701396

FILE BARCODE
00130012

Radiation Protection Dosimetry
Vol. 26 No. 1/4 pp. 151-158 (1989)
Nuclear Technology Publishing

DISTRIBUTION OF PLUTONIUM AND AMERICIUM IN WHOLE BODIES DONATED TO THE UNITED STATES TRANSURANIUM REGISTRY

J. F. McInroy†, R. L. Kathren‡ and M. J. Swint‡
†Health and Environmental Chemistry Group
Los Alamos National Laboratory, Los Alamos, NM 87545, USA
‡US Transuranium Registry, PO Box 100, Richland, WA 99352, USA

INVITED PAPER

Abstract — Radiochemical analysis of whole body donations from six former nuclear industry workers 30 or more years post-exposure revealed about 45% of the total body deposition of ^{239}Pu and 35% of the ^{241}Am in the respiratory tract of the four cases with inhalation exposure. These proportions are greater than predicted by the current ICRP lung model. Exclusive of the respiratory tract, the mean fractional systemic deposition of ^{239}Pu in the tissues of five whole bodies was: liver 35.4% ± 12.5%; skeleton 53.7% ± 12.5%; striated muscle 6.5% ± 1.8% and all other organs and tissues 4.4% ± 1.7%. For ^{241}Am, the comparable values in four cases were liver 6.5% ± 4.8%; skeleton 73.5% ± 12.4%; muscle 14.3% ± 7.6%; and all other tissues and organs 6.65% ± 4.2%. The systemic distribution of ^{239}Pu was generally consistent with ICRP Publication 30. A significant fraction of both nuclides was retained in the muscle and other soft tissues which serve as long-term storage depots. Initial fractionation of ^{241}Am between skeleton and liver is consistent with the 50:30 ratio proposed in ICRP Publication 48 assuming an effective clearance half-time from the liver of about 2 y. Estimates of ^{239}Pu deposition made on the basis of urinalysis results *in vivo* were typically greater than the observed deposition measured in the tissues of the whole body after death.

INTRODUCTION

The Health, Safety and Environment Division of the Los Alamos National Laboratory (LANL) has been analysing soft tissues and bones from former nuclear industry empoyees since 1959 to determine the uptake, retention and distribution parameters for the actinide elements in humans in order to provide data to improve models used for *in vivo* estimates of employee exposures. The United States Transuranium Registry (USTR) was formed in 1968 and LANL began analysing tissue specimens obtained by the Registry at autopsy in 1978. The USTR is the only human tissue research programme in the United States studying the internally deposited higher actinide elements of occupational origin[1]. The objectives and functions of the USTR are described in detail by R. L. Kathren in another paper presented at this meeting[2]. To date, the USTR has collected post-mortem tissue analytical data from more than 250 autopsy cases, including six whole bodies analysed at Los Alamos for plutonium and americium content.

METHODS

A complete description of the selection, collection, dissection and chemical analyses of the tissue from the 'partial body' and whole-body autopsies has been described elsewhere[2-5]. Briefly, the analytical procedure requires the tissue to be weighed, dried, dry ashed, wet ashed and the resulting salts dissolved in acid. Appropriate sized aliquots are ion exchanged to separate the actinide of interest and electroplated. Recent significant changes in the analytical procedures include: (1) determination of the ash weights of bone and soft tissues by heating the specimens slowly to 450°C, maintaining that temperature for 72 h, cooling the samples to room temperature and weighing; and (2) wet ashing and final dissolution of the tissue ash salts in 8 M HCl instead of HNO_3. A chloride anion exchange system is used to isolate the actinide of interest. A known quantity of ^{242}Pu or ^{243}Am tracer is added to each sample analysed prior to the ion exchange procedure. The samples are plated onto 15.9 mm (⅝ in) diameter stainless steel discs and counted in an alpha pulse height spectrometer using 300 mm^2 silicon surface barrier detectors. The background for each detector is approximately 1–2 counts per 70,000 s (1167 min) for plutonium and 3 counts per 1167 min for americium. The minimum detectable amount (MDA) of alpha activity is 1.0 mBq (0.06 disintegrations per min) per sample, assuming a mean recovery of the tracer of 60%, a mean background of 3 counts, a 1167 min count length, and a counting efficiency of 30%[6].

