3. A significant difference in ^{90}Sr concentration existed between Sites 1 and 2 ($\alpha=0.05$, $F=0.0681$) and concentrations of ^{40}K at Site 1 were significantly different from Site 3.

INTRODUCTION

A solid, low-level radioactive disposal facility has been operating at Area G, TA-54 since 1957 and has been used to dispose of various wastes including tritium waste, transuranic waste, volatile organic compounds, and mixed waste. Environmental monitoring of air, soil, water runoff, and vegetation has been in place to examine potential migration of contaminants. Recently, there has been no sampling to determine contaminant concentration of small mammals within the boundaries of Area G. Consequently, the collection and analysis of small mammals at TA-54, Area G, was

initiated as part of the Enhanced Environmental Annual Surveillance program at Area G by the Environmental, Safety, and Health Division in collaboration with the Solid Waste Management Group. The program is intended to provide data to aid in meeting requirements of DOE Order 5400.1, which specifies monitoring of existing operations at radioactive waste burial sites.

Rodents can affect the distribution of radionuclides at radioactive waste burial sites through their burrowing activities (Arthur et.al. 1987). Burrowing activity and mound building can expose contaminated soils which can then be dispersed by wind and water erosion (Winsor and Whicker 1980). Predators of small mammals can also disperse radioactive material in their feces, urine, or regurgitated pellets (Eisler 1994). Burrowing animals can also alter the soil profile and change the physical and chemical processes in the soil profile resulting in movements of buried contaminants (Hakanson et.al. 1982). In addition, small mammals utilizing waste burial sites can be contaminated through direct contact of contaminated soil or by ingestion of soil (i.e., soil consumption during pelt grooming) or from foraging on plant resources (O'Farrell and Gilbert 1975) and could subsequently become a form of contaminant transport off site via predation from predator species (Craig et.al. 1979).

The collection and analysis of burrowing, small mammals at two waste burial sites (Sites 1 and 2) within Area G, TA-54, Los Alamos National Laboratory, were used to 1) identify radionuclides potentially present within surface and subsurface soils at waste burial sites within Area G by sampling of burrowing, nocturnal small mammal tissues, 2) quantitatively estimate and compare the amount of radionuclide uptake at specific waste burial sites within Area G to a control site (Site 3) by sampling carcasses of burrowing, nocturnal small mammals, 3) determine the primary mode of contamination to small mammals, either by surface contact or through ingestion, and 4) estimate small mammal densities at each waste burial site and the control site for use in estimating potential contaminant loads within the rodent population. Data collected from the waste burial

sites was compared to a control site. A general description of Area G and the various wastes buried within its boundaries is given in Eklund (1995).

METHODOLOGY

Three sites were selected for sampling (trapping) within Area G (Figure 1) with respect to ongoing disposal operations. These sites were defined as follows:

- 1) Recently disturbed/contaminated site: a shallow earth-covered transuranic uranium drum storage site built on top of old previously filled disposal pits; vegetation not well established and consists of plant species associated with disturbed ground.
- 2) Partially disturbed/contaminated waste burial site: this site has established vegetation with a mixture of native plants and plant species associated with disturbed ground.
- 3) Control site, undisturbed/uncontaminated: no waste operations occurring at this site; consists of well-established native plant species associated with a piñon pine/juniper woodland

Site 1 is located on a recent waste storage earthen mound with a lack of well established vegetation, Site 2 was located on a waste burial site where vegetation has become well established, and Site 3 is located west of the check-in facility for Area G. Site 3, located within a piñon-juniper woodland and adjacent to the operating disposal site, was selected as the control site. Vegetation samples were also collected at various locations within and near Area G waste burial sites (Fresquez, et.al. 1995), including two locations at Site 1 of the small mammal sampling areas. When applicable, results of vegetation sampling are presented in the text of this report.

A grid design consisting of 100 snap traps placed approximately 10 m apart in a 10 x 10 design was used to collect animals at each of the three sites. Snap trapping took place over 3 to 4 nights

Figure 1. Locations of sites of small mammal grids at Area G. (Sites 4 and 5 were later added because of low capture rates at Site 3.)

(until at least 15 animals were captured at each site). Procedures for handling and field processing of small mammals with respect to potential infection of hantavirus, are given in Mills, et.al, and Biggs and Bennett. These same safety procedures were followed for collecting tissue samples from snap-trapped animals. At least 15 rodents were captured at Sites 1 and 2. However, low capture rates at Site 3 necessitated additional sampling in the vicinity of that location (identified as Sites 4 and 5 on Figure 1). Additional snap traps were placed in similar habitat adjacent to Site 3 and west of the Area G controlled access gate to ensure that a sufficient sample size was obtained for analysis. Snap traps were baited and set in late afternoon and checked in early morning. Traps with animals were taken to a central processing station where pelts were removed. Precautions during handling were taken to minimize cross contamination from carcass to pelt while removing pelts. All external hair was removed from appendages.

Three (3) composite samples were collected at each site with each sample consisting of a minimum 5 animals. The pelt was separated from the carcass of each animal and analysis was run on the pelt and carcass separately for each radionuclide. Due to total ashed weight, the three composite samples of pelts were combined for each site for a total of one sample per site only. The samples were placed into 1-L glass beakers. The beaker contents were covered with tin foil and ashed at 500°C for 120 hr. The sample ash was pulverized and homogenized before it was submitted to a LANL analytical laboratory for the analysis of ^{241}Am , ^{90}Sr , ^{238}Pu , ^{239}Pu , total U, gamma spectroscopy (including ^{137}Cs). All methods of radiochemical analysis have been described previously (Salazar 1984). Results are reported on a per ash weight basis (g/ash). There were insufficient amounts of pelts to analyze the composite samples separately due to a minimum amount of ash required to conduct the analysis. In these cases, the composite samples were combined for each site. Analysis of pelts and carcasses separately allowed for a more accurate determination of radionuclide concentration (ingestion/inhalation or external body surface).

The Statistical Analysis System (SAS) was used to analyze all data sets (SAS/STAT User's Guide 1988). A univariate test was used to determine if carcass radionuclide means were normally distributed within each site. Most means were normally distributed, therefore a parametric t-test was used to determine if the means of each radionuclide were equal between carcasses and pelts. This was not conducted by site since only one pelt sample per site existed. An Analysis of Variance (ANOVA) was used to determine if any significant differences in the amount of radionuclide in carcass samples existed between sites (the ANOVA generates an alpha [probability] at the 0.05 level) and Duncan's multiple range test was used to identify where the significant differences occurred between the sites.

Rodent densities were estimated using Leslie's regression method (Seber 1982) applied to each grid where daily total number of captures were plotted against the cumulative daily captures. Confidence intervals were calculated at 90% using the general method (Seber 1982).

RESULTS

Density Estimates

Deer mice (*Peromyscus maniculatus*) was the only small mammal species captured at Sites 1 and 2. Deer mice and pinyon mice (*P. trueii*) were captured at the control site. The highest densities of animals occurred on Sites 1 and 2 with very low capture rates at the control site. Because of the low capture rates at Site 3, additional locations were trapped adjacent to it. Density estimates of rodents occurring at Sites 1 and 2 were calculated by regressing the number of daily captures onto the cumulative number of captures for each day. Rodent density of Site 3 is based on total number of animals captured due to no new captures being recorded on the last day of trapping. The density of the trapping area is based on a 100 m by 100 m grid with an additional 5 m boundary strip to help account for animals being drawn into the grid due to the bait. Therefore the total effective trapping area is approximately 1.21 ha. Table 1 gives the estimated density (# animals/ha) of each site sampled after adjustment for the total effective trapping area.

Table 1. Rodent Density Estimate of Area G (Sites 1 and 2) and Control (Site 3).

SITE 1	DAY	NO. OF CAPTURES	NO. OF TRAPS
	1	13	100
	2	6	100
	3	5	100
DENSITY ESTIMATE (# animals/ha)	23.84		
VAR(N) ESTIMATE	13.24		
90% CONFIDENCE INTERVAL	Lower 90% Limit 4.08	Upper 90% Limit 61.85	

SITE 2	DAY	NO. OF CAPTURES	NO. OF TRAPS
	1	17	100
	2	6	100
	3	1	100
DENSITY ESTIMATE (# animals/ha)	20.67		
VAR(N) ESTIMATE	0.60		
90% CONFIDENCE INTERVAL	Lower 90% Limit 17.09	Upper 90% Limit 27.04	

SITE 3	DAY	NO. OF CAPTURES	NO. OF TRAPS
	1	4	100
	2	0	100
	3	—	—
DENSITY ESTIMATE (# animals/ha)	3.31*		

* no new captures were recorded after the first night of trapping, therefore, a third night of trapping was not conducted; this estimate is treated as a "complete census" of rodents at the site.

