USTUR-0197-04

United States Transuranium and Uranium Registries

ANNUAL REPORT FEBRUARY 1, 2003 - JANUARY 31, 2004

WASHINGTON STATE UNIVERSITY

USTUR-0197-04

United States Transuranium and Uranium Registries

WSU

Annual Report
February 1, 2003 - January 31, 2004

Compiled and Edited
Susan M. Ehrhart, Program Administrative Manager
Ronald E. Filipy, Director

Contributors
J.R. Alldredge, T.L. Brumbaugh, S.M. Ehrhart, J.T. Elliston, R.E. Filipy,
A.C. James, M.V. Pham, L.B. Sasser, T.G. Wood

USTUR

An important resource since 1968

Information for radiological protection standards and health effects of radiation

WASHINGTON STATE UNIVERSITY

Inside This Report

Staff Directory

Faculty

Filipy, Ronald E. 509-372-7316
Director rfilipy@tricity.wsu.edu
Sasser, Lyle B. 509-372-7170
Associate Research Professor lsasser@tricity.wsu.edu
Elliston, James T. 509-335-8316
Director of Radiochemistry elliston@mail.wsu.edu
Aman, Michael E. 509-335-1779
Radiochemist aman@mail.wsu.edu
Stuit, Dorothy B. 509-335-5032
Radiochemist stuit@mail.wsu.edu
Alldredge, J. Richard 509-335-8645
Statistician alldredg@wsu.edu

Adjunct Faculty

Birchall, Alan 011-44-1235-822655
Adjunct Professor alan.birchall@nrpb.org.uk
James, Anthony C. 509-375-7718
Adjunct Professor consult@acj-associates.com
Sikov, Melvin R. 509-372-7475
Adjunct Professor msikov@tricity.wsu.edu
Dagle, Gerald E. 509-372-7472
Adjunct Associate Professor dagle@tricity.wsu.edu
Cummings, Michael R. 509-586-6445
Adjunct Assistant Professor
Jacobson, Baruch S. 509-372-7472
Adjunct Scientist bjacobso@tricity.wsu.edu

Administrative Professionals

Ehrhart, Susan M. 509-372-7317
Program Administrative Manager syoung@tricity.wsu.edu
Wood, Tanya G. 509-372-7304
Scientific Assistant twood@tricity.wsu.edu

Staff

Brumbaugh, Tawnya L. 509-372-7370
Secretary Senior tbrumbau@tricity.wsu.edu
Emmel, Robert R. 509-374-7374
Tech. Assistant II remmel@tricity.wsu.edu
Pham, Minh V. 509-372-7374
Systems Analyst mpham@tricity.wsu.edu

Students

Bosted, Mishelle 509-372-7368
Undergraduate Student shelle_bean@yahoo.com
Bowles, Eric 509-335-8316
Undergraduate Student bowles@wsu.edu
Grass, Ginger M. 509-335-8316
Undergraduate Student

Greenwood, Douglas E. 509-335-8316
Undergraduate Student dgreenwood@wsu.edu
Linsday, Tiffany 509-335-8316
Undergraduate Student tmlinsday@hotmail.com
Warner, Paul.......... 509-335-8316
Undergraduate Student

Advisory Committee

Mahlum, Dennis 509-967-2353
Chairman dennis.mahlum@att.net
Aldrich, Joe.......... 303-463-3566
Member aldrichj@orau.gov
Brosemer, Ronald.......... 509-335-6095
Member xaire@wsu.edu
George, Kathryn Paxton.......... 208-634-4743
Member kpgeorge@uidaho.edu
Fisenne, Isabel.......... 212-620-3643
Member fisennei@eml.doe.gov
Lawson, Bruce 865-481-3395
Member blawson@esper.com
Thomas, Robert G 909-983-2483
Member rgthomas77@aol.com

United States Transuranium and Uranium Registries

Washington State University
College of Pharmacy
2710 University Drive
Richland, WA 99352
(509)372-7317
Toll-Free (800)375-9317
Fax (509)375-1817 or (509)372-7160

www.ustur.wsu.edu

Director's Message

Ronald E. Filipy, *Director*

This year was my fourteenth year with the U. S. Transuranium and Uranium Registries (USTUR). How time flies! Since I became the director of the program five years ago, one of my primary goals was to increase the usefulness of the large USTUR database that consists of six tables containing personal information, medical histories, radiation exposure histories, causes of death, and the results of radiochemical analysis of organ samples collected at autopsy. It is essential that a query of one or more of these tables by USTUR researchers or by collaborating researchers provides complete and reliable information. Also, some of the tables (those without personal identifiers) are destined to appear on the USTUR website for the use of the scientific community. I am pleased to report that most of the data in the database have now been verified and formatted for easy query. It is important to note that no data were discarded; copies of the original tables were retained and the original paper documents are still available for further verification of values as needed.

The past year has seen some personnel changes at the USTUR. John Russell, USTUR Associate Director and Curator of the National Human Radiobiological Tissue Repository (NHRTR) retired after twelve years with the Registries. A search for a replacement was partially successful in that Lyle Sasser, formerly a senior research scientist at Pacific Northwest National Laboratories (PNNL), agreed to work as a half-time Associate Professor in the USTUR. Lyle retired from PNNL and the part-time position fit in with his retirement plans; he will concentrate on the task of incorporating USTUR data into manuscripts for publication. Tanya Wood, USTUR Scientific Assistant has capably assumed the duties of curator of the NHRTR. A search is still underway for the Associate Director position.

Scientifically, this has been a good year for the USTUR. New collaborative research programs continue to be established and the USTUR staff has been quite productive in terms of research reports published in scientific journals. A few years ago, the USTUR Advisory Committee suggested that the USTUR Annual Report should be less technical in nature and contain fewer data. However, because of the many interesting results this year, we are offering a more detailed technical report. Additionally, these results and activities are the subjects of future publications in the scientific literature.

Dr. Ronald E. Filipy
Director

Highlights of 2003

Ronald E. Filipy, *Director*

Publication Activity

The January, 2003 issue (vol. 84) of the scientific journal, Health Physics, contained two papers published by USTUR authors. As a result, the USTUR was recognized on the front cover of the issue. One of the published papers included an analysis of a USTUR whole-body donation that had experienced inhalation intakes of a particularly insoluble form of plutonium-238; the lead author was Dr. Anthony C. James, USTUR Adjunct Professor. The other published work described a model for estimating the total skeletal contents of plutonium and americium on the basis of the contents of the few bones collected during a non-whole body autopsy for the USTUR; Dr. R. E. Filipy and Dr. J. R. Alldredge were the primary authors of that paper.

An analysis of a whole-body donation whose primary exposure was to uranium was described in a later issue of Health Physics. J. J. Russell and R. L. Kathren, former director of the USTUR, were the authors of this paper which was an important work in that there have been so few publications describing the distribution of uranium in the human body. There is, currently, grave concern about uranium dosimetry and health effects because of munitions containing depleted uranium.

Radiochemistry

For the first time in more than 10 years, the radiochemical laboratory is able to keep up with the tissue samples prepared for analyses and in avoiding large backlogs of tissue samples in the National Human Radiobiologic Tissue Repository. There are approximately 500 samples in various stages of analysis in the USTUR radiochemistry laboratory. Analyses of most of those samples are expected to be complete by the summer of 2005. Part of the reason for this is the small number of deaths among USTUR donors in recent years even though the average age of the living registrants is over 75 years.

Retrospective Dosimetry

The USTUR has acquired a licensed copy of the IMBA Expert™ USDOE Edition (Phase II) dosimetry software and it was used extensively during the past year after a period of familiarization. This software incorporates the most recent biokinetic and dosimetry models recommended by the International Commission on Radiological Protection (ICRP) and it can be used to predict specific organ burdens of the actinide elements on the basis of bioassay data. The code was used with the USTUR bioassay data of whole body donations to predict plutonium burdens of the respiratory tracts, livers, and skeletons and those predictions were compared to the plutonium burdens measured by the USTUR. Such comparisons provide a unique and rapid means of testing the ICRP models. This activity may help identify deficiencies in the ICRP models and suggest improvements to make organ burden predictions more accurate. Use of the IMBA code on data of eight whole-body donations to the USTUR are described in more detail elsewhere in this report.

Financial Report

Susan M. Ehrhart, *Program Admin. Manager*

Federal Resources

Grant
U.S. Department of Energy
Office of Health Studies
Management and Operation of the United States Transuranium and Uranium Registries
DE-FG06-92EH89181
Amount Awarded: $1,000,000
Period: 02/01/03-01/31/04

Grant
U.S. Department of Energy
Office of Science, BER
Operation of the National Radiobiology Archives
DE-FC03-96ER62213
Amount Awarded: $55,000
Period: 01/01/03-12/31/03

Amount Awarded: $22,028
Period: 01/01/04-12/31/04

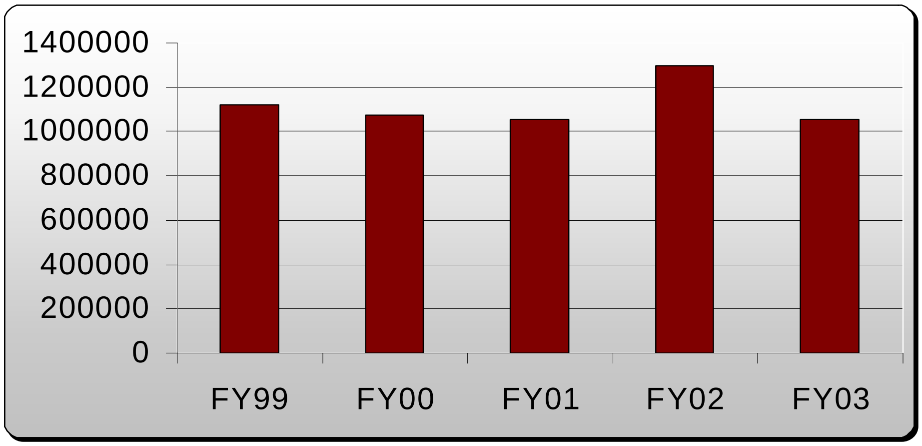
Subcontract - Federal Flow-down
University of Colorado
Health Sciences Center
Uncertainty Analyses to Characterize Plutonium Exposure
R01-CCR815762
Amount Awarded: $15,000
Period: 08/01/02-07/31/03

Grant and Contract Administration

Submitted
During FY03 USTUR submitted two (2) federal proposals totaling $1,270,897 to extramural sources. Both federal proposals were funded for a combined total of $1,055,000. The USTUR completed one collaborative (1) federal flow-down subcontract in July, 2003 that was funded for the period 08/01/02-07/31/03 in the amount of $14,219. Figure 1 shows the historical operating budget for the USTUR for the past five (5) fiscal years.

Figure 1

Operating Budget FY99-FY03, Fiscal Year is Febuary 1 - January 31



Reporting Requirements Met

Four (4) quarterly progress reports and two (2) year-end annual reports for the federally funded grants were distributed to the sponsoring agencies during this fiscal year. In addition, financial status reports were prepared and distributed to the investigators and federal sponsors on a monthly basis.

FTE

The USTUR Full Time Employee level (FTE) was decreased by .75 FTE for FY03 (Figure 2). The reduction in FTE was due to the Associate Director position vacancy for eight (8) months. A formal search is being conducted and will remain open until the position is filled by a qualified candidate.

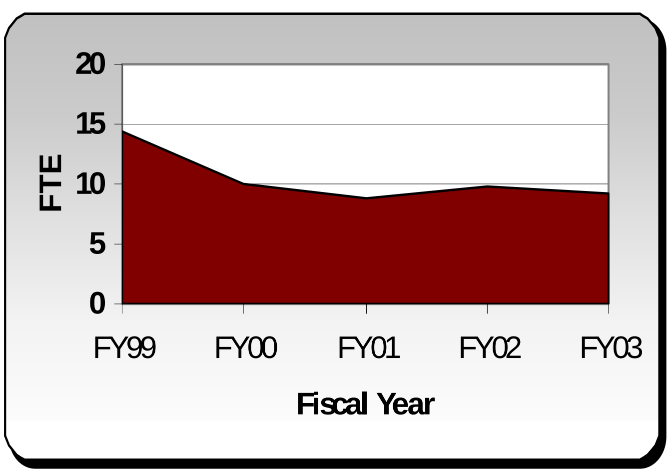


Figure 2

Employee Effort Supported

Registrant Statistics

Susan M. Ehrhart, *Program Administrative Manager*

Registrant Data

As of January 31, 2004, the Registries had a total of 915 Registrants in all categories. Of that number, 133 were active Registrants (those living Registrants whose authorizations were current and complete) and 356 were deceased Registrants. There were 426 Registrants in an inactive category which includes those who were lost to follow-up and, those whose agreements were not renewed.

Registrant Renewal

The USTUR ask the Registrants to renew their agreements every five years to ensure that it is still their desire to participate. The renewal process, along with the annual Registrant newsletter, serve as continual contact mechanisms. In 2003, eleven (11) Registrant renewals were processed. The next fiscal year will be a mass renewal year and there will be approximately eighty-eight (88) Registrant renewals to process during the period.

The breakdown of category 1* and 2** Registrants per worksite for living Registrants is shown in Table 1. There is a total of 106 Category 1 and 27 Category 2 living Registrants.

Table 1

Living Registrant Categorization

Site	Category 1*	Category 2**
Fernald	1	0
Hanford	18	16
Los Alamos	12	0
Mound	5	1
Oak Ridge	3	0
Rocky Flats	48	4
Savannah River	6	6
Uranium Mine Workers	3	0
Nevada Test Site	1	0
Special Cases	5	0
Other	4	0

*Significant actinide exposure with past or present positive bioassay results.
**Relatively high external radiation dose or professed exposures to beryllium, asbestos, or chemical solvents, but with minimal body burdens of the actinide elements.

Table 2

Average Age of Registrants

Site	# of Registrants	Average Age
Fernald	1	75
Hanford	34	78
Los Alamos	12	73
Mound	6	70
Oak Ridge	3	83
Rocky Flats	52	76
Savannah River	12	72
Uranium Mine Workers	3	83
Neveda Test Site	1	68
Other	9	51

Statistics

The average age of living USTUR Registrants is 75 (range 32-94 years) and 56% of the Registrants are 75 years of age or older. Table 2 shows the various DOE sites, the number of participants per site and the average age of the Registrants for each.

Records Aquisition

During the last few years, the Registries have made good progress in obtaining medical and health physics records of Registrants. The USTUR has been successful in acquiring medical records needed for 92% of active Registrants and for 96% of the deceased Registrants. Health physics record acquisition has also increased. The Registries possess health physics records for 95% of their active Registrants and 98% of their deceased Registrants.

Registrant Record Archival Project

As noted above, the Registries have spent a great deal of effort on obtaining the medical and health physics records for both living and deceased Registrants. These records are essential in carrying out the Registries research. It was decided to scan and archive all Registrant records to prevent a set-back in research should any accidental loss and/or damage occur to these valuable records. Two work-study students were hired, and the Registrant files were scanned and saved to compact disks (CD) using their Registrant identification number and the date that they were scanned. The CD's are now stored off-campus in a secure location. On an annual basis, Registrant files will be reviewed and new information scanned for archiving.

Information Systems

Minh V. Pham, *Systems Analyst*
Tawnya L. Brumbaugh, *Secretary Senior*

Database/Server

The USTUR network went through several major changes during this project year to accommodate the demand on the system. Due to the increased demand on the database server and the continuous changes in technology, the USTUR network system had become inadequate. The USTUR moved their server to a Windows environment with an enterprise network database at the end of the reporting project year. Unfortunately, security becomes an issue when using windows as a network server software, and an ISPEC security setting was implemented. ISPEC allows only certain computers to communicate with the USTUR server and rejects outside communications.

Access to SQL

The database transfer from Access to SQL was also completed during this period. With few obstacles, the data were successfully transferred and the database is currently running very efficiently. An added feature about SQL is that its security features significantly protect the integrity of the data.