Prior to the availability of actual data from a whole body, estimates of whole body plutonium content were made from tissue samples collected at routine autopsies by assuming that most of the plutonium remaining in the body at death would be found in the lungs, TBLN, liver and skeleton[7,8].

LANL

00130012.001

0006092

The activity in the respiratory tract and liver was measured directly as these organs were typically collected intact. The amount in the skeleton, however, had to be extrapolated from a few grammes of bone to a skeletal mass of approximately 14% of the total body weight, or 10 kg for Reference Man (a Caucasian male weighing 70 kg and age 20–30 years[9]). Although it was well known from animal data that plutonium, a bone surface seeker, was not evenly distributed in bone, the assumption of uniform distribution was made for lack of definitive data for humans and the measured concentration was extrapolated to 10 kg bone. Recognition of the errors associated with these calculations, and other considerations, prompted the USTR to initiate a whole-body donor programme. All soft tissues from these donors are analysed. One-half of the dissected skeleton is analysed and, assuming left–right symmetry, the results are extrapolated to the entire skeleton according to the method described by McInroy *et al*[5]. Procedures for calculation of americium content of the body are similar to those described for plutonium.

CASE DESCRIPTIONS

Six cases with known occupational exposure to ^{239}Pu or ^{241}Am have been analysed to date. For all cases but 102, who incurred an exposure to ^{241}Am through a wound, the individuals were likely to have been exposed to a mixture of both nuclides simultaneously. A brief medical and occupational history for each case is provided below:

Case 102: This case has been previously described in detail[10,11,12] and was a 49 year old Caucasian male radiochemist, 1.82 m in height who weighed, when healthy, 67 kg. He died in March 1979 from malignant melanoma. Widespread melanoma metastases were found at autopsy throughout the body tissues, including bone. This individual had been a research chemist from 1950-1979 and had worked with significant amounts of ^{241}Am early in his career (1952-54). Although there was no documented accidental exposure to americium during his working life, a routine urinalysis in 1958 indicated the presence of ^{241}Am. Follow-up urinalyses and *in vivo* counting led to an estimated skeletal deposition of 3.96 kBq based upon inhalation as the presumed route of intake. Post-mortem radiochemical analyses of the body resulted in an estimated total body deposition of 5.44 kBq of ^{241}Am. An elevated level of ^{241}Am was found in the soft tissues of the left hand raising the possibility of an unrecognised contaminated wound as a route of entry.

Case 193: The medical and work history of this case has also been previously described in the literature[13,14]. This individual was a 62 y old Caucasian male, 1.73 m in height and weighing 75 kg, who retired in January, 1982, about one year before his death in December 1982 from respiratory failure complicating pneumonia. He had been employed as a chemical engineer in Pu alloy research and other Pu work from 1945 until his retirement in 1982. There was potential for moderate inhalation exposure to Pu from 1945-1957; no wounds or ingestions were recorded; positive nasal swipes with >1 Bq of activity were obtained on 16 occasions before 1957. Exposure potential was significantly reduced in 1957 when he assumed supervisory responsibilities. *In vivo* chest measurements and radiouranalyses data provided estimates of 995 Bq whole body retention at the time of retirement.

Case 208: This male Caucasian, age 69 y at the time of death in April 1984 from a pulmonary embolus, was 1.78 m in height and weighed approximately 59 kg. He suffered a cerebral vascular accident (stroke) eight years prior to death and was physically inactive after that event. He began work in 1946 as an operations foreman in a Pu reduction and dry chemistry operation. He incurred the potential for acute inhalation exposure to Pu during the period from May 1946 through March 1947, showing on one occasion (August 1946) positive nose wipes for plutonium. *In vivo* estimates based upon urinalysis results indicated a retention of 574 Bq ^{239}Pu at the time of death.