Radionuclide Analysis

Results of data analysis presented in this paper are primarily for the radionuclides total U, ^{241}Am , ^{238}Pu and ^{239}Pu , ^{90}Sr , ^{137}Cs , Bi^{214} , ^{60}Co , ^{152}Eu , ^{40}K , and ^{208}Tl (Table 2). A total of 27 radionuclides were analyzed using gamma spectroscopy. However, results are presented only for those that showed detectable activity based on the gamma spectroscopy. These included ^{137}Cs , ^{214}Bi , ^{60}Co , ^{152}Eu , ^{40}K , and ^{208}Tl . A complete list of radionuclides analyzed and the analytical results are given in Appendix A.

Table 2. Summary of Analytical Results for Radionuclides Showing Detectable Activity.

SITE	SAMPLE NUMBER	RADIOISOTOPE	SAMPLE TYPE	ANALYTICAL RESULT ($\mu\text{g/g}$ or pCi/g) ¹	ANALYTICAL UNCERTAINTY
1	1	²⁴¹ Am	Carcass	0.01	0.03
1	2	²⁴¹ Am	Carcass	0.009	0.03
1	3	²⁴¹ Am	Carcass	0.012	0.03
1	1	²⁴¹ Am	Pelt	0.052	0.03
1	1	²³⁸ Pu	Carcass	0.137	0.031
1	2	²³⁸ Pu	Carcass	0.173	0.037
1	3	²³⁸ Pu	Carcass	0.012	0.03
1	1	²³⁸ Pu	Pelt	0.506	0.035
1	1	²³⁹ Pu	Carcass	0.034	0.02
1	2	²³⁹ Pu	Carcass	0.023	0.015
1	3	²³⁹ Pu	Carcass	0.02	0.02
1	1	²³⁹ Pu	Pelt	0.089	0.02
1	1	⁹⁰ Sr	Carcass	1.7	0.2
1	2	⁹⁰ Sr	Carcass	3.4	0.2
1	3	⁹⁰ Sr	Carcass	2.8	0.3
1	1	⁹⁰ Sr	Pelt	0.9	0.5
1	1	¹³⁷ Cs	Carcass	0.04	0.06
1	2	¹³⁷ Cs	Carcass	0.04	0.06
1	3	¹³⁷ Cs	Carcass	0.04	0.06
1	1	¹³⁷ Cs	Pelt	0.02	0.03
1	1	²¹⁴ Bi	Carcass	0.41	0.13
1	2	²¹⁴ Bi	Carcass	0.72	0.16
1	3	²¹⁴ Bi	Carcass	0.58	0.15
1	1	²¹⁴ Bi	Pelt	0.42	0.14
1	1	⁶⁰ Co	Carcass	0.94	0.17
1	2	⁶⁰ Co	Carcass	1.01	0.15
1	3	⁶⁰ Co	Carcass	1.12	0.16
1	1	⁶⁰ Co	Pelt	0.99	0.15
1	1	¹⁵² Eu	Carcass	2.24	0.55
1	2	¹⁵² Eu	Carcass	2.36	0.56
1	3	¹⁵² Eu	Carcass	2.66	0.63
1	1	¹⁵² Eu	Pelt	1.97	0.52
1	1	⁴⁰ K	Carcass	50.15	5.78

Table 2 (cont.).

SITE	SAMPLE NUMBER	RADIOISOTOPE	SAMPLE TYPE	ANALYTICAL RESULT ($\mu\text{g/g}$ or pCi/g) ¹	ANALYTICAL UNCERTAINTY
1	2	⁴⁰ K	Carcass	49.47	5.73
1	3	⁴⁰ K	Carcass	47.19	5.5
1	1	⁴⁰ K	Pelt	43.45	5.14
1	1	²⁰⁸ Tl	Carcass	0.22	0.07
1	2	²⁰⁸ Tl	Carcass	0.25	0.06
1	3	²⁰⁸ Tl	Carcass	0.26	0.07
1	1	²⁰⁸ Tl	Pelt	0.26	0.07
2	1	total U	Carcass	0.318	0.032
2	2	total U	Carcass	0.397	0.040
2	3	total U	Carcass	0.316	0.038
2	1	total U	Pelt	1.362	0.136
2	1	²⁴¹ Am	Carcass	0.099	0.030
2	2	²⁴¹ Am	Carcass	0.034	0.030
2	3	²⁴¹ Am	Carcass	0.019	0.030
2	1	²⁴¹ Am	Pelt	1.14	0.071
2	1	²³⁸ Pu	Carcass	0.033	0.010
2	2	²³⁸ Pu	Carcass	0.001	0.004
2	3	²³⁸ Pu	Carcass	0.006	0.002
2	1	²³⁸ Pu	Pelt	0.237	0.030
2	1	²³⁹ Pu	Carcass	0.121	0.017
2	2	²³⁹ Pu	Carcass	0.072	0.010
2	3	²³⁹ Pu	Carcass	0.042	0.006
2	1	²³⁹ Pu	Pelt	1.269	0.079
2	1	⁹⁰ Sr	Carcass	1.7	0.2
2	2	⁹⁰ Sr	Carcass	0.6	0.2
2	3	⁹⁰ Sr	Carcass	1.3	0.2
2	1	⁹⁰ Sr	Carcass	1.3	0.8
2	1	¹³⁷ Cs	Carcass	0.01	0.02
2	2	¹³⁷ Cs	Carcass	0.03	0.05
2	3	¹³⁷ Cs	Carcass	0.06	0.09
2	1	¹³⁷ Cs	Pelt	0.03	0.05
2	1	²¹⁴ Bi	Carcass	0.49	0.12
2	2	²¹⁴ Bi	Carcass	0.41	0.11
2	3	²¹⁴ Bi	Carcass	0.50	0.14
2	1	²¹⁴ Bi	Pelt	0.44	0.13

Table 2 (cont.).

SITE	SAMPLE NUMBER	RADIOISOTOPE	SAMPLE TYPE	ANALYTICAL RESULT ($\mu\text{g/g}$ or pCi/g) ¹	ANALYTICAL UNCERTAINTY
2	1	⁶⁰ Co	Carcass	0.94	0.12
2	2	⁶⁰ Co	Carcass	0.91	0.14
2	3	⁶⁰ Co	Carcass	0.96	0.17
2	1	⁶⁰ Co	Pelt	0.96	0.15
2	1	¹⁵² Eu	Carcass	2.89	0.64
2	2	¹⁵² Eu	Carcass	2.13	0.54
2	3	¹⁵² Eu	Carcass	2.39	0.56
2	1	¹⁵² Eu	Pelt	2.94	0.71
2	1	⁴⁰ K	Carcass	43.87	5.22
2	2	⁴⁰ K	Carcass	46.35	5.35
2	3	⁴⁰ K	Carcass	45.39	5.32
2	1	⁴⁰ K	Pelt	40.22	4.86
2	1	²⁰⁸ Tl	Carcass	0.20	0.06
2	2	²⁰⁸ Tl	Carcass	0.15	0.05
2	3	²⁰⁸ Tl	Carcass	0.21	0.07
2	1	²⁰⁸ Tl	Pelt	0.16	0.06
3	1	total U	Carcass	0.252	0.025
3	2	total U	Carcass	0.174	0.017
3	3	total U	Carcass	0.267	0.027
3	1	total U	Pelt	0.979	0.196
3	1	²⁴¹ Am	Carcass	0.009	0.030
3	2	²⁴¹ Am	Carcass	0.003	0.030
3	3	²⁴¹ Am	Carcass	0.007	0.030
3	1	²⁴¹ Am	Pelt	0.014	0.030
3	1	²³⁸ Pu	Carcass	0.012	0.030
3	2	²³⁸ Pu	Carcass	0.006	0.030
3	3	²³⁸ Pu	Carcass	0.001	0.030
3	1	²³⁸ Pu	Pelt	0.003	0.030
3	1	²³⁹ Pu	Carcass	0.003	0.020
3	2	²³⁹ Pu	Carcass	0.001	0.020
3	3	²³⁹ Pu	Carcass	0.005	0.020
3	1	²³⁹ Pu	Pelt	0.037	0.020
3	1	⁹⁰ Sr	Carcass	2.0	0.3
3	2	⁹⁰ Sr	Carcass	1.8	0.3
3	3	⁹⁰ Sr	Carcass	1.9	0.2

Table 2 (cont.).