USTUR Website

The USTUR website also underwent a major facelift to keep up with WSU's ever changing logos, color schemes, webpage banner and software requirements. The requirements are designed to create a sense of unity for all campus sites and ease of viewing. Using Macromedia Dream Weaver software has proven to be a great asset to not only the web design issues and changes but also for security purposes. Along with the required changes to meet with WSU policies, the Registries converted all publications, annual reports, abstracts, policies and procedures manuals and brochures to Adobe Acrobat for consistency with viewing and printing the documents.

The website continues to grow and is directly accessible via **www.ustur.wsu.edu**. It receives an average of three to four hundred (300-400) hits per month with a total of over 3948 hits for this project year (figure 4). The website serves as a direct link as to what the Registries are about, what is currently in the works, and what the goals are in the future. Located on the USTUR website is a complete listing of publications, annual reports, description of the database system and numerous pages and links for information on the NHRTR and NRA. It gives an in-depth look at what the USTUR is and what a valuable and unique resource is available for possible research collaborations.

The website contains:

1. a one-page Fact Sheet with summary information about the USTUR,
2. an Overview of Health Implications, which is a more detailed summary of USTUR operations and conclusions in non-scientific language,
3. a list of USTUR Publications in the scientific literature,
4. a list of USTUR Annual Reports to the DOE with full contents of the later reports,
5. a description of the USTUR Database System,
6. a detailed History of the Registries,
7. a description of the National Human Radiobiology Tissue Repository with a partial list of

the holdings available,

8. a description of the National Radiobiology Archive that contains materials from past animal experiments with radioactive materials,

9. a listing of the individuals who serve on the current USTUR Advisory Committee,

10. a listing of the USTUR Faculty and Professional Staff,

11. a Registries Telephone Directory,

12. a display of the Registries Information and Informed Consent showing the forms completed by registrants for participation in the Registries,

13. the USTUR Policy and Procedures Manual that contains all of the governing policies and operational methods used by the USTUR, and,

14. the Radchem Policy and Procedures Manual, containing all of the methods used by the USTUR Radiochemistry Laboratories to analyze tissues for the actinide elements.

To promote collaborative research, the USTUR has added images of the database to the website showing the numerous types of data that are compiled on each Registrant. The images are replicas of those in our database but contain mock information to give viewers a detailed idea of the content and relation between the database tables. Each of the forms is quite extensive and contains a large amount of data. Figure 4 shows an example of the ADMIN database form. Across the top there are seven additional forms linked to the admin form. Each of these forms (figures 4-11) contains detailed, pertinent information on each Registrant and their history. All information pertaining to a specific Registrant is accessed by clicking on any of the tabs at the top of the forms.

Figure 3

Website Results

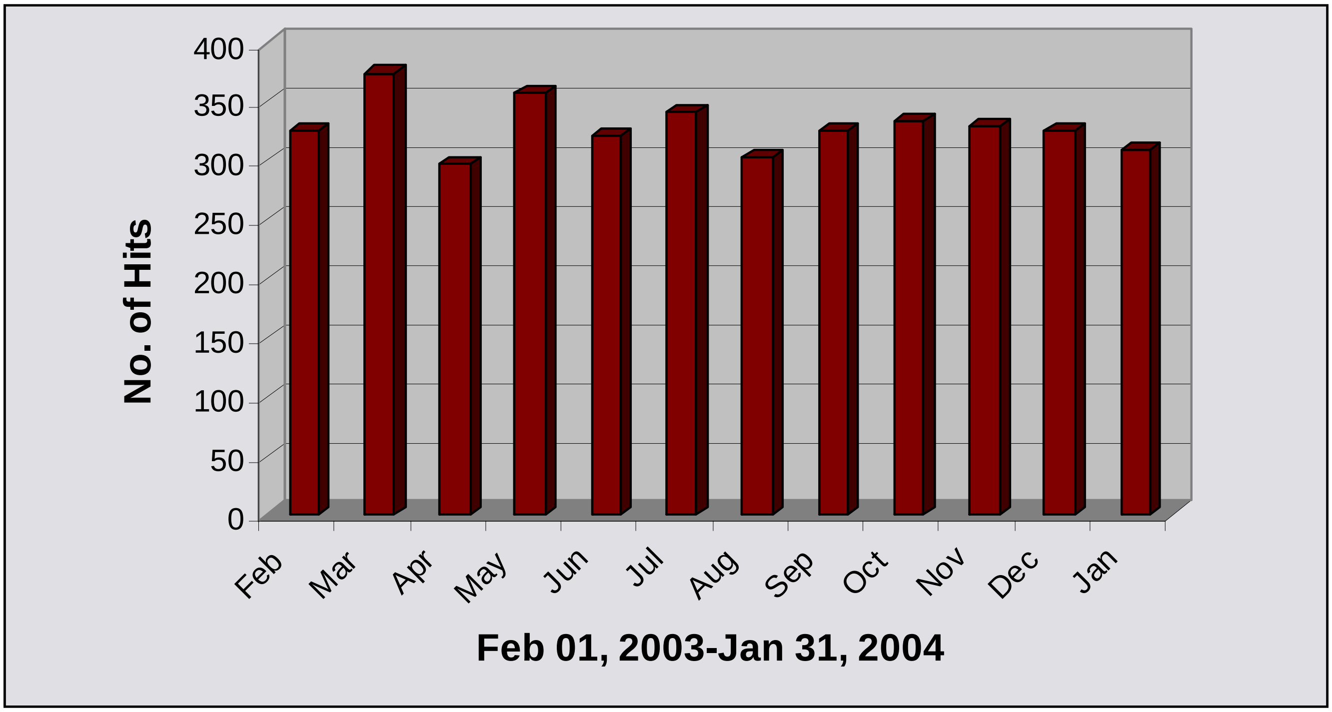


Figure 4

Admin Form

Figure 5

Medical Form

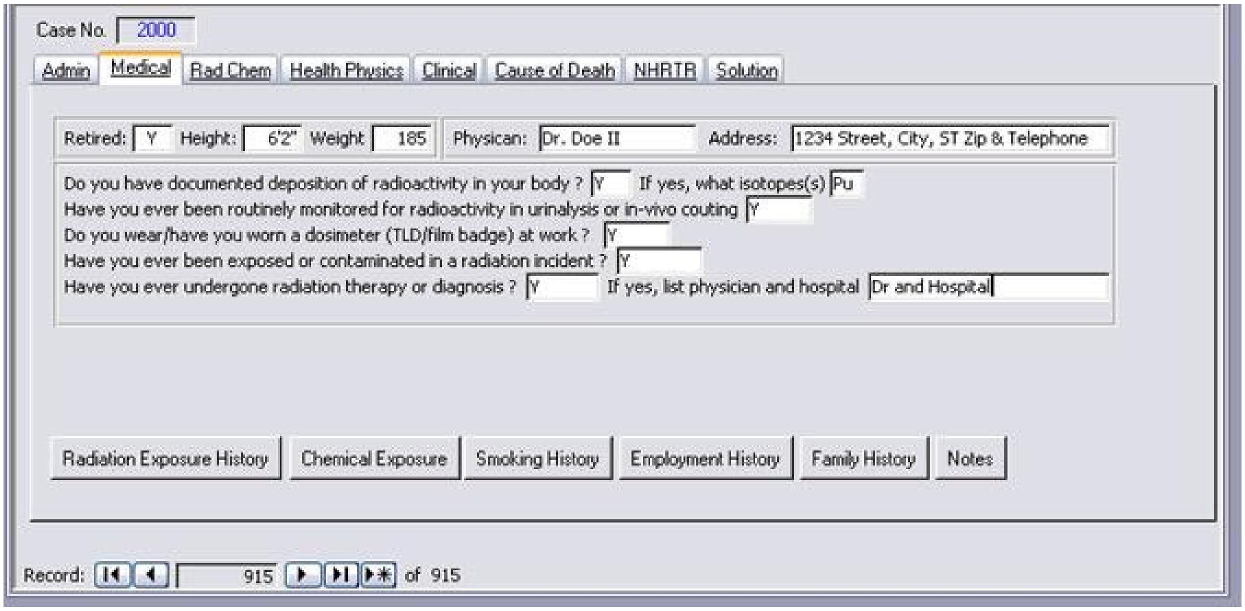
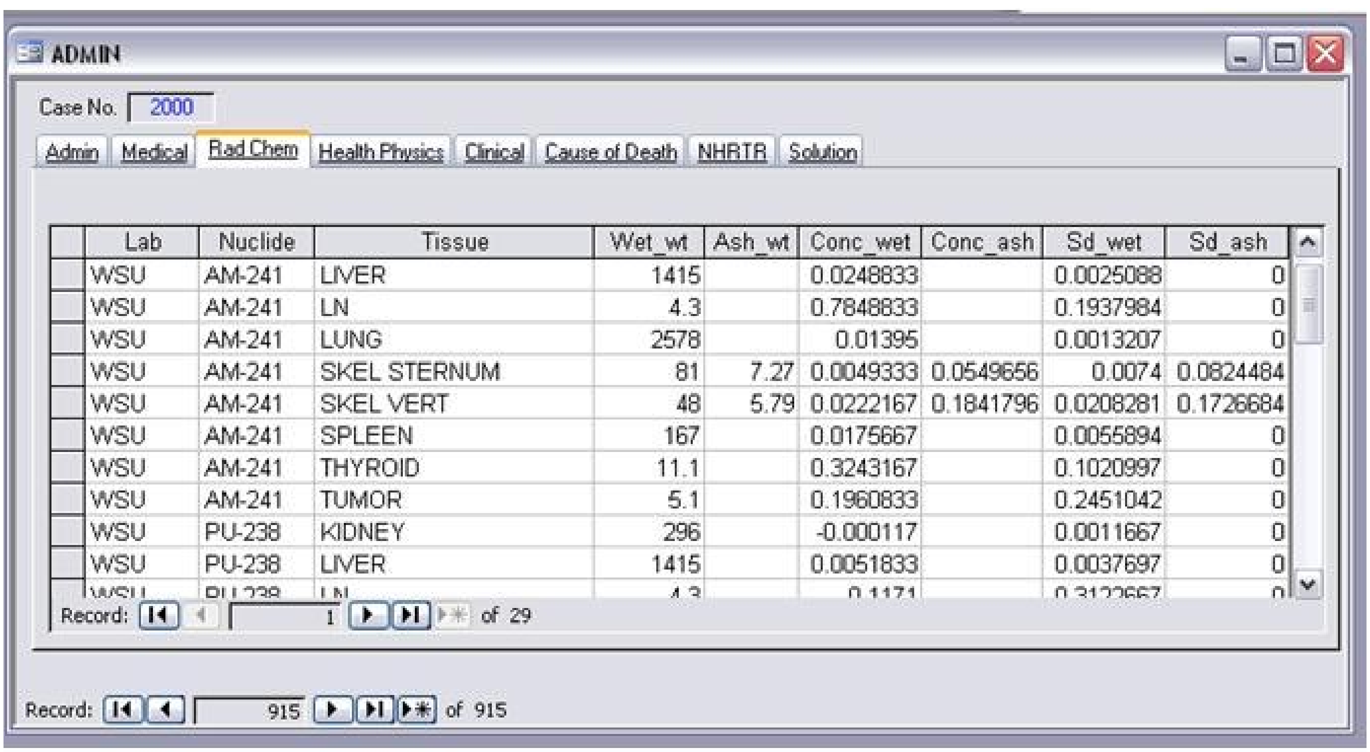


Figure 6

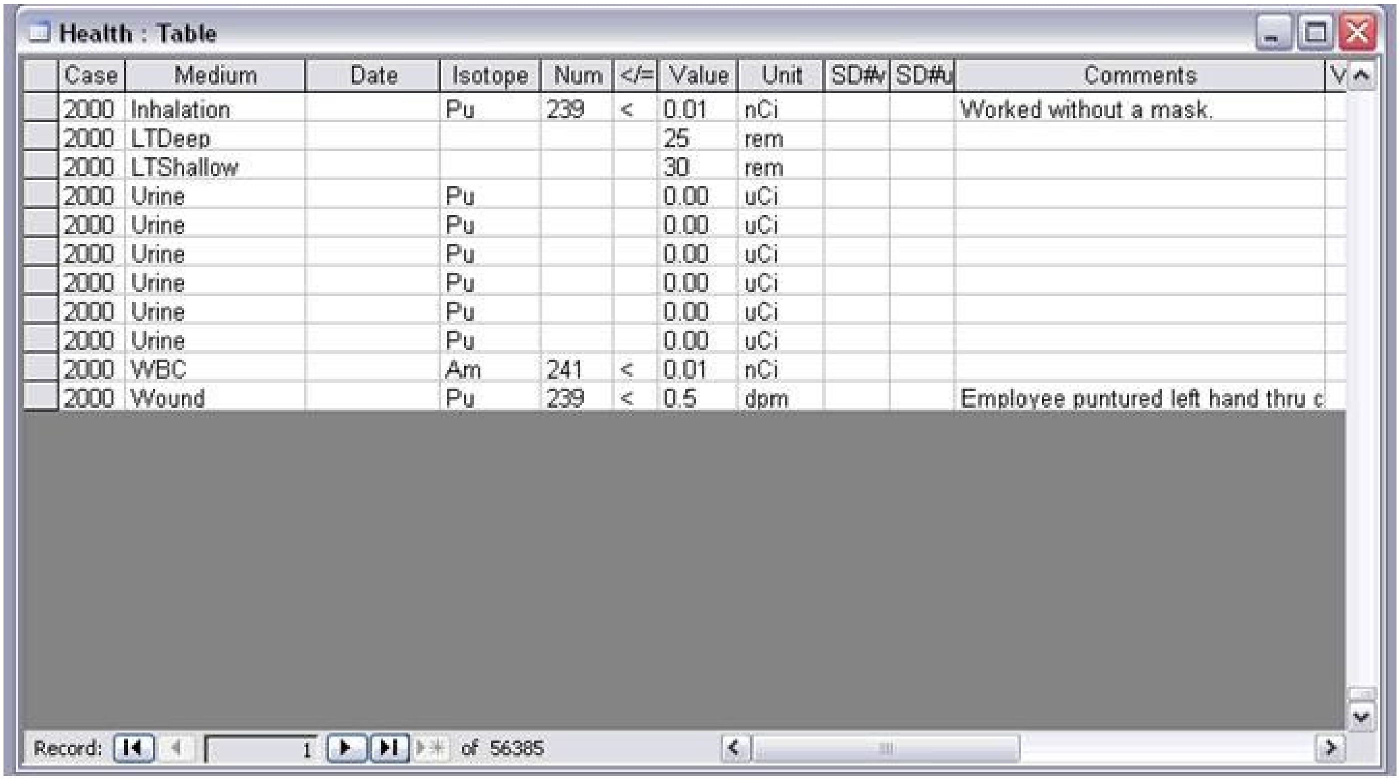
Rad Chem Form



Lab	Nuclide	Tissue	Wet_wt	Ash_wt	Conc_wet	Conc_ash	Sd_wet	Sd_ash
WSU	AM-241	LIVER	1415		0.0248833		0.0025088	0
WSU	AM-241	LN	4.3		0.7848833		0.1937984	0
WSU	AM-241	LUNG	2578		0.01395		0.0013207	0
WSU	AM-241	SKEL STERNUM	81	7.27	0.0049333	0.0549656	0.0074	0.0824484
WSU	AM-241	SKEL VERT	48	5.79	0.0222167	0.1841796	0.0208281	0.1726684
WSU	AM-241	SPLEEN	167		0.0175667		0.0055894	0
WSU	AM-241	THYROID	11.1		0.3243167		0.1020997	0
WSU	AM-241	TUMOR	5.1		0.1960833		0.2451042	0
WSU	PU-238	KIDNEY	296		-0.000117		0.0011667	0
WSU	PU-238	LIVER	1415		0.0051833		0.0037697	0
WSU	PU-238	LN	4.3		0.1171		0.3122667	0