Case 212: This 56 year old male Caucasian plumber measuring 1.81 m and weighing 89 kg, died in 1984 from acute left pneumothorax and associated complications of emphysema. During employment he was involved in two radiation incidents with the potential for internal deposition of plutonium. The first occurred in August 1956 and resulted in an estimated deposition based on urinalysis data of approximately 0.8 Bq of ^{239}Pu. In March 1967 he suffered a contaminated wound in a finger that was treated by debridement and chelation with DTPA. A total of 26.5 g of DTPA was administered in 47 treatments during the six month period following the injury. The estimated systemic deposition from this wound, based on urinalysis data, was 535 Bq of ^{239}Pu and 4.3 kBq ^{241}Pu.

Case 213: This donor was a 68 y old male Caucasian, measuring 1.72 m and weighing 64 kg at the time of death in 1984 from lung carcinoma. He began working with Pu in July 1946 as a chemist and had potential airborne Pu exposures until his retirement in January 1979. Five potential inhalation accident events were recorded between 1946 and 1967, including three occasions in 1946 and 1947 when positive nasal wipes for plutonium were obtained.

00130012.002

0006093

LANL

Seven *in vivo* chest measurements were made between 1970 and 1979. All were below the minimum detection levels for ^{239}Pu. Whole body deposition at the time of death, based on radiourinalysis data, was estimated at 585 Bq.

Case 242: This 78 y old Caucasian male was 1.80 m in height and weighed 85 kg at the time of death in January 1987 of left ventricular hypertrophy and coronary arteriosclerosis. He began working with Pu in 1946 as a plutonium chemical operator and had potential exposures to airborne plutonium until his retirement in June 1972. Six potential accidents were recorded during 1947-1948; all were exposures to airborne plutonium except an acid burn in 1947 having a recorded surface contamination level of >40,000 cpm (counting efficiency unstated). One additional exposure to airborne Pu was recorded in 1958. Urinalysis data gave an estimated whole body deposition of 925 Bq.

RESULTS

The ^{239}Pu and ^{241}Am content of specific tissues or organs for each whole-body case, expressed in terms of the percentage of the total activity in the whole body of each specific tissue or organ, are found in the tables in the Appendix. Complete analytical data have not been reproduced, but the results provided are sufficient to estimate the whole body distribution of ^{239}Pu from five cases and the distribution of ^{241}Am for four and to make a preliminary evaluation of these data in terms of existing biokinetic models. The systemic (excluding the lungs) ^{239}Pu activity measured in the tissues is compared with the deposition estimated *in vivo* in Table 1. In general, the estimated activity based on *in vivo* measurements is several times greater than the measured post-mortem activity in the tissues. These results are in excellent agreement with the recent study by Kathren, Heid and Swint in which *in vivo* estimates of systemic deposition were compared with estimates made from post-mortem analysis of selected tissues. This comparison showed an inverse relationship between the measured activity in the tissues and the ratio of *in vivo* to post-mortem estimates of systemic deposition[14].

The distributions of ^{239}Pu and ^{241}Am, expressed as a percentage of the total body content or of the systemic deposition, are given in Tables 2–5. For those cases in which inhalation was the primary route of entry, a large fraction of the total body burden was found in the respiratory tract. This does not appear consistent with the current ICRP lung model[8], that predicts a smaller fraction of actinide to be retained in the respiratory tract.

By comparison, the distributions of ^{239}Pu and

Table 1. Comparison of systemic ^{239}Pu estimates made *in vivo* with post-mortem tissue analysis results.

Case	Systemic ^{239}Pu content (Bq) *In vivo* estimate	Post-mortem measurement	Ratio, *in vivo* to post-mortem
193	995	116	8.6
208	574	141	4.1
212	535	209	2.6
213	585	247	2.4
242	925	929	1.0

Table 3. Distribution of ^{239}Pu in five whole bodies (% systemic content).

USTR Case no.	Liver	Skeleton	Muscle	Other
193	41.8	43.9	7.4	7.0
208	25.3	62.6	9.1	3.0
212	41.3	49.2	6.7	2.8
213	19.4	70.8	5.0	4.9
242	49.1	41.9	4.7	4.3
Mean	35.4	53.7	6.5	4.4
SD	12.5	12.5	1.8	1.7

Table 2. Distribution of ^{239}Pu in five whole bodies (% whole body content).