SITE	SAMPLE NUMBER	RADIOISOTOPE	SAMPLE TYPE	ANALYTICAL RESULT ($\mu\text{g/g}$ or pCi/g) ¹	ANALYTICAL UNCERTAINTY
3	1	⁹⁰ Sr	Pelt	1.8	0.6
3	1	¹³⁷ Cs	Carcass	0.12	0.05
3	2	¹³⁷ Cs	Carcass	0.02	0.03
3	3	¹³⁷ Cs	Carcass	0.06	0.09
3	1	¹³⁷ Cs	Pelt	0.02	0.03
3	1	²¹⁴ Bi	Carcass	0.30	0.14
3	2	²¹⁴ Bi	Carcass	0.52	0.14
3	3	²¹⁴ Bi	Carcass	0.39	0.18
3	1	²¹⁴ Bi	Pelt	0.56	0.24
3	1	⁶⁰ Co	Carcass	0.43	0.12
3	2	⁶⁰ Co	Carcass	2.42	0.28
3	3	⁶⁰ Co	Carcass	0.42	0.09
3	1	⁶⁰ Co	Pelt	1.28	0.28
3	1	¹⁵² Eu	Carcass	0.17	0.26
3	2	¹⁵² Eu	Carcass	2.72	0.65
3	3	¹⁵² Eu	Carcass	0.10	0.15
3	1	¹⁵² Eu	Pelt	0.03	0.05
3	1	⁴⁰ K	Carcass	22.58	2.7
3	2	⁴⁰ K	Carcass	46.52	5.48
3	3	⁴⁰ K	Carcass	28.92	3.08
3	1	⁴⁰ K	Pelt	529.19	40.64
3	1	²⁰⁸ Tl	Carcass	0.17	0.06
3	2	²⁰⁸ Tl	Carcass	0.22	0.06
3	3	²⁰⁸ Tl	Carcass	0.16	0.06
3	1	²⁰⁸ Tl	Pelt	0.33	0.11

¹ Total U in measurements of $\mu\text{g/g}$; all other contaminant measurements are in pCi/g .

All carcass means were normally distributed (Table 3) with the exception of ¹³⁷Cs in Site 1, total U in Site 2, and ⁶⁰Co and ¹⁵²Eu in Site 3.

Table 3. Probability Values for Normality Test on Mean Concentration of Radionuclides by Carcass.

CONTAMINANT	P Value*		
	SITE 1	SITE 2	SITE 3
total U	0.5399	0.0413	0.2879
²⁴¹ Am	0.6368	0.3386	0.6368
²³⁸ Pu	0.4099	0.2783	0.8995
²³⁹ Pu	0.2500	0.7364	0.9916
⁹⁰ Sr	0.6786	0.7016	0.9916
¹³⁷ Cs	0.0000	0.7803	0.7803
²¹⁴ Bi	0.8931	0.1939	0.8001
⁶⁰ Co	0.7562	0.7803	0.0083
¹⁵² Eu	0.5367	0.6555	0.0447
⁴⁰ K	0.4222	0.7523	0.4935
²⁰⁸ Tl	0.4632	0.2982	0.8774
* less than 0.05 indicates non-normal distribution			

The mean concentration of each radionuclide found in carcasses and pelts by site is given in Tables 4 and 5, respectively, and shown in Figure 2. For most sites, the mean concentration of radionuclides in carcasses were lower than the concentrations found in pelts¹ for total U, ²⁴¹Am, ²³⁸Pu, and ²³⁹Pu. For the remaining radionuclides, concentrations in carcasses were usually nearly equal to or exceeded the mean concentrations in the pelts. An ANOVA test was used to determine if the mean radionuclide concentrations in carcasses were different between sites and Duncan's multiple range test used to show where the differences occurred. The results are discussed below.

Total U

There were no significant differences in total U in carcasses between Sites 2 and 3. However, Site 1 had significantly higher ($\alpha=0.05$, $P=0.0095$) total U concentrations in carcasses than Sites 2 and 3 and was over two times higher than the control Site, 3.

¹ Only one composite pelt sample was analyzed per site due to low total ashed weight of combined samples.

Table 4. Mean Radionuclide Concentrations for Small Mammal Carcass Samples.

RADIONUCLIDE	SITE 1			SITE 2			SITE 3		
	N	Mean	SE	N	Mean	SE	N	Mean	SE
²¹⁴ Bi	3	0.57	0.089	3	0.467	0.029	3	0.403	0.064
²⁴¹ Am	3	0.01	0.001	3	0.051	0.025	3	0.006	0.002
²³⁸ Pu	3	0.107	0.049	3	0.013	0.010	3	0.006	0.003
¹³⁷ Cs	3	0.04	0.000	3	0.033	0.015	3	0.067	0.029
⁶⁰ Co	3	1.023	0.052	3	0.937	1.090	3	1.09	0.665
¹⁵² Eu	3	2.42	0.125	3	2.470	0.223	3	0.997	0.862
²⁰⁸ Tl	3	0.243	0.012	3	0.187	0.019	3	0.217	0.026
²³⁹ Pu	3	0.026	0.004	3	0.078	0.023	3	0.003	0.001
U	3	0.487	0.054	3	0.344	0.027	3	0.231	0.029
⁹⁰ Sr	3	2.6	0.498	3	1.2	0.321	3	1.9	0.058
⁴⁰ K	3	48.94	0.895	3	45.2	0.722	3	32.67	7.161

1 Radionuclide concentrations for U are measured µg/g; all other contaminants are measured in pCi/g.

Table 5. Radionuclide Concentrations¹ for Small Mammal Pelt Samples.

RADIONUCLIDE	SITE 1		SITE 2		SITE 3	
	N	CONCENTRATION	N	CONCENTRATION	N	CONCENTRATION
²¹⁴ Bi	1	0.42	1	0.44	1	0.56
²⁴¹ Am	1	0.052	1	1.14	1	0.014
²³⁸ Pu	1	0.506	1	0.237	1	0.003
¹³⁷ Cs	1	0.02	1	0.03	1	0.02
⁶⁰ Co	1	0.99	1	0.96	1	1.28
¹⁵² Eu	1	1.97	1	2.94	1	0.03
²⁰⁸ Tl	1	0.26	1	0.16	1	0.33
²³⁹ Pu	1	0.089	1	1.269	1	0.037
U	1	1.931	1	1.362	1	0.979
⁹⁰ Sr	1	0.9	1	1.3	1	1.8
⁴⁰ K	1	43.45	1	40.22	1	529.19

1 Radionuclide concentrations for U are measured µg/g; all other contaminants are measured in pCi/g.

²⁴¹Am, ²³⁸Pu, ¹³⁷Cs, ²¹⁴Bi, ¹⁵²Eu, ⁶⁰Co, ²⁰⁸Tl

There were no significant differences (alpha=0.05) in concentrations of ²⁴¹Am (P=0.1267), ²³⁸Pu (P=0.0846), ¹³⁷Cs (P=0.4607), ²¹⁴Bi (P=0.2697), ¹⁵²Eu (P=0.1539), ⁶⁰Co (P=0.9612), or ²⁰⁸Tl (P=0.2076) in rodent carcasses between sites.

Figure 2. Radionuclide Concentrations in Small Mammals by Site, TA-54, Area G.

Figure 2 (cont.). Radionuclide Concentrations in Small Mammals by Site, TA-54, Area G.

²³⁹Pu

No significant differences in concentrations of ²³⁹Pu in carcasses occurred between Sites 1 and 3 but Site 2 had significantly higher ($\alpha=0.05$, $P=0.0195$) ²³⁹Pu concentrations in carcasses than either Site 1 or Site 3. Mean concentrations in carcasses at Site 2 (0.078 pCi/g) were 3 and 26 times higher than Sites 1 and 3, respectively.

⁹⁰Sr

A significant difference in concentration of ⁹⁰Sr existed between Sites 1 and 2 ($\alpha=0.05$, $P=0.0681$) where the mean concentration of Site 1 was over two times that of Site 2.

⁴⁰K

Site 1 was significantly different from Site 3 for concentrations of ⁴⁰K ($P=0.0742$).

Analysis was conducted on overall mean concentrations of radionuclides to determine if differences existed between pelts and carcasses (Figure 3). The analysis was not conducted by site due to only one pelt sample per site being analyzed. For all sites combined, significant differences between pelt and carcass concentrations occurred for total U, ²⁴¹Am, ²³⁸Pu, ²³⁹Pu, and ⁴⁰K, and in all cases, pelts had a higher concentration of radionuclides. There were no significant differences in radionuclide measurements in our studies between pelts and carcasses for ⁹⁰Sr, ¹³⁷Cs, ²¹⁴Bi, ⁶⁰Co, ¹⁵²Eu, and ²⁰⁸Tl.