Figure 7

Health Physics Table



Health : Table

Case	Medium	Date	Isotope	Num	</=	Value	Unit	SD#v	SD#u	Comments
2000	Inhalation		Pu	239	<	0.01	nCi			Worked without a mask.
2000	LTDeep					25	rem			
2000	LTShallow					30	rem			
2000	Urine		Pu			0.00	uCi			
2000	Urine		Pu			0.00	uCi			
2000	Urine		Pu			0.00	uCi			
2000	Urine		Pu			0.00	uCi			
2000	Urine		Pu			0.00	uCi			
2000	Urine		Pu			0.00	uCi			
2000	WBC		Am	241	<	0.01	nCi			
2000	Wound		Pu	239	<	0.5	dpm			Employee puntured left hand thru c

Record: 1 of 56385

Figure 8

Clincal Form

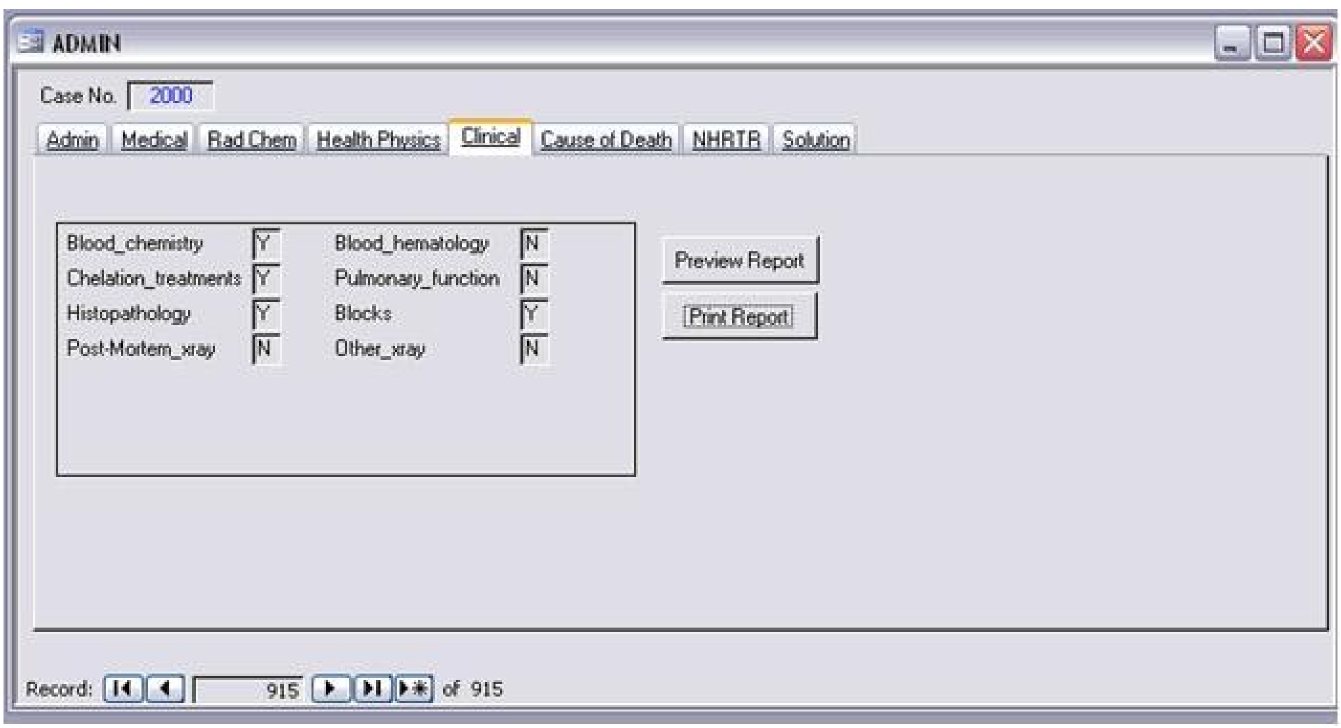
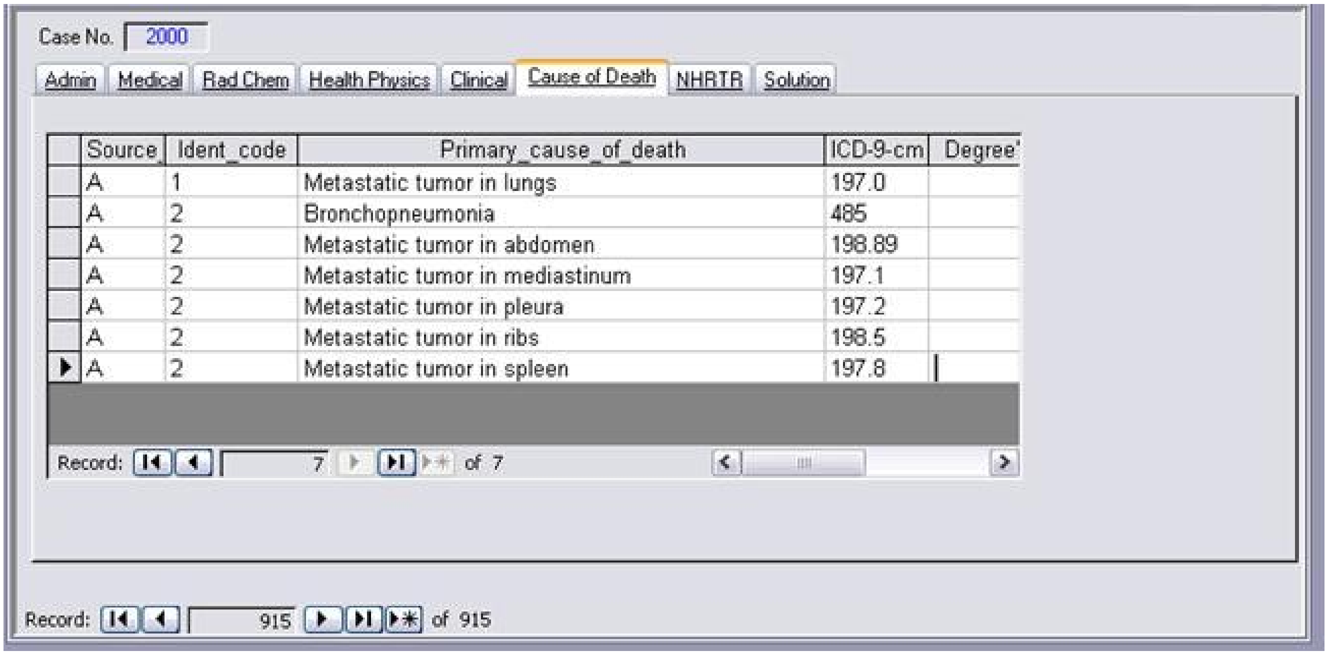


Figure 9

Cause of Death Table



Case No. 2000

Admin | Medical | Rad Chem | Health Physics | Clinical | Cause of Death | NHRTR | Solution

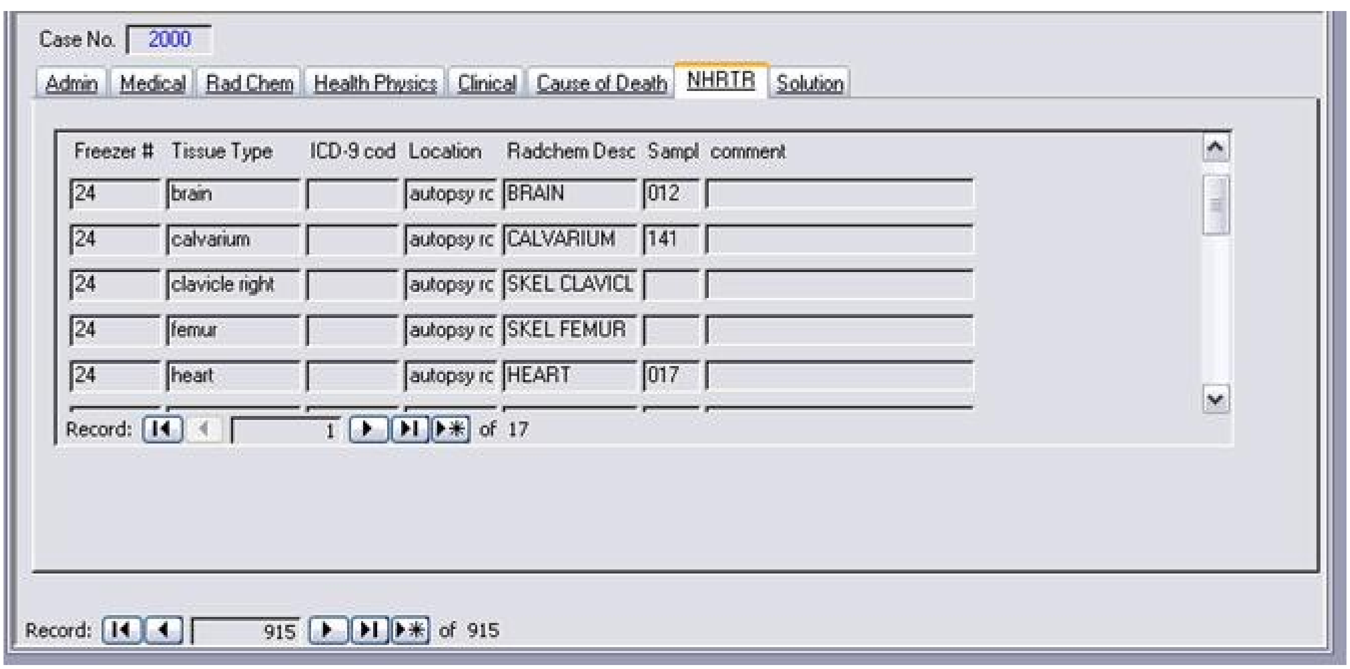
Source	Ident_code	Primary_cause_of_death	ICD-9-cm	Degree'
A	1	Metastatic tumor in lungs	197.0	
A	2	Bronchopneumonia	485	
A	2	Metastatic tumor in abdomen	198.89	
A	2	Metastatic tumor in mediastinum	197.1	
A	2	Metastatic tumor in pleura	197.2	
A	2	Metastatic tumor in ribs	198.5	
A	2	Metastatic tumor in spleen	197.8	

Record: 7 of 7

Record: 915 of 915

Figure 10

NHRTR Form



Case No. 2000

Admin | Medical | Rad Chem | Health Physics | Clinical | Cause of Death | NHRTR | Solution

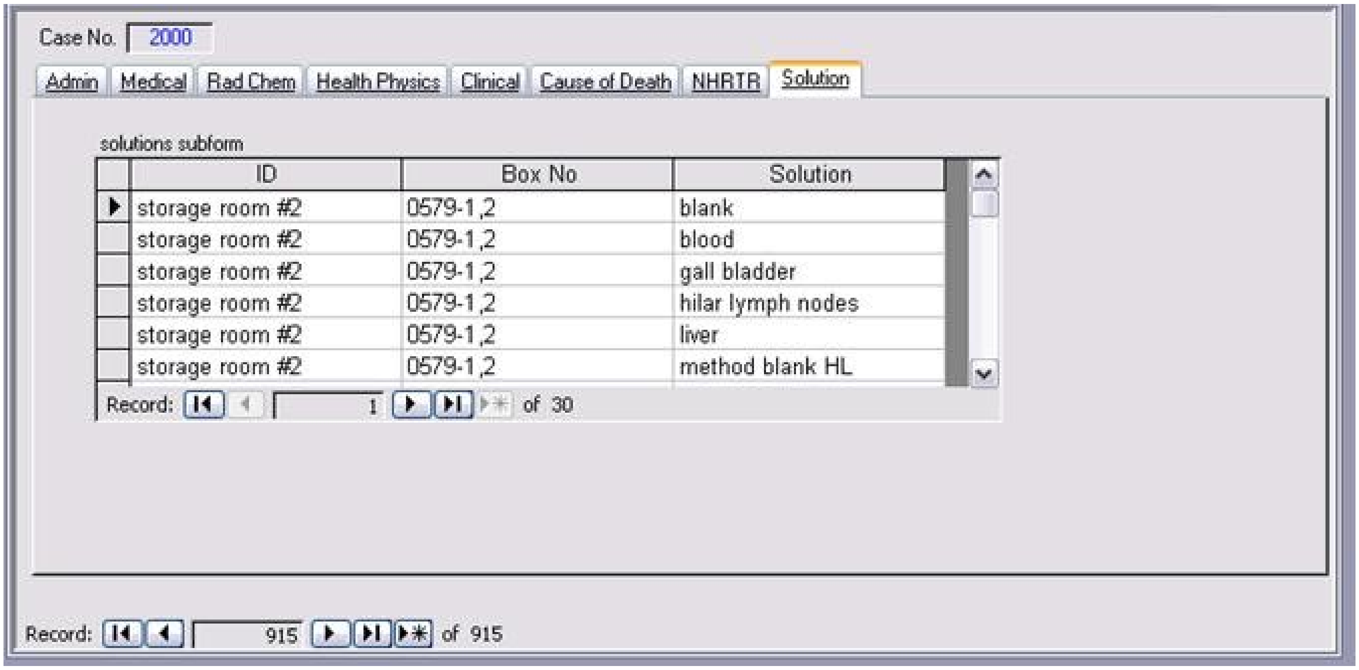
Freezer #	Tissue Type	ICD-9 cod	Location	Radchem Desc	Sampl	comment
24	brain		autopsy rc	BRAIN	012	
24	calvarium		autopsy rc	CALVARIUM	141	
24	clavicle right		autopsy rc	SKEL CLAVICL		
24	femur		autopsy rc	SKEL FEMUR		
24	heart		autopsy rc	HEART	017	

Record: 1 of 17

Record: 915 of 915

Figure 11

Solution Table



Case No. 2000

Admin | Medical | Rad Chem | Health Physics | Clinical | Cause of Death | NHRTR | Solution

solutions subform

ID	Box No	Solution
storage room #2	0579-1,2	blank
storage room #2	0579-1,2	blood
storage room #2	0579-1,2	gall bladder
storage room #2	0579-1,2	hilar lymph nodes
storage room #2	0579-1,2	liver
storage room #2	0579-1,2	method blank HL

Record: 1 of 30

Record: 915 of 915

The following is a list of collaborative research projects that investigate various aspects of internal dosimetry. All collaborators have confidentiality agreements (USTUR PPM F106) or Memoranda of Understanding on file that insure the protection of Registrant indentities. Research collaborators have also provided written assurance that the Registries' policies with respect to human subjects, informed consent, privacy of the Registrants and their next-of-kin, and national security will be followed.

European Community et. al.

Radioprotection Unit, SCR-CEN, Belgium
Dr. Christian Hurlgen

Objective: To contribute USTUR plutonium intake/tissue analytical data to the IDEAS Project (General Guidelines for Estimation of Committed Dose from Incorporation Monitoring Data).

Progress to report: As a result of the IDEAS Project, a large database of radiation exposure cases has been assembled with data gleaned from the open scientific literature and these data are available to any scientists who can make use of them. The USTUR contributed the data from 12 cases used in the Bioassay Interpretation Project to the IDEAS database.

Lovelace Respiratory Research Institute

Los Alamos, NM
Dr. Fletcher Hahn

Objective: Risk model for depleted uranium: measuring the amount of uranium deposition in the brain.

Progress to report: The Registries provided summary uranium body burden data from USTUR Cases 1002 and 1028 along with brain and kidney concentrations. Dr. Hahn will study brain tissue from these uranium cases to learn the specific location of uranium deposits in that organ.

Los Alamos National Laboratory

Los Alamos, NM
Dr. Sam Glover

Objective: Determine the uranium content in the femur relative to that in the skeleton.

Progress to report: The USTUR provided Los Alamos the femur-skeleton uranium ratios from one occupationally exposed whole-body uranium case and two whole body donations that were analyzed for uranium even though they had only background levels (no known occupational exposure).