USTR Case no.	Likely route of entry	Respiratory tract	Liver	Skeleton	Muscle	Other
193	Inhalation	52.8	[illegible]	20.8	3.5	3.3
208	Inhalation	37.8	[illegible]	39.0	5.6	1.9
212	Wound	0.4	[illegible]	49.1	6.6	2.8
213	Inhalation	18.6	[illegible]	57.6	4.1	4.0
242	Inhalation	70.1	[illegible]	12.5	1.4	1.3
Mean, all cases (N = 5)		35.9	[illegible]	35.8	4.2	2.7
Standard deviation		27.5	[illegible]	18.9	2.0	1.1
Mean, inhalation cases only (N = 4)		44.8	[illegible]	32.5	3.7	2.6
Standard deviation		21.9	[illegible]	20.1	1.7	1.2

LANL

00130012.003

0006094

Table 4. Distribution of ^{241}Am in four whole bodies (% whole body content).

USTR Case no.	Likely route of entry	Respiratory tract	Liver	Skeleton	Muscle	Other
102	Wound	1.5	6.4	82.4	8.8	0.9
193	Inhalation	60.7	5.3	22.9	6.8	4.3
208	Inhalation	28.9	2.2	48.8	16.8	3.3
213	Inhalation	14.7	2.5	71.2	6.3	5.3
Mean, all cases (N = 4)		26.4	4.1	56.3	9.7	3.4
SD		25.4	2.1	26.3	4.9	1.9
Mean, inhalation cases only (N = 3)		34.8	3.3	47.6	10.0	4.3
SD		23.6	1.7	24.2	5.9	1.0

Table 5. Distribution of ^{241}Am in four whole bodies (% systemic content).

USTR case no.	Liver	Skeleton	Muscle	Other
102	6.5	83.7	8.9	0.9
193	13.4	58.3	17.3	10.9
208	3.3	68.6	23.7	4.4
213	2.9	83.5	7.4	6.3
Mean	6.5	73.5	14.3	6.6
SD	4.8	12.4	7.6	4.2

^{241}Am differ. For both nuclides, a greater fraction of the total body burden is found in the soft tissues, in particular the muscle, than inferred from the models proposed in ICRP Publications 30 and 48[8,15]. For ^{239}Pu the distribution in skeleton and liver (Table 6) is more consistent with the initial equal fractionation of this nuclide between skeleton and liver proposed in ICRP Publication 30. The overall systemic distribution of ^{239}Pu is well characterised by using ICRP 30 parameters for initial fractionation and half-life in skeleton and liver, assuming that all or at least a portion of the remainder in the transfer compartment is deposited in the remaining soft tissues with a long half-life (Table 6).

For ^{241}Am, the systemic distributions observed in these cases are more consistent with the 50:30 fractionation between skeleton and liver proposed in ICRP Publication 48[15], and an effective clearance half-time of about 2 y for ^{241}Am in the liver as was proposed by Durbin and Schmidt[16] based on their analysis of Case 102, and by Griffith and co-workers[17] from animal data. The observed distributions are also consistent, as is the fractionation of plutonium discussed above, with the observations of Kathren *et al*[18] on long-term exposure cases from which selected tissues had been obtained, and with the preliminary analysis of Case 193 previously reported by McInroy *et al*[13].

Table 6. Percentage of systemic activity 30 years post exposure.

	Mean ± σ of 5 cases, this study	ICRP Parameters (a)	ICRP 48 Case I (b)	ICRP 48 Case II (c)
Skeleton	53.7 ± 12.5	50	52	52
Liver	35.4 ± 12.5	36	16	12
Rest of body	10.9 ± 2.1	14	20	33

(a) Assumes initial partitioning of 0.45 to skeleton, 0.45 to liver, and 0.10 to rest of body and early excretion, retention half-times of 100 years in skeleton and 40 years in liver[8]. Of portion not going to skeleton or liver, half is assumed to be excreted rapidly, and half deposits in other tissues with essentially infinite half-life.

(b) Assumes initial partitioning of 0.50 to skeleton, 0.30 to liver, and 0.20 to rest of body and early excretion, retention half-times of 100 years in skeleton and 40 years in liver[15]; other assumptions as in (a).