DISCUSSION

This study was intended to establish baseline measurements of radionuclide concentrations in small mammals at Area G, TA-54, during the summer of 1994. The data can then be used to modify future studies at Area G to better identify radionuclide transport and concentration loads in and around the site.

Figure 3. Overall Mean Contaminant Concentrations in Pelts and Carcasses.

Figure 3 (cont.). Overall Mean Contaminant Concentrations in Pelts and Carcasses.

Figure 3 (cont.). Overall Mean Contaminant Concentrations in Pelts and Carcasses.

As shown in Table 1, higher densities of rodents were recorded for the two sites within Area G, both of which are located on predisturbed ground. Typically, at other predisturbed locations within Laboratory boundaries, small mammal densities have been higher than in undisturbed habitats. The low densities recorded for the control site is also typical of other studies conducted on mesa top habitats within Laboratory boundaries, especially within pinyon pine/juniper woodlands. The primary species collected at Sites 1 and 2 was deer mice. Deer mice are a more “opportunistic” species compared to other mice expected to occur in the vicinity of Area G and are therefore more likely to invade and populate the disturbed sites.

Our studies generally showed greater amounts of radionuclides in the pelts of animals compared to the carcass. In studies conducted at waste burial sites or contaminated sites outside of the Laboratory, similar results were found. Markham et.al. (1978) found higher concentrations of ^{238}Pu , ^{239}Pu , and ^{241}Am in the pelts and gastrointestinal tracts compared to the carcass and lungs. Studies conducted at the Idaho National Engineering Laboratory on waste disposal sites also showed the highest concentration of ^{238}Pu , $^{239+240}\text{Pu}$, ^{241}Am , ^{90}Sr , and ^{137}Cs in pelt samples (Arthur et al., 1987).

Total U was shown to occur in significantly higher concentrations (in carcasses) at Site 1 compared to Sites 2 and 3. Also, Site 2 had higher concentrations of ^{239}Pu compared to Site 1 or 3. Total U concentrations in vegetation collected at Site 1 indicate a range of 1.23 to 1.72 pCi/g ash (Fresquez et al. 1995) whereas concentrations in small mammal carcasses were less than 0.5 pCi/g ash. Vegetation collected at Site 1 had ^{90}Sr concentrations ranging from 2.0 to 3.3 pCi/g ash (Fresquez et al. 1995). The mean concentration of ^{90}Sr in small mammal carcasses at Site 1 was 2.6 pCi/g ash, well within the range of concentrations found in vegetation at that location. Additional studies and further monitoring of these sites will more accurately assess if correlation's exist between radionuclide concentrations in vegetation and rodents. This information coupled with determining the mode (surface contact, inhalation/ingestion) of contamination to the animal

can help to identify potential pathways of contaminants in a particular plant/animal community by examining if radionuclides are ingested, inhaled, or picked up via surface contact. Additional studies that are currently being conducted elsewhere at the Laboratory, coupled with past data collected at the Laboratory, will be used to more closely examine the relationship between food habits of small mammals and radionuclide uptake via vegetation. Knowledge of densities, food habits, and population dynamics will also help to estimate contaminant loads within the biota at the waste site as well as potential transport off the site. The information can also be used to gain a better understanding on the distribution of radionuclides within the biotic community of Area G and its impact, if any, on biotic communities surrounding Area G.

ACKNOWLEDGMENTS

We would like to thank field crew members Mary Salisbury, Eric Pacheco, and Laura Payne for their hard work and patience while collecting field data. We owe thanks to Mary Mullin for her help in calculating density estimates. We thank Louisa Lujan-Pacheco and Hector Hinojosa, CIC-1, for editing the manuscript and Eric Vold, CST-14, for his assistance in site selection for trapping and for reviewing this manuscript. We would also like to thank Teralene Foxx, Acting Group Leader, ESH-20, for her support in attaining funds for this project. Finally, we would like to thank CST-14, The Solid Waste Management Program, for their support in funding this project.

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APPENDIX A

RAW DATA PRINTOUTS OF RADIONUCLIDE CONCENTRATIONS IN SMALL MAMMAL CARCASSES AND PELTS, AREA G, 1994

REPORT NUMBER: 30877

***** CST ANALYTICAL REPORT *****

Prepared by: AKS on 11-Jan-1995

ANALYSIS: SR-90 REQUEST NUMBER: 18705 MATRIX: BZ ANALYST: RICHARD PETERS PROGRAM CODE: M36A

OWNER: Philip R. Fresquez GROUP: ESH-20 MAIL-STOP: K490 PHONE: 7-0815

ANALYTICAL TECHNIQUE: PC ANALYTICAL PROCEDURE: ER 190 NOTEBOOK: PAGE:

CUSTOMER SAMPLES:

CUSTOMER NUMBER	SAMPLE NUMBER	ANALYTICAL RESULT	ANALYTICAL UNCERTAINTY	UNITS	COMPLETION DATE	COMMENT
6222-1C	94.20468	1.7	0.2	PCI/G	1/11/95	
6222-2C	94.20469	0.6	0.2	PCI/G	1/11/95	
6222-3C	94.20470	1.3	0.2	PCI/G	1/11/95	
6222-P	94.20471	1.3	0.8	PCI/G	1/11/95	
6211-P	94.20472	0.9	0.5	PCI/G	1/11/95	
6211-1C	94.20473	1.7	0.2	PCI/G	1/11/95	
6211-2C	94.20474	3.4	0.2	PCI/G	1/11/95	
6211-3C	94.20475	2.8	0.3	PCI/G	1/11/95	
6243-2C	94.20476	1.8	0.3	PCI/G	1/11/95	
6243-3C	94.20477	1.9	0.2	PCI/G	1/11/95	
6243-1C	94.20478	2.	0.3	PCI/G	1/11/95	
6243-P	94.20479	1.8	0.6	PCI/G	1/11/95	

***** CST ANALYTICAL REPORT *****

Prepared by: CEA on 29-Nov-1994

REQUEST NUMBER: 18705 MATRIX: BZ ANALYST: RICHARD PETERS PROGRAM CODE: M36A

OWNER: Philip R. Fresquez GROUP: ESH-20 MAIL-STOP: K490 PHONE: 7-0815

NOTEBOOK: PAGE:

CUSTOMER SAMPLES:

CUSTOMER NUM	SAMPLE NUM	ANALYSIS	ANALYTICAL TECHNIQUE	ANALYTICAL RESULT	ANALYTICAL UNCERTAINTY	UNITS	COMPLETION DATE	COMMENT
6222-1C	94.20468	AM-241	RAS	0.099	0.03	PCI/G	11/17/94	77%
6222-1C	94.20468	PU-238	RAS	0.0329	0.01	PCI/G	11/17/94	31%
6222-1C	94.20468	PU-239	RAS	0.1212	0.017	PCI/G	11/17/94	31%
6222-2C	94.20469	AM-241	RAS	0.034	0.03	PCI/G	11/17/94	86%
6222-2C	94.20469	PU-238	RAS	0.0008	0.0036	PCI/G	11/17/94	48%
6222-2C	94.20469	PU-239	RAS	0.0719	0.0104	PCI/G	11/17/94	48%
6222-3C	94.20470	AM-241	RAS	0.019	0.03	PCI/G	11/17/94	87%
6222-3C	94.20470	PU-238	RAS	0.0056	0.0024	PCI/G	11/17/94	84%
6222-3C	94.20470	PU-239	RAS	0.0416	0.0055	PCI/G	11/17/94	84%
6222-P	94.20471	AM-241	RAS	1.14	0.071	PCI/G	11/17/94	83%
6222-P	94.20471	PU-238	RAS	0.237	0.03	PCI/G	11/17/94	74%
6222-P	94.20471	PU-239	RAS	1.269	0.079	PCI/G	11/17/94	74%
6211-P	94.20472	AM-241	RAS	0.052	0.03	PCI/G	11/17/94	54%
6211-P	94.20472	PU-238	RAS	0.506	0.035	PCI/G	11/17/94	83%
6211-P	94.20472	PU-239	RAS	0.089	0.02	PCI/G	11/17/94	83%
6211-1C	94.20473	AM-241	RAS	0.01	0.03	PCI/G	11/17/94	72%
6211-1C	94.20473	PU-238	RAS	0.137	0.031	PCI/G	11/17/94	8%
6211-1C	94.20473	PU-239	RAS	0.034	0.02	PCI/G	11/17/94	8%
6211-2C	94.20474	AM-241	RAS	0.009	0.03	PCI/G	11/17/94	83%
6211-2C	94.20474	PU-238	RAS	0.1725	0.037	PCI/G	11/17/94	12%
6211-2C	94.20474	PU-239	RAS	0.0231	0.0147	PCI/G	11/17/94	12%
6211-3C	94.20475	AM-241	RAS	0.012	0.03	PCI/G	11/17/94	92%
6211-3C	94.20475	PU-238	RAS	0.012	0.03	PCI/G	11/17/94	73%
6211-3C	94.20475	PU-239	RAS	0.02	0.02	PCI/G	11/17/94	73%
6243-2C	94.20476	AM-241	RAS	0.003	0.03	PCI/G	11/17/94	99%
6243-2C	94.20476	PU-238	RAS	0.006	0.03	PCI/G	11/17/94	29%
6243-2C	94.20476	PU-239	RAS	0.001	0.02	PCI/G	11/17/94	29%
6243-3C	94.20477	AM-241	RAS	0.007	0.03	PCI/G	11/17/94	89%
6243-3C	94.20477	PU-238	RAS	0.001	0.03	PCI/G	11/17/94	79%
6243-3C	94.20477	PU-239	RAS	0.005	0.02	PCI/G	11/17/94	79%
6243-1C	94.20478	AM-241	RAS	0.009	0.03	PCI/G	11/17/94	85%
6243-1C	94.20478	PU-238	RAS	0.012	0.03	PCI/G	11/17/94	14%
6243-1C	94.20478	PU-239	RAS	0.003	0.02	PCI/G	11/17/94	14%
6243-P	94.20479	AM-241	RAS	0.014	0.03	PCI/G	11/17/94	58%
6243-P	94.20479	PU-238	RAS	0.003	0.03	PCI/G	11/17/94	87%
6243-P	94.20479	PU-239	RAS	0.037	0.02	PCI/G	11/17/94	87%