Midwest Epidemiology Associates

Naperville, IL

Dr. James Stebbings

University of Texas - MD Anderson Cancer Center

Diagnostic Radiology

Houston, TX

Dr. William Murphy

Objective: Analyze plutonium injection case bone samples.

Progress to report: Bone samples from case 40-010, one of the patients injected with plutonium in the 1940's were sent to Dr. Jim Stebbings. This patient was suffering from Cushing's syndrome prior to Pu-injection at age 18 and died at age 20. The patient had also been diagnosed with a pituitary adenoma at age 6. Dr. Stebbings believed that the Pu injection induced calciphylaxis in some of the young patient's bones that was observed as tiny bony projections on the surfaces of some pelvic and long bone samples. The bone samples for this study are still awaiting analyses at MD Anderson Cancer Center.

National Radiation Protection Board

Chilton, UNITED KINGDOM

Dr. Alan Birchall

Objective: Use of USTUR data to characterize the biokinetics of actinide elements and evaluate models proposed by the National Radiation Protection Board (NRPB).

Progress to Report: The NRPB has data regarding the short-term biokinetics of plutonium isotopes in the human body. The USTUR has data on the distribution of plutonium among tissues of subjects who were exposed to plutonium many years ago, and these data are essential to developing a complete biokinetics model for plutonium that is valid at both early and late times. The IMBA Expert™, USDOE Edition software program for internal dose assessment was co-developed by the NRPB and it is currently under evaluation using data from the USTUR (see section entitled "Data Management " in this report).

New York University

Stoneybrook, NY

Dr. Gerald Abraham

Objective: Identification of asbestos in Registrant lung tissue. To determine what fraction of USTUR lung tissue samples contain asbestos fibers and, secondly, to determine what fraction of lung tissue samples containing actinide and asbestos fibers also display fibrosis. Ultimately to determine if the level of fibrosis is related to the specific activity of Pu in the lung tissue sample and to what extent asbestos excerbates it.

Progress to report: A partial manuscript describing the asbestosis of USTUR Case 0420 was prepared before the USTUR collaborating researcher retired. Radiochemical analytical data were completed during this reporting period. At present, no current USTUR researcher is available to continue this collaboration.

Oak Ridge Associated Universities

Arvada, CO

Mr. Roger Falk

Objective: Conduct case studies to compare in-vivo estimates of actinide body burdens with those measured, after death, by the USTUR in former Rocky Flats workers who are USTUR tissue donors. The USTUR provides the radiochemical analytical data results from tissues of Rocky Flats donors in support of this project.

Progress to report: Radiochemical analyses for a USTUR case that was a previous Rocky Flats worker were completed during this period. Bioassay data for this case were processed with the IMBA Expert™ dosimetry code and the information from this case is being integrated into a manuscript for publication. ORAU performed an analysis of intake using the dosimetry code, CINDY, and organ contents at death were estimated with CINDY as well and with two excretion models proposed by Jones and by Durbin. The USTUR performed an assessment for plutonium intake using the IMBA-Expert dosimetry code that employs ICRP 66 and 67 biokinetics parameters. This work is continuing.

Pacific Northwest National Laboratory

Richland, WA

Mr. Tim Lynch

Objective: Americium special study case. An accidental americium (Am) inhalation exposure case. The Registries and the Pacific Northwest National Laboratory have been monitoring this case from approximately 48 days post accidental intake, which occurred in 1996.

Progress to Report: A manuscript describing this case was prepared and was published in the journal of Health Physics.

Multiple Collaboration: Bioassay Interpretation Project

Savannah River

Aiken, SC

Mr. Tom LaBone

Rocky Flats

Golden, CO

Mr. Roger Falk

Los Alamos

Los Alamos, NM

Mr. Guthrie Miller

Hanford

Richland, WA

Mr. Gene Carbaugh

AC James and Associates

Richland, WA

Dr. Anthony C. James

Objective: Comparison of estimated actinide element body and organ burden made with various methods at DOE worksites with the burdens measured, after death, by the USTUR.

Progress to report: On the basis of actinide organ contents and availability of urinalysis data, the USTUR selected four cases from each site. Data from the selected cases were sent to each representing site for quality assuance checks before the data will be distributed to all participants for evaluation of intake estimates and organ burdens.

University of Cincinnati

College of Engineering
Department of Mechanical, Industrial & Nuclear Engineering
Cincinnati, OH
Dr. HenrySpitz

Objective: Use Accelerator Mass Spectrometry to measure ultra-low quantities of plutonium in autopsy tissue samples, samples that contained undetectable amounts of plutonium with conventional alpha spectrometry. The USTUR will provide cases who have had plutonium intakes at very long times before death. The anayltical results would be used to verify or modify long-term plutonium retention models.

Progress to report: A proposal was submitted to the DOE Nuclear Engineering Education Research Program and was not approved for funding.

University of Colorado

Health Sciences Center
Denver, CO
Dr. James Ruttenber

Objective: Conduct epidemiologic studies at the Rocky Flats Environmental Technology site to explore important issues of measurement errors in quantifying exposures and their effects on estimates of risk in epidemiology studies. The USTUR provides bioassay data in support of this project.

University of Utah

Salt Lake City, UT
Dr. Ray D. Lloyd
Dr. Scott C. Miller

Objective: Microdosimetry and microdistribution of plutonium in human bone.

Progress to report: A manuscript regarding the comparison of plutonium content of bones from USTUR Case 0242 and a Russian worker was received for review from Scott Miller. Comparisons were made by neutron-induced autoradiography, which showed substantially higher plutonium contents in the bone sample from the Russian worker with somewhat different distribution patterns. The manuscript was submitted to the journal, Science for publication; R. Filipy (USTUR) was listed as a co-author.

University of Tel Aviv

Tel Aviv, ISRAEL
Dr. Baruch Gold

Objective: Evaluation of causes of death in USTUR Registrants.

Progress to report: Examination of autopsy files, medical records including death certificates, and ICD-9 coding on the Registrant deaths not included in the previous paper was completed. The data are scheduled to be placed on the USTUR website during the next reporting period.

Washington State University

Department of Chemistry
Pullman, WA
Dr. Sue Clark

Objective 1: Determining a suitable material for a dual method NAA procedure for Uranium.

Progress to report: The radiochemistry staff is investigating different matrix materials in order to identify materials with lower background levels of uranium. At this stage, the staff is experimenting with various purities of aluminum and copper foils used in electrodeposition to determine if any of these materials have ^{235}U concentrations sufficiently low enough to lower the uranium detection limit 2-3 orders of magnitude less that obtained by alpha spectrometry. Tests have been completed on the series of aluminum foils. Aluminum was rejected as a base electrodeposition material for combined alpha spectrometry - neutron activation analysis. Testing of copper foil as a suitable matrix is now underway.

Objective 2: Preparation of external quality assurance/quality control samples for the USTUR radiochemistry protocols in known matrices.

Progress to report: Twenty-four (24) external samples were prepared and will provide the USTUR radiochemistry with a minimum of two (2) years of external quality assurance/quality control samples.

Objective 3: Determine if sample drying followed by wet ashing is more effective and less time consuming than sample drying and high temperature muffle ashing followed by wet ashing for total dissolution for brain tissue samples due to the presence of large amounts of oily cholesterol like material.

Progress to report: Cow brains were obtained from the University of Idaho Meat Laboratory. The brains were divided into four samples of approximately the same weight. All four samples were dried at 120 °C for seven days. Two of the brain samples were muffle ashed at 500 °C for seven days. During the dissolution of the four brain samples, the two non-muffled brain samples were lost due to excessive chemical reaction. Replacement samples have been requested from the University of Idaho Meat Laboratory. This project will continue during the next reporting period.

NHRTR

Tanya G. Wood, *Scientific Assistant*

National Human Radiobiology Tissue Repository

Registrant Deaths

During this report period, the NHRTR arranged autopsy services and tissue acquisition for four (4) Registrants who died during the period; all four (4) Registrant deaths were routine autopsy cases (non-whole body donors).

Available Samples

Since the establishment of the NHRTR approximately 10 years ago, the USTUR has divided samples collected at autopsy into two portions. One portion is radiochemically analyzed, and the other portion is retained in a frozen state (-70C). The unanalyzed portions of samples from non-whole body autopsies and whole body donations are listed in Tables 3 and 4. When an autopsy is performed for the USTUR, a set of microscope slides, and the paraffin blocks from which those slides were made, are requested from the pathologist performing the autopsy. Not all pathologists comply; however, the blocks and slides of collected tissues are listed in Tables 5 and 6.

Radiochemical analysis of collected tissues involves ashing of the tissues and dissolution of the ash into acid solutions. Only a small aliquot of each solution is needed for spectrometric analysis and the remaining solution is retained and stored in the NHRTR. The solutions listed in Tables 7 and 8 include many of those that were analyzed in other laboratories such as LANL, many years ago.

The NHRTR also contains many samples from the Radium Dial Painter Study and a few samples from the Plutonium Injection Study; these were studies conducted at Argonne National Laboratory several years ago.

Table 3

Number of Frozen Samples from Autopsy Cases

		Am/Pu	Uranium
Lung		48	10
Hilar Lymph Nodes		31	4
Lymph Nodes Other		19	-
Liver		47	7
Ribs		32	4
Sternum		31	7
Patella		14	2
Clavicle		26	6
Spleen		32	9
Thyroid		25	8
Heart		21	3
Aorta Arch		7	-
Kidney		71	19
Testes		56	12
Ovary		5	-
Prostate		19	5
Stomach		20	5
Esophagus		11	6
Abdominal Muscle		27	8
Tumor		10	4
	Liver Tumor	3	1
	Lung Tumor	8	2
	Pancreas Tumor	1	-
	Rib Tumor	1	-
	Mediastinal Tumor	-	1
Blood from Heart		22	6
Abdominal Fat		25	6
Skin		29	8
Calvarium		12	4
Femur		16	5
Brain		23	5
Pituitary		13	3

Table 4

Number of Frozen Samples from Whole Body Donations

		Am/Pu	Uranium	Thorotrast
Lung		5	1	1
Hilar Lymph Nodes		1	-	-
Liver		7	1	1
Gall Bladder		4	-	-
Thyroid		5	1	-
Testis		3	1	1
Ovary		-	-	-
Spleen		4	1	-
Aortic Arch		2	-	-
Kidney		6	1	-
Brain		6	1	-
Larynx		4	-	-
Trachea		4	-	-
Esopagus		6	-	-
Blood		2	-	1
Heart		7	1	-
Urinary Bladder		6	1	-
Stomach		5	-	-
Small Intestine		8	1	-
Large Intestine		4	-	-
Colon/Rectum		5	-	-
Prostate		3	1	-
Tumor				
	Liver	1	-	-
	Lung	3	-	-
	Bone	1	-	-
	Kidney	-	1	-
	Breast	-	1	-
Pituitary		-	-	-
Wound Site Skin		3	1	-
Wound Site Muscle		3	1	-
Wound Site Fat		3	1	-
Thoracic Lymph Nodes		5	-	-
Axillary Nodes		-	-	-
Mesenteric Nodes		-	-	-
Pancreas		4	-	-
Adrenal		5	2	-
Eye		5	2	-
Upper Extremity Bone		47	6	5
Lower Extremity Bone		56	11	5
Rib Left Side (1-12)		12	3	1
Vertebra		144	36	12
Pelvis Left Half		12	3	1
Skull Left Half		9	2	1
Skin Samples		21	9	3
Muscle Samples		27	9	3
Fat Abdominal		7	3	1

Table 5

Number of Slides and Paraffin Blocks from Autopsy Cases

	Am/Pu	Uranium
Adrenal	48	6
Aorta	8	-
Appendix	1	-
Biliary System	1	-
Bladder	10	1
Bone	1	-
Bone Marrow	11	1
Brain	23	7
Central Nervous System	6	-
Cerebellum	1	-
Cerebrum	1	-
Colon	1	-
Diaphram	1	-
Endocrine	2	1
Esophagus	6	1
Gall Bladder	1	-
Gastrointestinal Tract	16	-
Heart	53	9
Ileum	1	-
Intestine	6	2
Jejunum	1	-
Kidney	59	10
Larynx	1	-
Liver	58	10
Lung	63	10
Lymphatic	35	4
Medulla	1	-
Myocardium	2	1
Pancreas	43	9
Pertoneal Tissue	14	-
Pituitary	4	1
Prostate	18	4
Respiratory Tract	27	-
Skeletal Muscle	4	-
Skin	5	-
Soft Tissue	3	-
Spleen	25	9
Stomach	14	1
Testes	16	2
Thymus	2	-
Thyroid	21	7
Tongue	2	-
Trachea	4	-
Tumor Lung	1	-
Vertebrae	2	-

Table 6

Number of Slides and Pafaffin Blocks from Whole Body Donations

	Am/Pu	Uranium
Adrenal	6	2
Aorta	1	-
Appendix	-	-
Biliary System	-	-
Bladder	2	-
Bone	2	-
Bone Marrow	2	-
Brain	6	1
Central Nervous System	2	-
Cerebellum	-	-
Cerebrum	-	-
Endocrine	3	-
Esophagus	-	-
Gastrointestinal Tract	3	-
Heart	10	2
Ileum	-	-
Intestine	-	-
Jejunum	-	-
Kidney	9	3
Larynx	-	-
Liver	11	2
Lung	11	3
Lymphatic	2	1
Medulla	-	-
Pancreas	7	2
Pertoneal Tissue	-	-
Pituitary	-	-
Prostate	5	2
Respiratory Tract	2	-
Skeletal Muscle	1	-
Skin	-	-
Spleen	9	2
Stomach	3	-
Testis	3	-
Thymus	-	-
Thyroid	5	3
Trachea	-	-
Vertebrae	-	-
Diaphram	1	-
Spinal Cord	1	-
Myocardium	1	1
Duodenum	-	1

Table 7

Number of Dissolved Tissue Solutions from Autopsy Cases

		Am/Pu	Uranium
Lung		50	20
Hilar Lymph Nodes		29	10
Lymph Nodes Other		15	4
Liver		47	22
Ribs		35	12
Sternum		19	4
Patella		33	11
Clavicle		28	6
Spleen		25	5
Thyroid		27	1
Heart		10	-
Aorta Arch		6	-
Kidney		34	7
Testes		29	3
Ovary		1	-
Prostate		18	1
Stomach		14	-
Esophagus		13	-
Abdominal Muscle		20	1
Tumor			
	Spleen	1	-
	Unspecified	1	1
	Liver Tumor	-	-
	Lung Tumor	-	-
	Pancreas Tumor	-	-
	RibTumor	-	-
	Mediastinal Tumor	-	-
Blood from Heart		5	-
Abdominal Fat		15	1
Skin		15	1
Calvarium		5	-
Femur		22	6
Brain		13	1
Pituitary		5	-
Vert. Wedge		13	1
Urinary Bladder		1	-
Adrenal		3	-
Pancreas		6	-
Trachea		3	-
Gall Bladder		2	1
Wrist Bone		1	-
Larynx		1	-

Table 8

Number of Dissolved Tissue Solutions from Whole Body Donations

		Am/Pu	Uranium	Thorotrast
Aortic Arch		9	-	1
Blood		1	-	-
Brain		13	1	1
Colon/Rectum		3	-	-
Esopagus		6	1	1
Gall Bladder		7	1	1
Heart		6	1	1
Hilar Lymph Nodes		10	1	1
Kidney		19	5	1
Large Intestine		9	1	1
Larynx		5	1	-
Liver		19	2	1
Lung		21	2	1
Ovary		-	-	-
Prostate		7	-	-
Small Intestine		6	1	-
Spleen		11	1	-
Stomach		6	1	1
Testis		13	1	-
Thyroid		11	-	1
Trachea		7	1	-
Urinary Bladder		6	-	-
Tumor				
	Liver	1	-	1
	Lung	3	-	-
	Bone	7	-	1
	Skin	1	1	-
Pituitary		3	-	1
Wound Site Skin		1	-	-
Wound Site Muscle		1	-	-
Wound Site Fat		1	-	-
Thoracic Lymph Nodes		6	-	-
Axillary Nodes		4	-	-
Mesenteric Nodes		6	-	-
Pancreas		8	1	1
Adrenal		4	4	2
Eye		10	2	1
Upper Extremity Bone		278	87	16
Lower Extremity Bone		334	48	18
Rib One		133	26	1
Vertebra		307	77	11
Pelvis Left Half		59	4	2
Skull Left Half		115	8	7
Skin Samples		152	17	5
Muscle Samples		115	12	5
Fat Abdominal		11	3	-
Tumor	Unspecified	1	-	-
Testis	Spermatic Cord	1	-	-

Tanya G. Wood, *Scientific Assistant*

National Radiobiology Archives

Program Background

The National Radiobiology Archives (NRA) is an archival program, started in 1989, to collect and organize data, lab notebooks, and animal tissue specimens from government (Department of Energy and its predecessor agencies) sponsored radiobiology life-span animal studies. These valuable records, histopathology slides and paraffin embedded tissue blocks are maintained in a central facility and are available for additional future research. They include electronic and paper records for each of more than 6000 life-span-observation dogs as well as details of major studies comparing strains of mice for nearly 30,000 mice. Although these studies were performed over many years and at different laboratories with differing data managment systems, the NRA has translated them into a more convenient set of relational database tables, which can be distributed to interested individuals following a written request.