(c) Assumptions as for (b) except retention half-times of 50 years in skeleton and 20 years in liver.

Activity calculation:

$$\text{\% activity at time } t \text{ in compartment } i = \frac{f_i e^{-\lambda_i t}}{\Sigma f_i e^{-\lambda_i t}} \times 100\%$$

where f_i is the fraction initially deposited in organ i, λ_i the effective removal constant from organ i, and t is the time after deposition.

0006095

00130012.004

LANL

CONCLUSIONS

Although it should be stressed that the data evaluations presented here are only preliminary, there appear to be clear differences between the recent ICRP biokinetic models for Pu and Am and the results in these six whole bodies, leading to the following tentative conclusions:

1. For the inhalation exposure cases, greater proportions of ^{239}Pu and ^{241}Am are found in the respiratory tract than would be predicted by the ICRP lung model[8]. This suggests that retention fractions and retention half-times in the respiratory tract may be greater than proposed by the ICRP lung model.
2. In general, systemic distribution of ^{239}Pu is reasonably well characterised by the model in ICRP Publication 30[8]. Initial fractionation of ^{239}Pu between liver and skeleton is approximately equal and consistent with the values specified in ICRP Publication 30.
3. Initial fractionation of ^{241}Am between liver and skeleton is consistent with the 50:30 ratio cited in ICRP Publication 48 and with a clearance half time from the liver of about two years.
4. After a long-term exposure, significant fractions of the systemic ^{239}Pu and ^{241}Am are found in the muscle and other soft tissues, suggesting these tissues represent a long-term depot for these nuclides.
5. *In vivo* estimates of systemic deposition typically are several times greater than the deposition measured in the tissues of the whole body after death. This confirms observations from prior studies using tissue samples only and suggests that *in vivo* estimates made from commonly used biokinetic models may greatly exaggerate the actual deposition.

Study and evaluation of these cases, as well as the results from partial body autopsy cases, is continuing, and additional and more detailed reports are anticipated.

ACKNOWLEDGEMENT

The above work was supported by the US Department of Energy Office of Health and Environmental Research under contracts DE-AC06-76RLO-1830, DE-AC06-76RL01837 and W-7405-ENG-36.

REFERENCES

1. Swint, M. J. and Kathren, R. L. *United States Transuranium Registry Annual Report, October 1, 1986 through September 30, 1987.* HEHF-54-87. (Hanford Environmental Health Foundation, Richland, WA 99352) (1988).
2. Kathren, R. L. *The United States Transuranium and Uranium Registries.* Radiat. Prot. Dosim. Ibid 323-330.
3. McInroy, J. F. *The Los Alamos Scientific Laboratory's Human Autopsy Tissue Analysis Study.* IN The Health Effects of Plutonium and Radium, ed. W. S. S. Jee, pp. 249-270 (Salt Lake City: J. W. Press) (1976).
4. Boyd, H. A., Eutsler, B. C. and McInroy, J. F. *Determination of Americium and Plutonium in Autopsy Tissue: Methods and Problems.* IN Actinides in Man and Animals, ed. M. E. Wrenn, pp. 269-272 (Salt Lake City, Utah: RD Press) (1981).
5. McInroy, J. F., Boyd, H. A., Eutsler, B. C. and Romero, D. *The U.S. Transuranium Registry Report on the ^{241}Am Content of a Whole Body, Part IV. Preparation and Analysis of the Tissues and Bones.* Health Phys. **49**, 587-621 (1985)
6. Boyd, H. A., Gonzales, E. R., Noveroske, D. L., Miglio, J. J. and Willis, L. C. *Radiotissue Chemistry Analytical Techniques.* IN Health and Environmental Chemistry Analytical Techniques, Data Management, and Quality Assurance, ed. M. A. Gautier, LA-10300-M, Vol. 1 (Los Alamos National Laboratory) (1987).
7. ICRP *The Metabolism of Compounds of Plutonium and other Actinides. ICRP Publication 19.* (Oxford: Pergamon Press (1972).
8. ICRP *Limits for Intakes of Radionuclides by Workers.* ICRP Publication 30 (Oxford: Pergamon Press) (1979).
9. ICRP. *Reference Man: Anatomical, Physiological and Metabolic Characteristics.* ICRP Publication 23. (Oxford: Pergamon Press) (1975).
10. Breitenstein, B. D., Newton, C. E. and Norris, H. T. *The U.S. Transuranium Report on the ^{241}Am Content of a Whole Body, Part I: Introduction and History of the Case.* Health Phys. **49**, 565-567 (1985).
11. Heid, K. R. and Robinson, B. *The U.S. Transuranium Report on the ^{241}Am Content of a Whole Body, Part II: Estimate of the Initial Systemic Burden.* Health Phys. **49**, 569-575 (1985).
12. Kathren, R. L., McInroy, J. F. and Swint, M. J. *Actinide Distribution in the Human Skeleton.* Health Phys. **52**, 179-192 (1987).
13. McInroy, J. F., Kathren, R. L., Voelz, G. L. and Swint, M. J. *U.S. Transuranium Registry Report on the Pu-239 Distribution in a Human Body.* Health Phys. **52** (Suppl 1), p. S37 (1987).
14. Kathren, R. L., Heid, K. R. and Swint, M. J. *Comparison of Estimates of Systemic Pu from Urinary Excretion with Estimates from Post-mortem Tissue Analysis.* Health Phys. **53**, 487-494 (1987).