REPORT NUMBER: 29431

***** EM-9 ANALYTICAL REPORT *****

Prepared by: AKS on 16-Nov-1994

ANALYSIS: U REQUEST NUMBER: 18705 MATRIX: BZ ANALYST: RICHARD PETERS PROGRAM CODE: M36

OWNER: Philip R. Fresquez GROUP: ESH-20 MAIL-STOP: K490 PHONE: 7-0815

ANALYTICAL TECHNIQUE: KPA ANALYTICAL PROCEDURE: NOTEBOOK: PAGE:

CUSTOMER SAMPLES:

CUSTOMER NUMBER	SAMPLE NUMBER	ANALYTICAL RESULT	ANALYTICAL UNCERTAINTY	UNITS	COMPLETION DATE	COMMENT
6222-1C	94.20468	0.318	0.032	UG/G	11/16/94	
6222-2C	94.20469	0.397	0.04	UG/G	11/16/94	
6222-3C	94.20470	0.316	0.038	UG/G	11/16/94	
6222-P	94.20471	1.362	0.136	UG/G	11/16/94	
6211-P	94.20472	1.931	0.193	UG/G	11/16/94	
6211-1C	94.20473	0.384	0.038	UG/G	11/16/94	
6211-2C	94.20474	0.565	0.057	UG/G	11/16/94	
6211-3C	94.20475	0.513	0.051	UG/G	11/16/94	
6243-2C	94.20476	0.174	0.017	UG/G	11/16/94	
6243-3C	94.20477	0.267	0.027	UG/G	11/16/94	
6243-1C	94.20478	0.252	0.025	UG/G	11/16/94	
6243-P	94.20479	0.979	0.196	UG/G	11/16/94	

***** CST ANALYTICAL REPORT *****

Prepared by: YIG on 21-Apr-1995

REQUEST NUMBER: 18705 MATRIX: BZ ANALYST: SAMMY GARCIA PROGRAM CODE: M36A

OWNER: Philip R. Fresquez GROUP: ESH-20 MAIL-STOP: M887 PHONE: 7-0815

NOTEBOOK: PAGE:

CUSTOMER SAMPLES:

CUSTOMER NUM	SAMPLE NUM	ANALYSIS	ANALYTICAL TECHNIQUE	ANALYTICAL RESULT	ANALYTICAL UNCERTAINTY	UNITS	COMPLETION DATE	COMMENT
6222-1C	94.20468	BA-140	G	9.82	14.73	PCI/G	4/12/95	
6222-1C	94.20468	BI-212	G	0.17	0.26	PCI/G	4/12/95	
6222-1C	94.20468	BI-214	G	0.49	0.12	PCI/G	4/12/95	
6222-1C	94.20468	CE-144	G	0.46	0.69	PCI/G	4/12/95	
6222-1C	94.20468	CO-57	G	0.07	0.03	PCI/G	4/12/95	
6222-1C	94.20468	CO-60	G	0.94	0.12	PCI/G	4/12/95	
6222-1C	94.20468	CS-134	G	0.04	0.06	PCI/G	4/12/95	
6222-1C	94.20468	CS-137	G	0.01	0.02	PCI/G	4/12/95	
6222-1C	94.20468	EU-152	G	2.89	0.64	PCI/G	4/12/95	
6222-1C	94.20468	K-40	G	43.87	5.22	PCI/G	4/12/95	
6222-1C	94.20468	LA-140	G	0.0		PCI/G	4/12/95	
6222-1C	94.20468	MN-54	G	0.11	0.06	PCI/G	4/12/95	
6222-1C	94.20468	NA-22	G	0.22	0.08	PCI/G	4/12/95	
6222-1C	94.20468	NP-237	G	0.09	0.14	PCI/G	4/12/95	
6222-1C	94.20468	PA-231	G	1.61	2.42	PCI/G	4/12/95	
6222-1C	94.20468	PA-233	G	0.82	1.23	PCI/G	4/12/95	
6222-1C	94.20468	PB-210	G	0.0	2.7	PCI/G	4/12/95	
6222-1C	94.20468	PB-212	G	0.17	0.07	PCI/G	4/12/95	
6222-1C	94.20468	PB-214	G	0.24	0.08	PCI/G	4/12/95	
6222-1C	94.20468	RA-223	G	42.86	64.29	PCI/G	4/12/95	
6222-1C	94.20468	RA-224	G	0.11	0.17	PCI/G	4/12/95	
6222-1C	94.20468	RA-226	G	0.79	1.19	PCI/G	4/12/95	
6222-1C	94.20468	RN-219	G	0.79	0.3	PCI/G	4/12/95	
6222-1C	94.20468	RU-106	G	0.08	0.12	PCI/G	4/12/95	
6222-1C	94.20468	SE-75	G	0.08	0.12	PCI/G	4/12/95	
6222-1C	94.20468	TL-208	G	0.2	0.06	PCI/G	4/12/95	
6222-1C	94.20468	ZN-65	G	0.75	1.13	PCI/G	4/12/95	
6222-2C	94.20469	BA-140	G	42.55	63.83	PCI/G	4/12/95	
6222-2C	94.20469	BI-212	G	0.18	0.27	PCI/G	4/12/95	
6222-2C	94.20469	BI-214	G	0.41	0.11	PCI/G	4/12/95	
6222-2C	94.20469	CE-144	G	0.41	0.62	PCI/G	4/12/95	
6222-2C	94.20469	CO-57	G	0.05	0.08	PCI/G	4/12/95	
6222-2C	94.20469	CO-60	G	0.91	0.14	PCI/G	4/12/95	
6222-2C	94.20469	CS-134	G	0.01	0.02	PCI/G	4/12/95	
6222-2C	94.20469	CS-137	G	0.03	0.05	PCI/G	4/12/95	
6222-2C	94.20469	EU-152	G	2.13	0.54	PCI/G	4/12/95	
6222-2C	94.20469	K-40	G	46.35	5.35	PCI/G	4/12/95	