Since transfer of the NRA to Washington State University (WSU), the USTUR has actively promoted and publicized the availability of these materials for research. In addition, the Registries have developed a brochure that describes the NRA program. The brochure is featured on the USTUR Website and is otherwise distributed to potential clients.

Public Requests

The following request was received from an individual seeking NRA data and/or information:

> A PhD student at the Medical University of South Carolina, Environmental Biosciences Program in Charleston, South Carolina contacted the NRA and was interested in learning more about the potential health effects of low-dose exposure to plutonium that might occur in an occupational setting. A request for information about 22 separate experiments in which animals (dogs, mice, rats, monkeys) were exposed to plutonium was received.

NRA Grant Renewal

The Registries submitted a proposal written by R.E. Filipy to the DOE Office of Science for disposition of the National Radiobiology Archives collection. A parallel proposal was written by the PNNL waste management group to facilitate the disposal of the paraffin blocks and microscope slides as waste. Both proposals were approved by the DOE however, disposition is on hold pending DOE's consideration of other options. The Registries assume that the disposition of the written materials (175 cardboard storage boxes) will ultimately be accepted by a DOE repository for long-term storage.

Radiochemistry

James T. Elliston, *Director of Radiochemistry*
Dorothy B. Stuit, *Radiochemist*
Michael Aman, *Junior Radiochemist*

Radiochemistry Operations

Background

The end of 2003 marked over 34 years of radioanalytical measurements of actinides in human tissues for the U.S. Transuranium and Uranium Registries since its inception in 1968. The Radiochemistry component of the USTUR was transferred to Washington State University, Pullman, WA in 1994 and continues to be housed in the Nuclear Radiation Center of Washington State University. In the last ten years the radiochemistry laboratory has been successful in developing a quality radioanalytical laboratory, reducing the backlog of samples, developing new separation methods, publishing, and participating in the graduate and undergraduate educational process at Washington State University.

Case Analyses

Cases for sample analyses are divided into three categories: Routine Cases, Prioritized Routine Cases, and Whole Body Cases based on the expected body burdens predicted by bioassay results in the occupational records.

During this project year 359 tissue samples were analyzed for Am, 351 tissue samples were analyzed for Pu, 16 tissue samples were analyzed for U, and 20 sediment samples were analyzed for Th to test modifications to the dissolution procedures that enable us to validate the thorium analytical procedure for sedimentary samples. In addition, 27 tissue samples were reanalyzed for Am, 12 tissue samples were reanalyzed for Pu, 17 tissue samples were reanalyzed for U, and 8 sediment samples were reanalyzed due to problems with the original analyses. An additional 62 blanks and 72 QA/QC samples were analyzed as controls for the various separation runs. Also, 10 test samples were analyzed for training purposes. The total number of analyses for Pu, Am, U and/or Th including tissue, test, blanks, and QA/QC samples is 954. It is anticipated that 350-400 samples will be analyzed during the forth-coming project year (2004).

Routine Cases

The expedited analytical protocol (EAP) for Routine Cases generally involves analyses of 4-6 samples from each case for radionuclides suspected to be predominant in the samples. Samples typically include the lung, pulmonary lymph nodes, liver, and 1-2 bone samples to establish an estimate of the radioactive body burden. Samples from 18 Routine cases were processed and analyzed during project year 2003-2004:

Case 0271: A routine Registrant from Hanford. This case was added to the Prioritized List for additional samples to be processed due to its plutonium body burden activity estimate (235 Bq).

Case 0325: A routine Registrant from Hanford. This case is a low priority for additional analyses due to its plutonium body burden activity estimate (1 Bq).

Case 0458: A routine Registrant from Rocky Flats. This case is a low priority for additional samples to be processed due to its low plutonium body burden activity estimate (13 Bq).

Case 1019: A routine URW (uranium worker) Registrant. This case is a low priority for additional analyses due to its low body burden activity estimate (3 Bq). However the kidney was not part of the original analytical protocol and will be processed during project year 2004-2005.

Case 1027: A routine URW Registrant. This case is a low priority for additionalanalyses due to its low uranium body burden activity estimate (5 Bq). However the kidney was not part of the original analytical protocol and will be processed during project year 2004-2005.

Case 1030: A routine Registrant from Fernald. This case is a low priority for additional analyses due to its low uranium body burden activity estimate (4 Bq). However the kidney was not part of the original analytical protocol and will be processed during project year 2004-2005 and the case report will be updated.

Case 1057: A routine URW Registrant. This case is a low priority for additional analyses due to its low uranium body burden activity estimate (4 Bq). However the kidney was not part of the original analytical protocol and will be processed during project year 2004-2005.

Case 1062: A routine Registrant from Rocky Flats. This case is a low priority for additional analyses due to its low uranium body burden activity estimate (2 Bq). However the kidney was not part of the original analytical protocol and will be processed during project year 2004-2005 and the case report will be updated. Case 1062 is being rerun for Pu/Am.

Case 1065: A routine URW Registrant. This case is a low priority for additional analyses due to its low uranium body burden activity estimate (3 Bq). However the kidney was not part of the original analytical protocol and will be processed during project year 2004-2005.

Samples from cases 0737 and 0796 have been analyzed and data are in the review process. These were plutonium and americium cases.

Routine autopsy cases 0270, 0341, 0439, 0445, 0727, 0733, and 0839 are being analyzed for plutonium and americium.

Prioritized Routine Cases

The USTUR Radiochemistry Program has been analyzing routine autopsy cases by the EAP since 1997. Four to five samples from 66 Routine Cases have been analyzed to date. Thus far, 19 of the Routine Cases evaluated have body burden activities estimated to be greater than 16 Bq at death. Activities less than 16 Bq make precise measurement of the actinide content in other tissues difficult and the analyses of additional samples for these cases have been assigned a low priority. Samples from the following 13 Prioritized Routine cases were processed and the cases completed during project year 2003-2004:

Case 0333: A routine Registrant from Hanford. This case was added to the Prioritized List due to its estimated plutonium body burden activity (579 Bq) and analyses were completed by February 19, 2003.

Case 0427: A prioritized routine Registrant from Rocky Flats. This case was added to the Prioritized List due to its plutonium body burden activity estimate (36 Bq) and analyses were completed by December 09, 2003.

Samples from cases 0444 and 0672 have been analyzed and data are in the review process.

Case 0271: A routine Registrant from Hanford. This case was added to the Prioritized List due to its plutonium body burden activity estimate (235 Bq. Additional samples have been requested for radiochemical analysis.

Samples from prioritized routine cases 0279, 0379, 0511, 0709, 0719, 0728, 0795, are still being analyzed for plutonium and americium and Case 1016 for uranium.

Whole Body Cases

Reduction in the backlog of whole body cases continues to be one of the primary goals of the USTUR Radiochemistry Program. In keeping with this goal, samples from seven whole body cases were completed or continue to be processed during this project year. Typically the tissues analyzed for a whole body case include half of the bones and all of the major organs. Cases in process include:

Case 0425: A male whole body Registrant from Rocky Flats. This case was reported in the Annual Report February 1, 2001 - January 31, 2002 (USTUR-0185-02) for plutonium and americium. In addition to Pu and Am this case was analyzed for total uranium by recovery corrected kinetic phosphorescence analysis. During the uranium review stage it was decided to process additional samples. The U analyses for the additional samples will be completed during the next project year.

Case 0503: A male whole body Registrant from Rocky Flats. The initial survey of five samples gave a plutonium body burden activity estimate of 572 Bq. All 118 samples for this case have been dried, muffle ashed, and 8% have been analyzed for Pu/Am.

Case 0635: A male whole body Registrant from Los Alamos. The initial survey of five samples gave a body burden activity estimate of 1083 Bq. All 96 samples from this case have been dried, muffle ashed, and analyzed for Pu/Am. This case is in the initial review stage.

Case 0679: This is a new whole body case of a male Registrant from Los Alamos. Thus far out of 103 samples, 86% have been muffle ashed, 28% have been dissolved and 7% have been analyzed for plutonium and americium. Analysis of a bone samplewill complete the initial survey.

Case 0680: A male whole body Registrant from Los Alamos National Laboratory. The initial survey of five samples gave a plutonium body burden activity estimate of 1636 Bq. All of the samples from this case have been analyzed, reviewed and the data are available.

Case 0682: A male whole body Registrant from Mound Laboratories was exposed to ^{238}Pu as a result of a glove box explosion. Preliminary results show that there are several dpm of ^{238}Pu per gram of bone ash. Ninety five percent of the samples from this case have been muffle ashed, dissolved and analyzed. Four replacement samples are in the dissolution stage. All of the soft tissue samples for this case were lost at LANL due to a freezer outage.

Case 0706: A male whole body registrant from Rocky Flats. The initial survey of five samples gave a plutonium body burden activity estimate of 723 Bq. Thus far 113 samples have been received; 100% of the samples muffle ashed, 99% dissolved and 99% analyzed. Two samples are in the dissolution stage.

Case 1007: A whole body Registrant from Mound Laboratories. This case was initially started at LANL where the major soft tissues were dried, muffle ashed, dissolved and analyzed for total uranium content by kinetic phosphorescence analysis (KPA). Thus far 74 tissue samples have been received; 100% have been dried and muffle ashed, 97% have been dissolved and 13% are being prepared for KPA.

Applying the International Commission on Radiological Protection (ICRP) Biokinetic Models

Ronald E. Filipy, *Director*

The United States Transuranium and Uranium Registries (USTUR) have a unique collection of human bioassay data reflecting the intakes and retention of actinide elements in the bodies of workers who were involved in the processing of materials containing those elements. These data include the results of urinalyses and fecal analyses, in-vivo determinations, and, finally, the results of tissue analyses after deaths of the workers who donated tissues to the Registries by autopsies.

The USTUR obtained a licensed copy of the IMBA Expert™ USDOE—Edition (Phase II) software, which incorporates the most recently recommended biokinetic and dosimetry models of the ICRP (1989; 1993; 1994; 1995). Application of this software to USTUR bioassay and tissue content data provides a powerful means of testing the full applicability of the ICRP models. This latest version of IMBA allows the user to define the total skeleton as a bioassay quantity in addition to the whole body, lungs, liver, and excretion. This report contains a description of the use of the IMBA code to estimate plutonium contents of the respiratory tract, liver, and skeleton from the bioassay data of six whole body donations to the USTUR at long times after plutonium intakes. The estimates were compared to the radiochemical analytical results for those organs obtained by the USTUR after the deaths of the individuals and whole body donations.

For each case, a first estimate was made with the ICRP default values for respiratory tract absorption rates. A refined estimate was then made by altering the final dissolution rate from the lung (S_t) so that the estimate of lung contents of plutonium would more nearly approximate the result of radiochemical analysis of the lung. Summaries of the results are shown in Tables 9-16.

USTUR Case 0193

This whole body donor worked in Los Alamos laboratories for 37 years before his death at age 62. His most probable intakes of plutonium by inhalation occurred during his first year of employment while he was fluorinating plutonium oxide in a chemical hood, although, he experienced a substantial plutonium intake during the twelfth year of work. After 25 years of work, his work assignment was such that there was little contact with plutonium-containing materials. He died from respiratory failure associated with pneumonia; however, he had a clinical history of coronary insufficiency. More information is available in reports by Kathren (1994), Hempelmann et al. (1973), and Voelz et al. (1979; 1985; 1991). USTUR Case 0193 was subject 27 of the last four of those reports. Radioanalytical results for the major organ systems were reported by McInroy et al. (1989).

There were 179 urinalyses results and one fecal analysis result among the bioassay data available for Case 0193. In-vivo counts included seven whole body counts, three "lung" counts, ten "chest" counts and one liver count. The whole body counts were all performed within four years of his death and all but the last result were below detectable limits for Am-241; the result of the last count was 0.20 nCi of Am-241. Two of the three "lung" counts were below detectable limits for Pu-239 and the result of latest count, eleven years before death, was listed as 0.47 nCi of Am-241. The "chest" counts were all performed during the last ten years of life and results were all between 0.35 and 0.55 nCi of Am-241. There was no indication in the dosimetry record of the Am-Pu ratio that could be used to calculate a Pu-239 burden. For these reasons, only urinalyses results were imported into the IMBA code for estimation of organ burdens of Pu-239. Two acute intakes were presumed, one at 230 d and the other at 4600 d after the beginning of work with plutonium.

The results are shown in Table 9. ICRP default values of absorption rate for Type "S" material resulted in a dramatic underestimate of the lung content of plutonium at death. Estimated skeletal contents were close to the measured value; however, the liver estimate was approximately 60% of the measured value. Reduction of the final dissolution rate by a factor of 7 resulted in an estimate of the plutonium lung content close to the measured value, but there was little change in the estimated contents of the liver and the skeleton.

USTUR Case 0208

This donor also worked at Los Alamos for 37 years before his death at age 69. His most probable intakes of plutonium by inhalation occurred during his first year of employment when he worked in a Pu reduction and dry chemistry operation. He had plutonium-positive nose wipes 74 days after beginning work and a relatively high urinary plutonium excretion rate in the four months following that incident. He died from a pulmonary embolus. More information about the work and medical histories of this individual was reported by Kathren (1993) and the radiochemical analytical results for the major organ systems were reported by McInroy et al. (1989).

There were 95 urinalyses results and three daily fecal analyses results among the bioassay data of Case 0208. The fecal analyses were performed approximately 16 years after the presumed inhalation incident and the results were quite low, 0.0012-0.0018 Bq/d. The fecal collections were apparently not associated with any particular incident and urinary plutonium excretion rates at the time were not remarkable. In-vivo determinations of plutonium burdens included only one lung count 24 years after the presumed intake and the results were below detection limits. Only urinalyses results were imported to the IMBA code for estimating organ contents by the same procedure as discussed above for Case 0193.

The results are shown in Table 10. Liver content estimates were reasonable with ICRP default values of absorption rates although the skeletal contents were somewhat underestimated and the lung plutonium contents were underestimated by factor of eight. An estimate of the lung contents nearly equal to the measured value was obtained by reducing the final dissolution rate by a factor of 3.5 and, again, the estimated contents of the liver and the skeleton were little changed by the alteration of this ICRP lung model parameter value.

USTUR Case 0213

Case 0213 worked as a chemist at Los Alamos for approximately 33 years. He died as a result of a lung carcinoma approximately five years after his retirement from work. He was involved in five potential acute inhalation incidents with plutonium; however, the IMBA code indicated intakes from only three of those incidents. These intakes occurred 48 d, 3666 d, and 7760 d after he began work with plutonium. More details of the work and medical histories of this donor were reported by Kathren (1993) and the plutonium contents of his major organ systems were reported by McInroy et al. (1989).