00130012.005

0006096

LANL

15. ICRP. *The Metabolism of Plutonium and Related Elements*. Publication 48 (Oxford: Pergamon Press) (1986).
16. Durbin, P. W. and Schmidt, C. T. *The U.S. Transuranium Registry Report on the ^{241}Am Content of a Whole Body. Part V: Implications for Metabolic Modelling*. Health Phys. 49, 623-661 (1985).
17. Griffith, W. C., Mehwhinney, J. A., Muggenburg, B. B., Boecker, B. B. and Cuddihy, R. G. *Bioassay Model for Estimating Body Burdens of ^{241}Am from Excretion Analysis*. Health Phys. 44 (Suppl. 1), 545-554 (1983).
18. Kathren, R. L., McInroy, J. F., Reichert, M. M. and Swint, M. J. *Partitioning of ^{238}Pu, ^{239}Pu and ^{241}Am in Skeleton and Liver of the U.S. Transuranium Registry Autopsy Cases*. Health Phys. 54, 181-188 (1988).

APPENDIX

Table A1. Distribution of ^{241}Am in USTR Case No. 102 (^{239}Pu data not available).

Tissue/organ	Wet weight (g)	Ash weight (g)	^{241}Am retention Activity (Bq)	^{241}Am retention Distribution (%)
Respiratory tract	2521		82.9	1.55
Liver	1450		344.8	6.44
Kidneys	250		13.3	0.25
Spleen	145		3.4	0.06
Smooth muscle organs	990		28.1	0.52
Striated muscle and skin	23909		469.9	8.78
Other tissue	86		4.1	0.08
Testes	26		0.2	0.004
Bones and teeth	8992	2539	4406.7	82.36
Total whole body	38366		5350.2	100.00

Table A2. Distribution of ^{239}Pu and ^{241}Am in USTR Case No. 193.

Tissue/organ	Wet weight (g)	Ash weight (g)	^{239}Pu retention Activity (Bq)	^{239}Pu retention Distribution (%)	^{241}Am retention Activity (Bq)	^{241}Am retention Distribution (%)
Respiratory tract	1337		130.0	52.75	16.28	60.70
Liver	1863		48.6	19.74	1.42	5.29
Kidneys	326		0.1	0.03	0.01	0.03
Spleen	258		1.5	0.59	0.10	0.46
Smooth muscle organs	1972		0.6	0.24	0.14	0.53
Striated muscle	24659		8.6	3.48	1.82	6.80
Other muscle	968		0.3	0.12	0.03	0.11
Skin	19688		2.6	1.06	0.49	1.82
Other soft tissue	1806		3.0	1.23	0.39	1.45
Testes	14		0.0	0.00	0.00	0.01
Bones and teeth	8691	2681	51.1	20.76	6.15	22.93
Total whole body	61583		246.4	100.00	26.82	100.00

LANL

Table A3. Distribution of ^{239}Pu and ^{241}Am in USTR Case No. 208.