6222-2C	94.20469 LA-140	G	0.0		PC1/G	4/12/95
6222-2C	94.20469 MN-54	G	0.08	0.12	PC1/G	4/12/95
6222-2C	94.20469 NA-22	G	0.1	0.15	PC1/G	4/12/95
6222-2C	94.20469 NP-237	G	0.3	0.45	PC1/G	4/12/95
6222-2C	94.20469 PA-231	G	1.42	2.13	PC1/G	4/12/95
6222-2C	94.20469 PA-233	G	0.14	0.21	PC1/G	4/12/95
6222-2C	94.20469 PB-210	G	0.0	2.7	PC1/G	4/12/95
6222-2C	94.20469 PB-212	G	0.24	0.07	PC1/G	4/12/95
6222-2C	94.20469 PB-214	G	0.31	0.08	PC1/G	4/12/95
6222-2C	94.20469 RA-223	G	0.0		PC1/G	4/12/95
6222-2C	94.20469 RA-224	G	0.37	0.56	PC1/G	4/12/95
6222-2C	94.20469 RA-226	G	0.06	0.09	PC1/G	4/12/95
6222-2C	94.20469 RN-219	G	0.05	0.08	PC1/G	4/12/95
6222-2C	94.20469 RU-106	G	0.52	0.78	PC1/G	4/12/95
6222-2C	94.20469 SE-75	G	0.09	0.14	PC1/G	4/12/95
6222-2C	94.20469 TL-208	G	0.15	0.05	PC1/G	4/12/95
6222-2C	94.20469 ZN-65	G	0.8	0.22	PC1/G	4/12/95
6222-3C	94.20470 BA-140	G	34.02	51.03	PC1/G	4/12/95
6222-3C	94.20470 BI-212	G	0.3	0.45	PC1/G	4/12/95
6222-3C	94.20470 BI-214	G	0.5	0.14	PC1/G	4/12/95
6222-3C	94.20470 CE-144	G	0.23		PC1/G	4/12/95
6222-3C	94.20470 CO-57	G	0.06	0.03	PC1/G	4/12/95
6222-3C	94.20470 CO-60	G	0.96	0.17	PC1/G	4/12/95
6222-3C	94.20470 CS-134	G	0.05	0.08	PC1/G	4/12/95
6222-3C	94.20470 CS-137	G	0.06	0.09	PC1/G	4/12/95
6222-3C	94.20470 EU-152	G	2.39	0.56	PC1/G	4/12/95
6222-3C	94.20470 K-40	G	45.39	5.32	PC1/G	4/12/95
6222-3C	94.20470 LA-140	G	0.0		PC1/G	4/12/95
6222-3C	94.20470 MN-54	G	0.15	0.23	PC1/G	4/12/95
6222-3C	94.20470 NA-22	G	0.15	0.07	PC1/G	4/12/95
6222-3C	94.20470 NP-237	G	0.03	0.05	PC1/G	4/12/95
6222-3C	94.20470 PA-231	G	1.52	2.28	PC1/G	4/12/95
6222-3C	94.20470 PA-233	G	0.11	0.17	PC1/G	4/12/95
6222-3C	94.20470 PB-210	G	0.0	2.7	PC1/G	4/12/95
6222-3C	94.20470 PB-212	G	0.1	0.15	PC1/G	4/12/95
6222-3C	94.20470 PB-214	G	0.18	0.05	PC1/G	4/12/95
6222-3C	94.20470 RA-223	G	0.0		PC1/G	4/12/95
6222-3C	94.20470 RA-224	G	0.56	0.84	PC1/G	4/12/95
6222-3C	94.20470 RA-226	G	0.41	0.62	PC1/G	4/12/95
6222-3C	94.20470 RN-219	G	0.68	0.23	PC1/G	4/12/95
6222-3C	94.20470 RU-106	G	0.85	1.28	PC1/G	4/12/95
6222-3C	94.20470 SE-75	G	0.09	0.14	PC1/G	4/12/95
6222-3C	94.20470 TL-208	G	0.21	0.07	PC1/G	4/12/95
6222-3C	94.20470 ZN-65	G	0.62	0.21	PC1/G	4/12/95
6222-P	94.20471 BA-140	G	1.09	1.64	PC1/G	4/12/95
6222-P	94.20471 BI-212	G	1.25	0.61	PC1/G	4/12/95
6222-P	94.20471 BI-214	G	0.44	0.13	PC1/G	4/12/95
6222-P	94.20471 CE-144	G	0.21	0.32	PC1/G	4/12/95
6222-P	94.20471 CO-57	G	0.09	0.03	PC1/G	4/12/95
6222-P	94.20471 CO-60	G	0.96	0.15	PC1/G	4/12/95
6222-P	94.20471 CS-134	G	0.08	0.03	PC1/G	4/12/95
6222-P	94.20471 CS-137	G	0.03	0.05	PC1/G	4/12/95
6222-P	94.20471 EU-152	G	2.94	0.71	PC1/G	4/12/95
6222-P	94.20471 K-40	G	40.22	4.86	PC1/G	4/12/95
6222-P	94.20471 LA-140	G	0.0		PC1/G	4/12/95
6222-P	94.20471 MN-54	G	0.07	0.11	PC1/G	4/12/95
6222-P	94.20471 NA-22	G	0.19	0.29	PC1/G	4/12/95
6222-P	94.20471 NP-237	G	0.41	0.62	PC1/G	4/12/95
6222-P	94.20471 PA-231	G	0.35	0.53	PC1/G	4/12/95
6222-P	94.20471 PA-233	G	0.75	1.13	PC1/G	4/12/95

6222-P	94.20471 PB-210	G	0.0	2.7	PCI/G	4/12/95
6222-P	94.20471 PB-212	G	0.11	0.06	PCI/G	4/12/95
6222-P	94.20471 PB-214	G	0.11	0.05	PCI/G	4/12/95
6222-P	94.20471 RA-223	G	3.71	5.57	PCI/G	4/12/95
6222-P	94.20471 RA-224	G	0.53	0.8	PCI/G	4/12/95
6222-P	94.20471 RA-226	G	0.01	0.02	PCI/G	4/12/95
6222-P	94.20471 RH-219	G	1.09	1.64	PCI/G	4/12/95
6222-P	94.20471 RU-106	G	0.34	0.51	PCI/G	4/12/95
6222-P	94.20471 SE-75	G	0.07	0.11	PCI/G	4/12/95
6222-P	94.20471 TL-208	G	0.16	0.06	PCI/G	4/12/95
6222-P	94.20471 ZN-65	G	0.17	0.26	PCI/G	4/12/95
6211-P	94.20472 BA-140	G	9.94	14.91	PCI/G	4/12/95
6211-P	94.20472 BI-212	G	0.63	0.95	PCI/G	4/12/95
6211-P	94.20472 BI-214	G	0.42	0.14	PCI/G	4/12/95
6211-P	94.20472 CE-144	G	0.33	0.5	PCI/G	4/12/95
6211-P	94.20472 CO-57	G	0.01	0.03	PCI/G	4/12/95
6211-P	94.20472 CO-60	G	0.99	0.15	PCI/G	4/12/95
6211-P	94.20472 CS-134	G	0.05	0.08	PCI/G	4/12/95
6211-P	94.20472 CS-137	G	0.02	0.03	PCI/G	4/12/95
6211-P	94.20472 EU-152	G	1.97	0.52	PCI/G	4/12/95
6211-P	94.20472 K-40	G	43.45	5.14	PCI/G	4/12/95
6211-P	94.20472 LA-140	G	0.0		PCI/G	4/12/95
6211-P	94.20472 MH-54	G	0.04	0.06	PCI/G	4/12/95
6211-P	94.20472 NA-22	G	0.08	0.12	PCI/G	4/12/95
6211-P	94.20472 NP-237	G	0.33	0.5	PCI/G	4/12/95
6211-P	94.20472 PA-231	G	0.14	0.21	PCI/G	4/12/95
6211-P	94.20472 PA-233	G	0.08	0.12	PCI/G	4/12/95
6211-P	94.20472 PB-210	G	0.0	2.7	PCI/G	4/12/95
6211-P	94.20472 PB-212	G	0.33	0.09	PCI/G	4/12/95
6211-P	94.20472 PB-214	G	0.39	0.1	PCI/G	4/12/95
6211-P	94.20472 RA-223	G	4.61	6.92	PCI/G	4/12/95
6211-P	94.20472 RA-224	G	0.84	1.26	PCI/G	4/12/95
6211-P	94.20472 RA-226	G	0.22	0.33	PCI/G	4/12/95
6211-P	94.20472 RH-219	G	0.07	0.11	PCI/G	4/12/95
6211-P	94.20472 RU-106	G	0.34	0.51	PCI/G	4/12/95
6211-P	94.20472 SE-75	G	0.03	0.05	PCI/G	4/12/95
6211-P	94.20472 TL-208	G	0.26	0.07	PCI/G	4/12/95
6211-P	94.20472 ZN-65	G	0.14	0.21	PCI/G	4/12/95
6211-1C	94.20473 BA-140	G	0.0		PCI/G	4/12/95
6211-1C	94.20473 BI-212	G	0.58	0.87	PCI/G	4/12/95
6211-1C	94.20473 BI-214	G	0.41	0.13	PCI/G	4/12/95
6211-1C	94.20473 CE-144	G	0.24	0.36	PCI/G	4/12/95
6211-1C	94.20473 CO-57	G	0.05	0.02	PCI/G	4/12/95
6211-1C	94.20473 CO-60	G	0.94	0.17	PCI/G	4/12/95
6211-1C	94.20473 CS-134	G	0.04	0.06	PCI/G	4/12/95
6211-1C	94.20473 CS-137	G	0.04	0.06	PCI/G	4/12/95
6211-1C	94.20473 EU-152	G	2.24	0.55	PCI/G	4/12/95
6211-1C	94.20473 K-40	G	50.15	5.78	PCI/G	4/12/95
6211-1C	94.20473 LA-140	G	0.0		PCI/G	4/12/95
6211-1C	94.20473 MH-54	G	0.02	0.03	PCI/G	4/12/95
6211-1C	94.20473 NA-22	G	0.11	0.06	PCI/G	4/12/95
6211-1C	94.20473 NP-237	G	0.25	0.38	PCI/G	4/12/95
6211-1C	94.20473 PA-231	G	1.88	2.82	PCI/G	4/12/95
6211-1C	94.20473 PA-233	G	0.0		PCI/G	4/12/95
6211-1C	94.20473 PB-210	G	0.0	2.7	PCI/G	4/12/95
6211-1C	94.20473 PB-212	G	0.23	0.07	PCI/G	4/12/95
6211-1C	94.20473 PB-214	G	0.21	0.06	PCI/G	4/12/95
6211-1C	94.20473 RA-223	G	0.0		PCI/G	4/12/95
6211-1C	94.20473 RA-224	G	0.0	1.6	PCI/G	4/12/95
6211-1C	94.20473 RA-226	G	1.63	0.68	PCI/G	4/12/95