In-vivo determination of lung contents indicated 1.2 nCi of Pu-238 and 4.0 nCi Pu-239. These estimates were made approximately 24 years after Case 0213 began work and nearly three years after his last acute inhalation incident. Six subsequent "chest" counts between that and his retirement were all less than the limits of detection. There were results from 227 plutonium urinalyses in the dosimetry file. This would have exceeded the capacity of the IMBA code which can accommodate 200 results so the final 27 results were not used for the IMBA analyses. The cut-off date was approximately 8 years after the final exposure incident and all results were very small values. The measured and estimated contents of the respiratory tract, liver, and skeleton of this case are shown in Table 11. Liver plutonium contents were predicted quite well with the ICRP default values of absorption rates for Type "S" material, although the predicted lung and skeletal estimates were approximately one-half of the measured values. It was necessary to reduce the final dissolution rate by only a factor of 1.5 to increase the predicted lung content to match the measured value.

USTUR Case 0242

This donor was a chemical operator at Los Alamos for approximately 26 years until his retirement. He died 15 years after retirement, at the age of 78, as a result of coronary atherosclerosis. He was involved in at least six incidents that could have resulted in acute inhalation intake of plutonium during his work. He had a relatively high plutonium body burden at death when compared with other USTUR registrants. A summary of his work history was reported by Kathren (1993).

There were 212 results of plutonium urinalyses in the dosimetry file. The first seven results and the final 5 results were not imported into the IMBA code because of the capacity constraints. All 12 of the omitted results were lower than the detection limits. In-vivo determinations of plutonium and americium lung burdens performed two years before retirement indicated 0.16 nCi of Am-241 and 4.0 nCi of Pu-239. Nearly two years later, in-vivo lung burdens were listed as 2.08 nCi of Am-241 and 21 nCi of Pu-239. Only three months later, lung burdens were estimated by this method to be 2.07 nCi of Am-241 and less than the detectable amount of Pu-239. There is a note in the file that cautions against the use of in-vivo data from before 1978 so these data were not imported to the IMBA code and organ burden estimates were based solely on urinalysis data. Five acute inhalation intakes of plutonium were specified in the IMBA code based on incident information in the dosimetry file. They were at 506, 2016, 2452, 3447, and 4130 days after the beginning of work. The final intake would have occurred approximately 14 years before the retirement of Case 0242.

IMBA-generated predictions of respiratory tract, liver, and skeletal plutonium contents resulting from the five acute intakes are shown in Table 12. With ICRP default Type "S" absorption behavior, predictions of the plutonium contents of all three organs were well below the measured values. The estimated lung content was increased to approximate the measured value by reducing final dissolution rate by two orders of magnitude, but that also slightly reduced the liver and skeletal estimates.

Visually, there were no obvious dramatic increases in the urinary plutonium concentrations at the times specified as intakes so it was decided to use chronic plutonium intakes for the sake of comparison of the organ burden estimates. Five periods of chronic intakes were specified as follows:

Days 506 to 2015—1510 days,
Days 2016 to 2451—436 days,
Days 2452 to 3446—995 days,
Days 3447 to 4129—683 days, and,
Days 4130 to 9004—4875 days.

From this series of chronic intakes, the IMBA code predicted the organ burdens shown in Table 13. Estimates of the plutonium contents of all three organs were slightly larger than they were with acute intakes; however, all were still well below the measured values. Reduction of the final dissolution rate by a factor of 33 increased the estimate of lung contents but, again, liver and skeletal estimates were further reduced and considerably below the measured values.

USTUR Case 0425

This whole body donor had worked at the Rocky Flats Plant for nearly 24 years until retirement. He died 19 years after that from acute bronchopneumonia at the age of 83 years. He was involved in a number of incidents with airborne plutonium, personal contamination, and minor wounds during his first decade of employment; however, bioassays during that time indicated no particular intake of the actinide elements. Urinalyses results during the first 15 years of employment were below the detection limits for plutonium.

In-vivo determinations of lung burdens included six lung counts; three were performed in the last few months before retirement and three were done 5, 6, and 8 years after retirement, apparently as part of a worker call-back program. They indicated plutonium lung burdens between 1.6 and 5.1 nCi (60 and 190 Bq).

For the first two applications of the IMBA code to bioassay data of Case 0425, only urinalyses results were imported into the code and the predicted plutonium contents of body organs were considerably less than the measured contents, especially the estimate of lung contents. Reduction of the lung absorption rate (S_t) to 3.0 E-6 resulted in a lung burden estimate close to the measured amount (Table 14); however, the predicted liver and skeletal contents were still well below the measured amounts. Including the six "lung" counts among the bioassay data imported into the IMBA code brought the estimates of liver and skeletal contents closer to the measured amounts; however, the additional bioassay data had little effect on the estimate of lung contents. Reduction of the final dissolution rate from the lung (S_t) increased the lung burden estimate to approximately one-third of the measured amount but dropped the estimates of liver and skeletal burdens to less than they were without the additional bioassay data. Further reduction of the S_t had only minimal effects on the organ estimates.

USTUR Case 0744

Case 0744 worked at the Rocky Flats Plant for 32 years and died eight years after cessation of work. He died at age 67 of myocardial infarction. During his work at the plant, he was involved in as many as 17 incidents that might be considered dosimetrically significant including two plutonium contaminated wounds and an uncontained plutonium fire. There were 192 urinalyses results and 52 in-vivo determinations of lung burdens in the dosimetry file.

The first application of the IMBA code for this case was performed with only urinalyses results and five exposure incidents that were considered most likely to have caused intakes. Only one of the wounds appeared to have resulted in residual plutonium deposition and it was included in the IMBA analyses; the other wound was decontaminated to background levels. Wound retention was modeled as two compartments (Bailey et al. 2003). The first compartment (28%) was retained with a half-life of 10 days and the second (72%) with a half-live of 4600 days. The predictions of respiratory tract, liver, and skeletal plutonium contents and the amounts measured in those organs are shown in Table 15. ICRP Type S default absorption rates resulted in a considerable underestimation of the lung content, a slightly high estimate of the liver content, and a reasonable estimate of the skeletal content. Reduction of the final dissolution rate from the lung from the Type S value increased the estimate of respiratory tract contents as expected; however, this had little effect on the estimated liver and skeletal content.

Two additional applications of the IMBA code were performed with the addition of the 52 in-vivo bioassay estimates of lung contents of plutonium. The additional bioassays had little effect on the estimates of organ contents with the ICRP Type S designation (Table 15). Reduction of the dissolution rate by two orders of magnitude increased the predicted lung burden but it was still below the measured amount and further reduction of the rate had only minimal effects on the predicted organ burdens.

Observations

There are a number of observations that were made as a result of application of the ICRP default absorption behavior and biokinetic models to the bioassay data of the six whole body donations. The predicted plutonium contents of the respiratory tracts, livers, and skeletons (based on urinalyses, only) are compared to the measured contents of those organs in Table 16.

1. It is obvious that all six of the whole body donors inhaled plutonium that was less soluble than the ICRP Type S material. Use of the ICRP default parameters resulted in lung burden estimates that were, on average, 18% of the measured burdens at death (range = 2 – 49%).

2. Plutonium intakes necessary to produce lung burden predictions at death more nearly equal to

the measured amounts in four of the cases (0193, 0208, 0213, and 0744) were an average of 2.7 times higher than intakes estimated with ICRP Type S material. In two of the cases (0425 and 0242), it was necessary to increase the intakes by an average factor of 15.

3. Estimated liver burdens of plutonium at death were an average of 60% of the measured burdens (range = 20 – 100%) with one exception; the estimated liver content of Case 0744 was 177% of the measured content.

4. Estimated skeletal burdens of plutonium at death were an average of 60% of the measured burdens in all six cases (range =33 – 105%).

5. Increasing the plutonium intake by reducing the final dissolution rate from the lung had little impact on the estimates of the liver and skeleton.

6. Addition of in-vivo determinations of lung burdens for two of the cases (0425 and 0744) made little difference in the organ burden estimates even though some lung "counts" indicated higher lung burdens that those measured at death.

During these initial applications of the IMBA code, only the final dissolution rate from the lung was altered. There are several more key ICRP parameter values within the code that could be altered to predict the measured organ burdens more closely (James et al. 2003). This kind of activity is precisely what the founders of the USTUR had in mind and what the USTUR mission statement reflects.

References

Bailey BR, Eckerman KF, Townsend LW. An analysis of a puncture wound case with medical intervention. Radiat. Prot. Dosim. 105;509-512; 2003.

Hempelmann LH, Langham, WH, Richmond CR, Voelz GL. Manhattan project plutonium workers: a twenty seven year followup study of selected cases. Health Phys. 25:461-479; 1973.

International Commission on Radiological Protection. Age-dependent doses to members of the public from intake of radionuclides: Part 1. Oxford: Pergamon Press; ICRP Publication 56, Ann ICRP 20(2); 1989.

International Commission on Radiological Protection. Age-dependent doses to members of the public from intake of radionuclides: Part 2 – Ingestion dose coefficients. Oxford: Pergamon Press; ICRP Publication 67, Ann ICRP 23(3-4); 1993.

International Commission on Radiological Protection. Human respiratory tract model for radiological protection. Oxford: Pergamon Press; ICRP Publication 66, Ann ICRP
24(1-3); 1994.

International Commission on Radiological Protection. Individual monitoring for internal exposures of workers: Replacement of ICRP Publication 54. Oxford: Pergamon Press; ICRP Publication 78, Ann ICRP 27(3-4); 1997.

International Commission on Radiological Protection. Basic anatomical and physiological data for use in radiological protection: the skeleton. Oxford: Pergamon Press; ICRP Publication 70, Ann ICRP 25(2); 1995a.

International Commission on Radiological Protection. Dose coefficients for intakes of radionuclides by workers. Oxford: Pergamon Press; ICRP Publication 68, Ann ICRP 24(4); 1995b.

Kathren, RL. Postmortem tissue analysis in-vivo bioassay, and exposure information for five whole body donors. In: Annual report of the United States Transuranium and Uranium Registries. USTUR-0015-94; 1994.

McInroy JF, Kathren RL, Swinth MJ. Distribution of plutonium and americium in whole bodies donated to the United States Transuranium Registry. Radiat Prot Dosim
26:151-158; 1989.

Voelz Gl, Hempelmann LH, Lawrence JNP, Moss WD. A 32-year follow-up of Manhattan project Pu workers. Health Phys. 37:445-485; 1979.

Voelz GL, Hempelmann LH. A 37-year medical follow-up of Manhattan project workers. Health Phys. 48:249-259; 1985.

Voelz GL, Lawrence JNP. A 42-y follow-up of Manhattan project plutonium workers. Health Phys. 61:181-190; 1991.

Table 9

Measured and Estimated Plutonium Contents of the Respiratory Track, Liver, and Skeleton of USTUR Case 0193

Measured Organ Content (Bq)	
Respiratory tract	157.0
Liver	48.5
Skeleton	49.2
IMBA Estimates with Type S material (Bq)	
Intake	20,600
Respiratory tract	14.5
Liver	28.3
Skeleton	48.0
IMBA Estimates with S_t[a] = 1.3 E-5 (Bq) S_t	
Intake	94,700
Respiratory tract	153.0
Liver	27.6
Skeleton	48.5

[a] final dissolution rate from the lungs

Table 10

Measured and Estimated Plutonium Contents of the Respiratory Track, Liver, and Skeleton of USTUR Case 0208

Measured Organ Content (Bq)	
Respiratory tract	86.7
Liver	35.6
Skeleton	87.2
IMBA Estimates with Type S material (Bq)	
Intake	24,000
Respiratory tract	11.8
Liver	31.2
Skeleton	55.6
IMBA Estimates with S_t[a] = 2.8 E-5 (Bq) S_t	
Intake	65,600
Respiratory tract	86.4
Liver	33.0
Skeleton	57.8

[a] final dissolution rate from the lungs

Table 11

Measured and Estimated Plutonium Contents of the Respiratory Track, Liver, and Skeleton of USTUR Case 0213

Measured Organ Content (Bq)	
Respiratory tract	56.4
Liver	47.8
Skeleton	177.0
IMBA Estimates with Type S material (Bq)	
Intake	34,400
Respiratory tract	27.5
Liver	48.0
Skeleton	79.9
IMBA Estimates with S_t[a] = 6.5 E-5 (Bq) S_t	
Intake	48,500
Respiratory tract	55.0
Liver	49.1
Skeleton	81.7

[a] final dissolution rate from the lungs

Table 12

Measured and Estimated Plutonium Contents of the Respiratory Track, Liver, and Skeleton of USTUR Case 0242 Assuming Five Acute Intakes

Measured Organ Content (Bq)	
Respiratory tract	1860.0
Liver	390.0
Skeleton	408.0
IMBA Estimates with Type S material (Bq)	
Intake	57,600
Respiratory tract	34.7
Liver	77.5
Skeleton	134.0
IMBA Estimates with S_t[a] = 1.0 E-6 (Bq) S_t	
Intake	904,000
Respiratory tract	1900.0
Liver	68.0
Skeleton	122.0

[a] final dissolution rate from the lungs

Table 13

Measured and Estimated Plutonium Contents of the Respiratory Track, Liver, and Skeleton of USTUR Case 0242 Assuming Five Periods of Chronic Intakes

Measured Organ Content (Bq)	
Respiratory tract	1860.0
Liver	390.0
Skeleton	408.0
IMBA Estimates with Type S material (Bq)	
Intake	1,560,000
Respiratory tract	53.9
Liver	96.6
Skeleton	163.0
IMBA Estimates with S_t[a] = 3.0 E-6 (Bq) S_t	
Intake	84.000
Respiratory tract	1780.0
Liver	89.9
Skeleton	152.0

[a] final dissolution rate from the lungs

Table 14

Measured and Estimated Plutonium Contents of the Respiratory Track, Liver, and Skeleton of USTUR Case 0425 Assuming Five Equal Periods of Chronic Intakes

Measured Organ Content (Bq)	
Respiratory tract	206.0
Liver	13.6
Skeleton	32.4
IMBA Estimates with Type S material (Bq)	
Intake	5150
Respiratory tract	5.06
Liver	7.52
Skeleton	12.0
IMBA Estimates with [a] S_t = 3.0 E-6 (Bq) S_t	
Intake	73,400
Respiratory tract	196.0
Liver	6.30
Skeleton	10.2
IMBA Estimates with Type S material and "lung" counts included (Bq)	
Intake	8050
Respiratory tract	9.09
Liver	11.9
Skeleton	18.7
IMBA Estimates with "lung" counts and S_t[a] = 1 E -6 S_t	
Intake	35,400
Respiratory tract	67.7
Liver	2.52
Skeleton	4.71

[a] final dissolution rate from the lungs

Table 15

Measured and Estimated Plutonium Contents of the Respiratory Track, Liver, and Skeleton of USTUR Case 0744

Measured Organ Content (Bq)	
Respiratory tract	77.1
Liver	30.0
Skeleton	86.3
IMBA Estimates with Type S material (Bq)	
Intake	36,500
Respiratory tract	25.0
Liver	52.3
Skeleton	90.5
IMBA Estimate with S_t[a] = 5.0 E-5 (Bq) S_t	
Intake	63,000
Respiratory tract	72.9
Liver	54.0
Skeleton	93.0
IMBA Estimate with Type S material and "lung" counts included (Bq)	
Intake	42.400
Respiratory tract	23.4
Liver	55.3
Skeleton	97.5
IMBA Estimate with "lung" counts and S_t[a] = 1 E -6 S_t	
Intake	28,300
Respiratory tract	53.4
Liver	4.7
Skeleton	75.8

[a] S_t = final dissolution rate from the lungs

Comparison of Estimated Plutonium Contents of the Respiratory Tracts, Livers, and Skeletons with the Measured Organ Contents in Six Whole-body Donations to the USTUR

Table 16

Case Number	0193	0208	0213	0425	0744	0242 (acute)	0242 (chronic)
Measured Organ Content (Bq)							
Respiratory tract	157.0	86.7	56.4	206.0	77.1	1860.0	1860.0
Liver	48.5	35.6	47.8	13.6	30.0	390.0	390.0
Skeleton	49.2	87.2	177.0	32.4	86.3	408.0	408.0
IMBA Estimate with ICRP Type S material (Bq)							
Intake	20.6k	20.4k	34.4k	5.15k	36.5k	57.6k	1,560.0k
Respiratory tract	14.5	11.8	27.5	5.06	25.0	34.7	53.9
Liver	28.3	31.2	**48.0**	7.52	52.3	77.5	96.6
Skeleton	**48.0**	55.6	79.9	12.0	**90.5**	134.0	163.0
IMBA Estimate with User-defined Final Dissolution Rate from Lungs[a]							
Dissolution rate	1.4 E – 5	2.8 E – 5	6.5 E – 5	3.0 E – 6	5.0 E – 5	1.0 E – 6	3.0 E – 6
Intake	94.7k	65.6k	48.5k	73.4k	63.0k	904.0k	784.0k
Respiratory tract	**153.0**	**86.4**	**55.0**	**196.0**	**72.9**	**1900.0**	**1780.0**
Liver	27.6	**33.0**	**49.1**	6.30	54.0	68.0	89.9
Skeleton	**48.5**	57.8	81.7	10.2	**93.0**	122.0	152.0

[a]The ICRP default value is: 1.0 E – 4

Estimates in bold type are those within 10% of measured values.