Tissue/organ	Wet weight (g)	Ash weight (g)	^{239}Pu retention Activity (Bq)	^{239}Pu retention Distribution (%)	^{241}Am retention Activity (Bq)	^{241}Am retention Distribution (%)
Respiratory tract	972		85.6	37.75	2.08	28.89
Liver	1600		35.7	15.74	0.16	2.23
Kidneys	375		0.1	0.07	0.01	0.13
Spleen	104		0.1	0.04	0.02	0.26
Smooth muscle organs	2699		0.1	0.35	0.03	0.48
Striated muscle	24686		12.7	5.69	1.21	16.83
Other muscle	1111		0.8	0.37	0.03	0.44
Skin	7082		1.4	0.61	0.09	1.20
Other soft tissue	1355		1.1	0.42	0.05	0.72
Testes	29		0.17	0.03	0.004	0.06
Bones and teeth	8407	2600	88.1	38.97	3.50	48.76
Total whole body	49420		226.7	100.00	7.18	100.00

Table A4. Distribution of ^{239}Pu and ^{241}Am in USTR Case No. 213.

Tissue/organ	Wet weight (g)	Ash weight (g)	^{239}Pu retention Activity (Bq)	^{239}Pu retention Distribution (%)	^{241}Am retention Activity (Bq)	^{241}Am retention Distribution (%)
Respiratory tract	1698		46.3	18.57	2.54	14.73
Liver	2604		27.8	15.[illegible]	0.42	2.46
Kidneys	670		[illegible]	0.16	0.02	0.14
Spleen	236		[illegible]	0.5[illegible]	0.02	0.12
Smooth muscle organs	2518		[illegible]	0.43	0.10	0.57
Striated muscle	23930		[illegible]	4.06	1.08	6.26
Other muscle	835		1.8	0.27	0.04	0.25
Skin	12720		[illegible]	1.27	0.55	3.19
Other soft tissue	207[illegible]		[illegible]	1.23	0.19	1.08
Testes	38		[illegible]	0.15	0.001	0.01
Bones and teeth	9084	2850	17.[illegible]	57.61	12.29	71.17
Total whole body	56403		3[illegible]	100.00	17.26	100.00

Table A5. Distribution of ^{239}Pu in USTR Case No. 212 (^{241}Am data not available).

Tissue/organ	Wet weight (g)	Ash weight (g)	^{239}Pu retention Activity (Bq)	^{239}Pu retention Distribution (%)
Respiratory tract	1698		0.8	0.36
Liver	2382		85.7	41.09
Kidneys	461		0.2	0.08
Spleen	243		0.3	0.16
Smooth muscle organs	594		0.03	0.02
Striated muscle	27735		13.9	6.65
Other muscle	618		0.2	0.08
Skin	23650		4.8	2.29
Other soft tissue	2104		0.3	0.16
Testes	61		0.1	0.04
Bones and teeth	10704	2998	102.3	49.08
Total whole body	70247		208.5	100.00

LANL

00130012.007

0006098

Table A6. Distribution of ^{239}Pu in USTR Case No. 242 (^{241}Am data not available).

Tissue/organ	Wet weight (g)	Ash weight (g)	^{239}Pu retention Activity (Bq)	^{239}Pu retention Distribution (%)
Respiratory tract	1207		1861.7	67
Liver	1620		390.4	14
Kidneys	312		0.3	0.01
Spleen	205		11.8	0.4
Smooth muscle organs	262		0.2	0.01
Striated muscle	36729		37.2	1
Other muscle	677		5.3	0.2
Skin	19858		13 *	0.5
Other soft tissue	5286		133.4	5
Testes	24		0.1	<0.01
Bones and teeth	9523	3069	3382 **	12
Total whole body	75703		2791	100.00

* Skin contents estimated from small samples. Expect final results may be higher.
** Skeletal contents estimated from patellae contents.

LANL

00130012.008

0006099