6211-1C	94.20473 RN-219	G	0.55	0.83	PCI/G	4/12/95
6211-1C	94.20473 RU-106	G	0.09	0.14	PCI/G	4/12/95
6211-1C	94.20473 SE-75	G	0.01	0.02	PCI/G	4/12/95
6211-1C	94.20473 TL-208	G	0.22	0.07	PCI/G	4/12/95
6211-1C	94.20473 ZN-65	G	0.61	0.17	PCI/G	4/12/95
6211-2C	94.20474 BA-140	G	9.79	14.69	PCI/G	4/12/95
6211-2C	94.20474 BI-212	G	0.59	0.89	PCI/G	4/12/95
6211-2C	94.20474 BI-214	G	0.72	0.16	PCI/G	4/12/95
6211-2C	94.20474 CE-144	G	0.4	0.6	PCI/G	4/12/95
6211-2C	94.20474 CO-57	G	0.1	0.03	PCI/G	4/12/95
6211-2C	94.20474 CO-60	G	1.01	0.15	PCI/G	4/12/95
6211-2C	94.20474 CS-134	G	0.07	0.03	PCI/G	4/12/95
6211-2C	94.20474 CS-137	G	0.04	0.06	PCI/G	4/12/95
6211-2C	94.20474 EU-152	G	2.36	0.56	PCI/G	4/12/95
6211-2C	94.20474 K-40	G	49.47	5.73	PCI/G	4/12/95
6211-2C	94.20474 LA-140	G	0.0		PCI/G	4/12/95
6211-2C	94.20474 MN-54	G	0.01	0.02	PCI/G	4/12/95
6211-2C	94.20474 NA-22	G	0.07	0.11	PCI/G	4/12/95
6211-2C	94.20474 NP-237	G	0.19	0.29	PCI/G	4/12/95
6211-2C	94.20474 PA-231	G	2.76	4.14	PCI/G	4/12/95
6211-2C	94.20474 PA-233	G	0.38	0.57	PCI/G	4/12/95
6211-2C	94.20474 PB-210	G	0.0	2.7	PCI/G	4/12/95
6211-2C	94.20474 PB-212	G	0.09	0.14	PCI/G	4/12/95
6211-2C	94.20474 PB-214	G	0.17	0.08	PCI/G	4/12/95
6211-2C	94.20474 RA-223	G	78.29	117.44	PCI/G	4/12/95
6211-2C	94.20474 RA-224	G	0.02	0.03	PCI/G	4/12/95
6211-2C	94.20474 RA-226	G	0.39	0.59	PCI/G	4/12/95
6211-2C	94.20474 RN-219	G	0.39	0.59	PCI/G	4/12/95
6211-2C	94.20474 RU-106	G	0.87	1.31	PCI/G	4/12/95
6211-2C	94.20474 SE-75	G	0.02	0.03	PCI/G	4/12/95
6211-2C	94.20474 TL-208	G	0.25	0.06	PCI/G	4/12/95
6211-2C	94.20474 ZN-65	G	0.07	0.11	PCI/G	4/12/95
6211-3C	94.20475 BA-140	G	25.8	38.7	PCI/G	4/12/95
6211-3C	94.20475 BI-212	G	0.75	1.13	PCI/G	4/12/95
6211-3C	94.20475 BI-214	G	0.58	0.15	PCI/G	4/12/95
6211-3C	94.20475 CE-144	G	0.28	0.42	PCI/G	4/12/95
6211-3C	94.20475 CO-57	G	0.1	0.03	PCI/G	4/12/95
6211-3C	94.20475 CO-60	G	1.12	0.16	PCI/G	4/12/95
6211-3C	94.20475 CS-134	G	0.04	0.06	PCI/G	4/12/95
6211-3C	94.20475 CS-137	G	0.04	0.06	PCI/G	4/12/95
6211-3C	94.20475 EU-152	G	2.66	0.63	PCI/G	4/12/95
6211-3C	94.20475 K-40	G	47.19	5.5	PCI/G	4/12/95
6211-3C	94.20475 LA-140	G	0.0		PCI/G	4/12/95
6211-3C	94.20475 MN-54	G	0.02	0.03	PCI/G	4/12/95
6211-3C	94.20475 NA-22	G	0.12	0.18	PCI/G	4/12/95
6211-3C	94.20475 NP-237	G	0.22	0.33	PCI/G	4/12/95
6211-3C	94.20475 PA-231	G	2.14	3.21	PCI/G	4/12/95
6211-3C	94.20475 PA-233	G	0.23	0.35	PCI/G	4/12/95
6211-3C	94.20475 PB-210	G	0.0	2.7	PCI/G	4/12/95
6211-3C	94.20475 PB-212	G	0.12	0.06	PCI/G	4/12/95
6211-3C	94.20475 PB-214	G	0.16	0.07	PCI/G	4/12/95
6211-3C	94.20475 RA-223	G	54.27	81.41	PCI/G	4/12/95
6211-3C	94.20475 RA-224	G	0.98	1.47	PCI/G	4/12/95
6211-3C	94.20475 RA-226	G	1.68	0.64	PCI/G	4/12/95
6211-3C	94.20475 RN-219	G	0.45	0.68	PCI/G	4/12/95
6211-3C	94.20475 RU-106	G	0.15	0.23	PCI/G	4/12/95
6211-3C	94.20475 SE-75	G	0.17	0.26	PCI/G	4/12/95
6211-3C	94.20475 TL-208	G	0.26	0.07	PCI/G	4/12/95
6211-3C	94.20475 ZN-65	G	0.82	1.23	PCI/G	4/12/95
6243-2C	94.20476 BA-140	G	87.81	131.72	PCI/G	4/12/95