Estimation of Systemic Actinide Element Content in Humans

Ronald E. Filipy, *Director*
J. Richard Alldredge, *Statistician*

The U. S. Transuranium and Uranium Registries (USTUR) have described a model that is used to estimate skeletal contents of plutonium and americium on the basis of one to five bone samples collected at autopsy of non-whole body donors (Filipy et al. 2003). The purpose of this report is to describe additional models useful in estimating systemic contents of the same actinide elements if only liver and skeletal contents were measured in those donors. Results of urinalyses for those elements frequently reflect systemic contents if performed at long times after intakes or potential intakes.

Methods

Concentrations of plutonium in the livers, clavicles, patellae, ribs, sternums, and vertebral wedges, as well as the total systemic plutonium contents of eight whole body donors to the USTUR, were used to create the described models. Least squares regression was chosen for estimating systemic actinide content from liver content and individual bone concentrations because expected bias and precision are smaller using the least squares estimator compared to the ratio of sample means or the mean of sample ratios (Kendall and Stuart (1968). Furthermore, the simple regression estimator is easily extended to multiple regressions for estimating systemic content from more than one bone. Regression through the origin, subsequently called ratio estimation, and regression assuming a non-zero y-intercept were both computed for comparative purposes. One argument is that if no actinide concentration was detected in available bone(s) and/or no content was detected in the liver, the estimated systemic content should also be undetectable. An alternative argument is that systemic content may still be present even if actinides are not detected in the liver or selected bones.

Systemic actinide content may be estimated from the liver content or an individual bone concentration by using the ratio estimator:

Systemic content = (ratio coefficient) x (liver content), (1)
or
Systemic content = (ratio coefficient) x (bone concentration). (2)

An alternative method of estimation is to use the regression estimator:

Systemic content = intercept + (regression coefficient) x (liver content) (3)
or
Systemic content = intercept + (regression coefficient) x (bone concentration) (4)

The maximum bound on the error of prediction can be used to compare the predictive capabilities of liver content and individual bone concentrations among ratio estimators, among regression estimators, and between ratio and regression estimators. The maximum bound on the error of prediction is the largest value of the half width of the simultaneous 95% prediction interval. For the simple linear regression model with the intercept set to zero (regression through the origin), the maximum prediction error is associated with the largest value of the bone concentration. Smaller error of prediction implies less error in predicting systemic actinide content.

Results

A summary of the ratio and regression models relating systemic ^{239}Pu content to liver content and individual bone concentration for wet tissue samples are given in Table 17. For ^{239}Pu, the regression estimate for liver content has the smallest maximum prediction error (157.7) indicating the best estimator for systemic content. In this case the maximum half-width of the 95% prediction interval is 157.7 so the true systemic content would be expected to be within ± 157.7 of the estimated concentration with 95% confidence. Among the bone concentrations, the ratio estimator for sternum provides the smallest maximum prediction error (221.2). For example, the regression prediction equation for liver content is:

$$\text{Systemic content} = 50.05 + 2.37 * \text{liver content}, \qquad (5)$$

and the ratio prediction equation for sternum concentration is:

$$\text{Systemic content} = 19.78 * \text{sternum concentration}. \qquad (6)$$

If both liver content and bone concentration data are available or if more than one bone is available, an improved estimate of systemic content may be possible by using multiple ratio or multiple regression methods. A summary of these models relating systemic content to liver content plus the concentration in a single bone are given in Table 18 for ratio and regression estimators. For example, if ^{239}Pu content in the liver and concentration in the vertebral wedge were available, the prediction equation for the systemic content using a ratio estimator would be (from Table 18):

$$\text{systemic content} = 1.50 * \text{liver content} + 7.42 * \text{wedge concentration}. \qquad (7)$$

In this case, the maximum half-width of the 95% prediction interval is 90.5. The true systemic content would be expected to be within ± 90.5 of the estimated concentration with 95% confidence. The corresponding value, using the regression estimator, would be 104.3.

It is noted that some multiple ratio estimates and multiple regression coefficients could be negative, which is a consequence of correlation among the measured liver content and bone concentrations. This phenomenon, known as multicollinearity, occurs when two or more predictor variables, (i.e., bone concentrations) are highly correlated (Zar, 1996). The choice between using ratio estimators or regression estimators depends on the assumptions about presence of systemic content when liver content and/or bone concentration is below the detectable limit. For the data examined here the size of the prediction error does not clearly show whether ratio or regression estimators are better.

References

Filipy RE, Alldredge JR, Hall CA, McInroy JF, Glover SE, Qualls S. Estimation of actinide skeletal content in humans based on bone samples collected at autopsy. Health Phys. 84:34-45; 2003.

Kendall MG, Stuart A. The advanced theory of statistics, Volume 3. New York, NY: Hafner Publishing; 1968.

Zar JH. Biostatistical analysis. Upper Saddle River, NJ; Prentice Hall; 1996.

Table 17

Coefficients and Goodness of fit of Diagnostic for Predicting Systemic Burden from Wet Samples for ^{239} Plutonium Using Ratio or Regression Estimates

	Ratio		Regression		
	Ratio Coefficient	Maximum Prediction Error	Regression Coefficient	Intercept	Maximum Prediction Error
^{239}Pu					
Liver	2.45	200.3	2.37	50.05	157.7
Clavicle	18.47	407.0	18.46	0.22	462.2
Patella	17.19	590.9	16.26	89.58	593.6
Ribs	20.35	546.4	22.48	-133.65	507.1
Sternum	19.78	221.2	19.80	-1.24	258.30
Wedge	18.92	293.3	20.00	-78.57	242.2

Table 18

Ratio and Regression Coefficients and Goodness of Fit Diagnostics for ^{239} Plutonium from Wet Samples with Liver Plus Bone

Intercept	Liver	Clavicle	Patella	Ribs	Sternum	Wedge	Max. Prediction Error
Ratio Coefficients							
	1.85	4.58					180.0
	2.47		-0.14				231.0
	1.86			5.03			97.6
	1.27				9.59		155.4
	1.50					7.42	90.5
Regression Coefficients							
39.8	2.00	2.96					157.4
50.5	2.32		0.390				186.0
9.06	1.92			4.51			110.0
29.2	1.51				7.23		158.0
1.28	1.52					7.31	104.3

[a] Regression equations containing sternum regression coefficients are based on seven observations. All others are based on eight observations.

Comparison of Measured and Predicted Organ Burdens of Plutonium

Lyle Sasser, *Assoc. Research Prof.*
Ronald E. Filipy, *Director*

Introduction

The United States Transuranium and Uranium Registries (USTUR) have a collection of tissues donated at death by former workers who were exposed to the actinide elements during their employment in the nuclear industry. Although the actinide body burdens of most USTUR Registrants resulted from inhalation exposure, several cases resulted by mixed intakes from wounds and inhalation or via wounds alone. This USTUR data base is ideally suited for testing the International Commission on Radiological Protection's (ICRP) models and biokinetic data. A software program, IMBA Expert USDOE-Edition (Phase II), designed for the assessment of internal radiation dose based on in vivo bioassays, permits the estimation of radioisotope intake and content of various organs at given times after intake (James et al. 2004). The IMBA Expert code specifically applies the ICRP recommended respiratory tract, GI-tract, tissue dosimetry, biokinetic, and bioassay models for the ICRP 68 Reference Worker (ICRP, 1995), to estimate intakes, and predict tissue contents and doses from bioassay measurements. For estimation of dermal retention in a subcutaneous wound, the IMBA Expert code uses a "generic wound model" in which retention is represented by the sum of a series of user-defined exponentially decaying terms.

The purpose of this report is to describe the use of the current ICRP models to predict organ burdens of plutonium at the time of death in two USTUR whole body donations, on the basis of the *in vivo* bioassay data available for those donors. The primary route of internal exposure for both donors was via contaminated subcutaneous wound. Since there are currently no ICRP or NCRP-recommended parameter values to represent wound retention for actinides, the IMBA Expert code does not include such so-called "default" retention half-times or retention fractions. Therefore, for initial application of the code, retention fractions and half-times reported by Bailey et al. (2003) were used.

USTUR Case 0262

This donor worked directly with plutonium for approximately the first 13 years during his 32 years of employment at a plutonium processing site. During that time he had several possible acute intakes of inhaled plutonium, but urinalyses indicated that his intake was minimal. His primary plutonium intake resulted from a puncture wound to the left thumb inflicted when a drill slipped and sliced the thumb. Medical findings were a 1/4 inch laceration (1/8 inches deep) on the terminal phalanges of the left thumb with no bleeding. A suction cup was applied and about 2 ml of fluid was obtained. There was apparently no radioactivity above background in the fluid removed, but information about the detection methods used is not available. There was no mention in the dosimetry records of chelation therapy or surgical removal of tissue. The routes of accidental intake and subsequent urinalysis data were taken from the Registrant's health physics records supplied by his former employer. Dosimetry records obtained from the Registrant's employer show that he incurred an external radiation dose to the whole body of 110 mSv (11 rem) during his 32 year employment, of which about 42 mSv (4.2 rem) was received during a three year period early in his employment. The Registrant died 33 years after the accident, from hepatocellular carcinoma, and the whole body was radiochemically analyzed for plutonium.

Measured ^{239}Pu content of selected tissues at autopsy are presented in Table 19. Liver and total skeletal ^{239}Pu contents were 20.7 and 22.6 Bq, respectively. The total ^{239}Pu body burden at autopsy was 111 Bq. The ^{239}Pu content of the left axillary lymph node at autopsy was 56 Bq, greater than any other organ, but the content of the right axillary lymph node was negligible. Pulmonary lymph nodes contained about 1 Bq of ^{239}Pu and the lung contained 2.59 Bq, suggesting a possible small exposure from inhalation.

Results of all urinalyses from the time of hiring until death are plotted in Figure 12. ^{239}Pu levels of most of the samples taken before the wound accident were below the detection limit, whereas ^{239}Pu was generally detected in the urine for 5-6 years after the accident. Urinary excretion of ^{239}Pu was essentially nondetectable beyond this time period. Urine ^{239}Pu bioassay data were entered into the IMBA Expert code and a model was developed to estimate plutonium intake and the contents of the liver and skeleton from the bioassay data. (James et al. 2003; James et al., 2004). Bailey et al. (2003), using a two component model, reported retention half lives of 10 and 4600 days for the first and second components, respectively, and that the longer component represented 72 % of the activity in a wound contamination case. Thus, as a first approach to wound retention analysis we assumed a two-compartment function with half lives of 10 and 4600 days and retention fractions of 0.28 and 0.72, respectively.

The projected liver and skeleton content predicted by this urinary bioassay model were 11.3 and 17.8 Bq, respectively (Table 19). The predicted total ^{239}Pu intake was only 53.8 Bq, less than the measured total whole body content at autopsy. Based on the assumed two-component wound retention behavior, the IMBA Expert code under-predicted the measured liver values in this case by nearly a factor of 2. The predicted skeletal content agreed very well with the measured value. However, the predicted urinary excretion curve fit the data poorly with a Chi-squared sum of 57 (Figure 12). Improvement in the data fit (Chi-squared sum of 31) was possible by using a three-compartment model with retention half lives of 7, 70 and 1.4×10^4 days (Figure 13). However, this approach underestimated both liver and skeleton plutonium content and total plutonium intake.

The urine bioassay data probably does not reflect the kinetics of liver and skeletal deposition during the life of the donor in this case. We were able to maintain the data fit of the urinary excretion curve and improve the predicted values by using this three-compartment model and applying the measured liver and skeletal ^{239}Pu values at autopsy to the IMBA Expert code as additional bioassay values (Figure 13). The projected intake value increased to 171 Bq and liver and skeletal content was not appreciably different than measured values, 20.7 and 22.6 Bq, respectively (Table 19).

USTUR Case 0769

USTUR whole body donor Case 0769 was a chemical operator involved with highly purified ^{239}Pu at a plutonium purification and recovery laboratory. He worked with plutonium for about 13 months under extraordinarily crude conditions (Hempelmann et al. 1973), after which he had no further contact withradioactive materials during his working career. Shortly after being assigned to work duty, the Registrant cut and contaminated his left thumb while pouring a plutonium solution from a flask. No chelation therapy was given, but about 70 Bq of plutonium was excised from the wound at the time (Voelz et al. 1997). Although this was the major exposure incident, there was also potential for inhalation exposure to plutonium on several occasions during his employment. Nasal swab counts were consistently positive during much of this work assignment. The Registrant had been subject to routine urine bioassay monitoring for plutonium during his work period and up to 4 years before his death at age 66. Further information regarding this case has been reported by Voelz and his colleagues (Hempelmann et al. 1973; Voelz et al. 1979; Voelz et al. 1985; Voelz and Lawrence 1991; Voelz et al. 1997). USTUR Case 0769 is identified as Subject 20 in these reports.

The whole body of this Registrant was donated to the USTUR for radiochemical analysis of actinides. He died of metastatic osteoblastic osteosarcoma at age 66, approximately 45 years after the accident. At autopsy the measured liver ^{239}Pu content was 85.8 Bq and the total skeletal ^{239}Pu content was 151 Bq. There were 17.9 Bq of ^{239}Pu found in the lungs. The total ^{239}Pu in the whole body was 272 Bq (Table 19).

Urine ^{239}Pu bioassay data were entered into the IMBA Expert code and a model was developed to estimate plutonium intake and the contents of the liver and skeleton from the bioassay data (James et al 2004). Again, as in case 0262 above, a two- component wound retention model was used (Bailey et al., 2003) for the initial wound retention analysis and half lives of 10 and

4600 days and retention fractions of 0.28 and 0.72 were assumed. Plotted in Figure 14 are the 15 ^{239}Pu urinary bioassay values and the predicted urinary excretion curve. The predicted organ burdens are shown in Table 19. The estimated ^{239}Pu intake for the two components of the curve was 1075 Bq. The model predictions for liver and total skeleton content were 201 and 369 Bq, respectively. Based on the assumed wound retention, the IMBA Expert code over-predicted the measured liver and skeletal values in this case by more than a factor of 2.