6243-2C	94.20476 B1-212	G	0.41	0.62	PCI/G	4/12/95
6243-2C	94.20476 B1-214	G	0.52	0.14	PCI/G	4/12/95
6243-2C	94.20476 CE-144	G	0.11	0.17	PCI/G	4/12/95
6243-2C	94.20476 CO-57	G	0.08	0.03	PCI/G	4/12/95
6243-2C	94.20476 CO-60	G	2.42	0.28	PCI/G	4/12/95
6243-2C	94.20476 CS-134	G	0.13	0.05	PCI/G	4/12/95
6243-2C	94.20476 CS-137	G	0.02	0.03	PCI/G	4/12/95
6243-2C	94.20476 EU-152	G	2.72	0.65	PCI/G	4/12/95
6243-2C	94.20476 K-40	G	46.52	5.48	PCI/G	4/12/95
6243-2C	94.20476 LA-140	G	0.0		PCI/G	4/12/95
6243-2C	94.20476 MH-54	G	0.07	0.11	PCI/G	4/12/95
6243-2C	94.20476 HA-22	G	0.11	0.17	PCI/G	4/12/95
6243-2C	94.20476 HP-237	G	0.99	1.49	PCI/G	4/12/95
6243-2C	94.20476 PA-231	G	1.56	0.73	PCI/G	4/12/95
6243-2C	94.20476 PA-233	G	0.18	0.27	PCI/G	4/12/95
6243-2C	94.20476 PB-210	G	0.0	2.7	PCI/G	4/12/95
6243-2C	94.20476 PB-212	G	0.12	0.06	PCI/G	4/12/95
6243-2C	94.20476 PB-214	G	0.27	0.07	PCI/G	4/12/95
6243-2C	94.20476 RA-223	G	38.53	57.8	PCI/G	4/12/95
6243-2C	94.20476 RA-224	G	0.28	0.42	PCI/G	4/12/95
6243-2C	94.20476 RA-226	G	0.47	0.71	PCI/G	4/12/95
6243-2C	94.20476 RN-219	G	0.11	0.17	PCI/G	4/12/95
6243-2C	94.20476 RU-106	G	1.34	2.01	PCI/G	4/12/95
6243-2C	94.20476 SE-75	G	0.04	0.06	PCI/G	4/12/95
6243-2C	94.20476 TL-208	G	0.22	0.06	PCI/G	4/12/95
6243-2C	94.20476 ZN-65	G	1.34	2.01	PCI/G	4/12/95
6243-3C	94.20477 BA-140	G	4.73	7.1	PCI/G	4/12/95
6243-3C	94.20477 B1-212	G	0.52	0.78	PCI/G	4/12/95
6243-3C	94.20477 B1-214	G	0.39	0.18	PCI/G	4/12/95
6243-3C	94.20477 CE-144	G	0.08	0.12	PCI/G	4/12/95
6243-3C	94.20477 CO-57	G	0.01	0.02	PCI/G	4/12/95
6243-3C	94.20477 CO-60	G	0.42	0.09	PCI/G	4/12/95
6243-3C	94.20477 CS-134	G	0.1	0.04	PCI/G	4/12/95
6243-3C	94.20477 CS-137	G	0.06	0.09	PCI/G	4/12/95
6243-3C	94.20477 EU-152	G	0.1	0.15	PCI/G	4/12/95
6243-3C	94.20477 K-40	G	28.92	3.08	PCI/G	4/12/95
6243-3C	94.20477 LA-140	G	0.0		PCI/G	4/12/95
6243-3C	94.20477 MH-54	G	0.1	0.04	PCI/G	4/12/95
6243-3C	94.20477 HA-22	G	0.03	0.05	PCI/G	4/12/95
6243-3C	94.20477 HP-237	G	0.16	0.24	PCI/G	4/12/95
6243-3C	94.20477 PA-231	G	0.75	1.13	PCI/G	4/12/95
6243-3C	94.20477 PA-233	G	1.4	0.93	PCI/G	4/12/95
6243-3C	94.20477 PB-210	G	0.0	2.7	PCI/G	4/12/95
6243-3C	94.20477 PB-212	G	0.14	0.08	PCI/G	4/12/95
6243-3C	94.20477 PB-214	G	0.04	0.06	PCI/G	4/12/95
6243-3C	94.20477 RA-223	G	13.38	20.07	PCI/G	4/12/95
6243-3C	94.20477 RA-224	G	0.27	0.42	PCI/G	4/12/95
6243-3C	94.20477 RA-226	G	1.61	0.65	PCI/G	4/12/95
6243-3C	94.20477 RN-219	G	0.57	0.86	PCI/G	4/12/95
6243-3C	94.20477 RU-106	G	0.45	0.68	PCI/G	4/12/95
6243-3C	94.20477 SE-75	G	0.04	0.06	PCI/G	4/12/95
6243-3C	94.20477 TL-208	G	0.16	0.06	PCI/G	4/12/95
6243-3C	94.20477 ZN-65	G	0.06	0.09	PCI/G	4/12/95
6243-1C	94.20478 BA-140	G	40.6	29.67	PCI/G	4/12/95
6243-1C	94.20478 B1-212	G	0.99	0.66	PCI/G	4/12/95
6243-1C	94.20478 B1-214	G	0.3	0.14	PCI/G	4/12/95
6243-1C	94.20478 CE-144	G	0.07	0.11	PCI/G	4/12/95
6243-1C	94.20478 CO-57	G	0.01	0.02	PCI/G	4/12/95
6243-1C	94.20478 CO-60	G	0.43	0.12	PCI/G	4/12/95
6243-1C	94.20478 CS-134	G	0.01	0.02	PCI/G	4/12/95

6243-1C	94.20478 CS-137	G	0.12	0.05	PCI/G	4/12/95
6243-1C	94.20478 EU-152	G	0.17	0.26	PCI/G	4/12/95
6243-1C	94.20478 K-40	G	22.58	2.7	PCI/G	4/12/95
6243-1C	94.20478 LA-140	G	0.0		PCI/G	4/12/95
6243-1C	94.20478 MN-54	G	0.11	0.06	PCI/G	4/12/95
6243-1C	94.20478 NA-22	G	0.02	0.03	PCI/G	4/12/95
6243-1C	94.20478 NP-237	G	0.0	0.53	PCI/G	4/12/95
6243-1C	94.20478 PA-231	G	1.98	2.97	PCI/G	4/12/95
6243-1C	94.20478 PA-233	G	2.32	0.71	PCI/G	4/12/95
6243-1C	94.20478 PB-210	G	0.0	2.7	PCI/G	4/12/95
6243-1C	94.20478 PB-212	G	0.08	0.05	PCI/G	4/12/95
6243-1C	94.20478 PB-214	G	0.1	0.05	PCI/G	4/12/95
6243-1C	94.20478 RA-223	G	0.0		PCI/G	4/12/95
6243-1C	94.20478 RA-224	G	0.34	0.51	PCI/G	4/12/95
6243-1C	94.20478 RA-226	G	3.42	0.78	PCI/G	4/12/95
6243-1C	94.20478 RN-219	G	0.62	0.47	PCI/G	4/12/95
6243-1C	94.20478 RU-106	G	1.04	0.6	PCI/G	4/12/95
6243-1C	94.20478 SE-75	G	0.0	1.5	PCI/G	4/12/95
6243-1C	94.20478 TL-208	G	0.17	0.06	PCI/G	4/12/95
6243-1C	94.20478 ZN-65	G	0.1	0.15	PCI/G	4/12/95
6243-P	94.20479 BA-140	G	7.89	11.84	PCI/G	4/12/95
6243-P	94.20479 BI-212	G	1.18	1.77	PCI/G	4/12/95
6243-P	94.20479 BI-214	G	0.56	0.24	PCI/G	4/12/95
6243-P	94.20479 CE-144	G	0.35	0.53	PCI/G	4/12/95
6243-P	94.20479 CO-57	G	0.13	0.2	PCI/G	4/12/95
6243-P	94.20479 CO-60	G	1.28	0.28	PCI/G	4/12/95
6243-P	94.20479 CS-134	G	0.0	0.15	PCI/G	4/12/95
6243-P	94.20479 CS-137	G	0.02	0.03	PCI/G	4/12/95
6243-P	94.20479 EU-152	G	0.03	0.05	PCI/G	4/12/95
6243-P	94.20479 K-40	G	529.19	40.64	PCI/G	4/12/95
6243-P	94.20479 LA-140	G	0.0		PCI/G	4/12/95
6243-P	94.20479 MN-54	G	0.01	0.02	PCI/G	4/12/95
6243-P	94.20479 NA-22	G	0.08	0.12	PCI/G	4/12/95
6243-P	94.20479 NP-237	G	1.36	0.58	PCI/G	4/12/95
6243-P	94.20479 PA-231	G	6.84	3.04	PCI/G	4/12/95
6243-P	94.20479 PA-233	G	0.24	0.36	PCI/G	4/12/95
6243-P	94.20479 PB-210	G	0.0	2.7	PCI/G	4/12/95
6243-P	94.20479 PB-212	G	0.01	0.02	PCI/G	4/12/95
6243-P	94.20479 PB-214	G	0.22	0.33	PCI/G	4/12/95
6243-P	94.20479 RA-223	G	3.17	4.76	PCI/G	4/12/95
6243-P	94.20479 RA-224	G	0.35	0.53	PCI/G	4/12/95
6243-P	94.20479 RA-226	G	3.63	1.58	PCI/G	4/12/95
6243-P	94.20479 RN-219	G	0.84	1.26	PCI/G	4/12/95
6243-P	94.20479 RU-106	G	0.77	1.16	PCI/G	4/12/95
6243-P	94.20479 SE-75	G	0.0	1.5	PCI/G	4/12/95
6243-P	94.20479 TL-208	G	0.33	0.11	PCI/G	4/12/95
6243-P	94.20479 ZN-65	G	0.29	0.435	PCI/G	4/12/95