Using a three-component function with retention half lives of 7, 70 and 1.4 x 10^4 days improved the fit of the predicted excretion curve for the urinary bioassay data, but again overestimated the liver and skeleton plutonium content (Table 19). When measured liver and skeleton values were included as bioassay data, they dominated the calculations and the resulting liver and skeletal predictions were not appreciably different from measured values, but the fit to the excretion data was poor. A much better fit of the urine bioassay data was achieved when only measured liver ^{239}Pu content was included in the IMBA Expert code as bioassay data (Figure 15). Predicted liver and skeletal ^{239}Pu values were 86 and 175 Bq respectively, agreeing with measured values.

Conclusions

These two wound cases are examples of how measured liver and skeletal plutonium data with the aid of the IMBA Expert code may be used to test and possibly improve ICRP biokinetic models and characterize the time-course of actinide uptake from subcutaneous wounds. In these initial analyses we concentrated on the wound retention behavior. However, the IMBA Expert code should enable a more comprehensive analysis of other biokinetic parameter values to be carried out by replicating the actual measured values of organ retention at the time of death for both cases (James et al 2003).

References

Bailey BR, Eckerman KF, Townsend LW. An analysis of a puncture wound case with medical intervention. Radiat Prot Dosim 105: 509-512; 2003.

Hempelmann LH, Langham WH, Richmond CR, Voelz GL. Manhattan Project Plutonium Workers: A twenty-seven-year follow-up study of selected cases. Health Phys 25:461-479; 1973.

International Commission on Radiological Protection. Dose coefficients for intakes of radionuclides by workers. Oxford: Pergamon Press Publication 68, Ann ICRP 24(4): 1995.

James AC, Filipy RE, Russell JJ, McInroy JF. USTUR case 0259 whole body donation: A comprehensive test of the current ICRP models for the behavior of inhaled $^{238}PuO_2$ ceramic particles. Health Phys 84:2-33; 2003.

James AC, Birchall A, Marsh JW, Puncher M. User Manual for IMBA Expert[tm] USDOE-Edition (Phase II). Richland, WA. ACJ and Associates, Inc. 2004.

Voelz GL, Hempelmann LH, Lawrence JNP, Moss WD. A 32-year medical follow-up of Manhattan project plutonium workers. Health Phys 37:445-485; 1979.

Voelz GL, Grier RS, Hempelmann LH. A 37-year medical follow-up of Manhattan project Pu workers. Health Phys 48:249-259; 1985.

Voelz GL, Lawrence JNP. A 42-y medical follow-up of Manhattan project plutonium workers. Health Phys 61:181-190; 1991.

Voelz GL, Lawrence JNP, Johnson ER. Fifty years of plutonium exposure to the Manhattan Project plutonium workers: an update. Health Phys 73:611-619; 1997.

Summary of Measured and IMBA Predicted ^{239}Pu in Two Wound Contamination Cases

	CASE 0262	CASE 0769
Measured	Bq	Bq
Lung	2.59	17.9
Liver	20.7	85.8
Skeleton	22.6	151
Total Systemic Deposition	107.0	252
Whole body	111.0	272
IMBA Prediction from Urine (Two-compartment analysis)		
Total Intake	54	1075
Liver	11.3	201
Skeleton	17.8	369
Chi-squared Sum	56.7	19.7
IMBA Predictions from Urine (Three-compartment analysis)		
Total Intake	28.8	952
Liver	6.7	144
Skeleton	11.8	275
Chi-squared Sum	31.1	14.0
IMBA Predictions with Liver and/or Skeleton Included		
Total Intake	171	511
Liver	20.6	86
Skeleton	22.6	175
Chi-squared Sum	33.2	18.8

Figure 12

Urinalyses Results of USTUR Case 0262 and the Predicted IMBA Regression on Curve Based on Urine Bioassay Data (two-compartment Model)

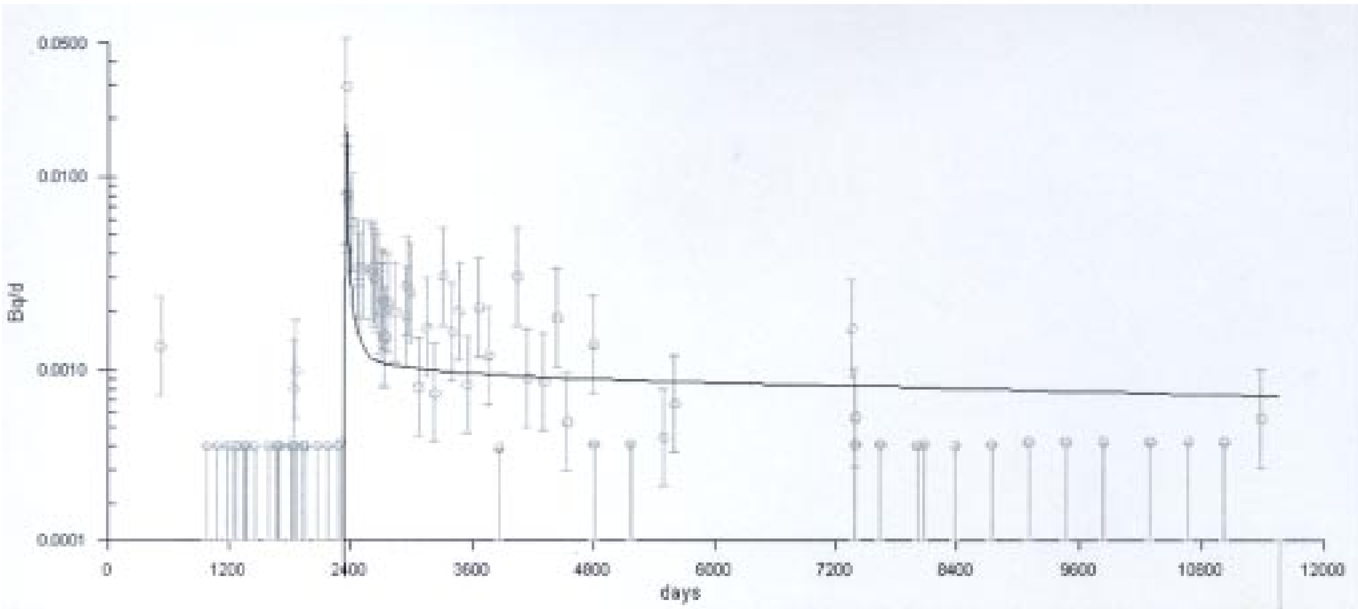


Figure 13

Urinalyses Results of USTUR Case 0262 and the Predicted IMBA Regression Curve Based on Urine Bioassay Data and Measured Liver and Skeleton Data (three-compartment model)

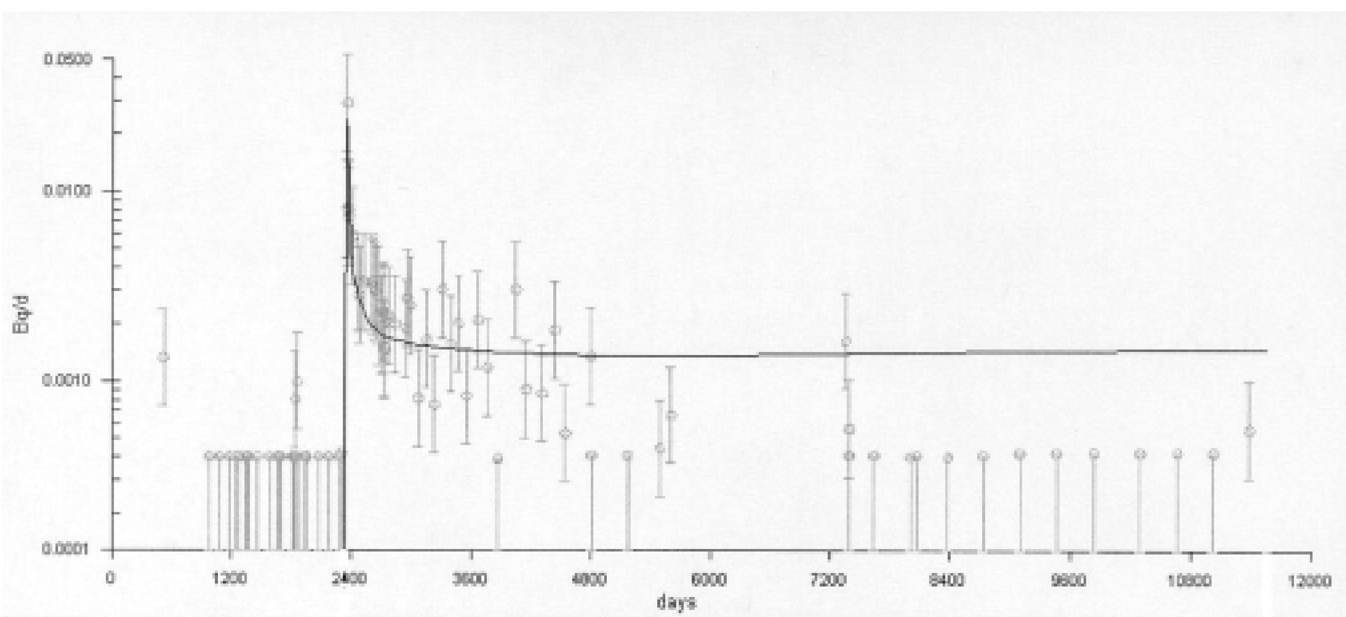


Figure 14

Urinalyses Results of USTUR Case 00769 and the Predicted IMBA Regression Curve Based on Urine Bioassay Data (Two-Compartment Model)

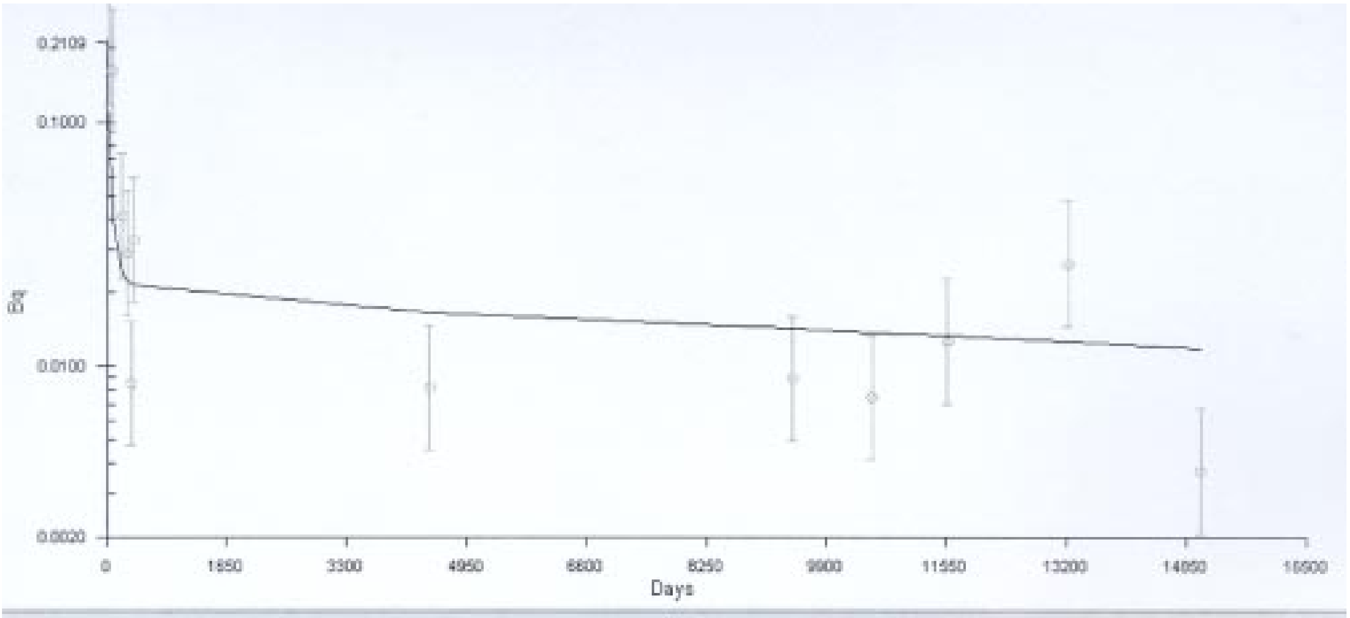
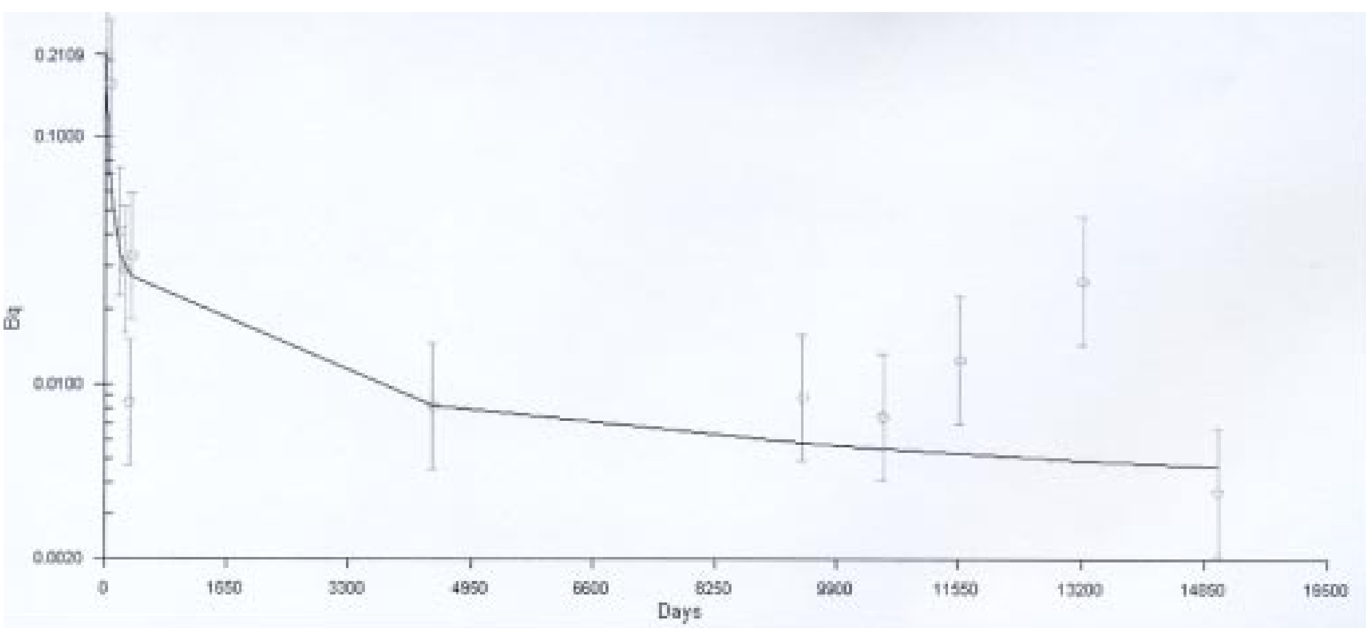


Figure 15

Urinalyses Results of USTUR Case 0769 and the Predicted IMBA Regression Curve Based on Urine Bioassay Data and Measured Liver Data (three-compartment model)



Acute Plutonium Nitrate Inhalation Case

A.C. James, *Adjunct Professor*

This Registrant was accidentally exposed by inhalation while handling a freshly separated solution of $^{239}Pu(NO_3)_4$. He provided several samples of urine within a day of the accident, and approximately 300 further samples over the following 33 years. Even more remarkably, he provided approximately 100 fecal samples, spanning the period 1 d through 31 years post intake. Within a day of the intake the Registrant was treated with intravenous CaEDTA, with an approximately week-on, week-off regime over the following 6 months. 24-h urine (and fecal) samples were collected both during the periods of EDTA therapy and in the intervening non-treated periods. Several other types of chelation therapy were tried over the following years, culminating in the effective use of intravenously injected CaDTPA from about 2.5 y through 3.5 y after the incident. The Registrant died from extensive carcinomatosis secondary to prostatic carcinoma at 79 years of age, 38 y after the accident. A preliminary summary of his body organ contents of plutonium isotopes and ^{241}Am was given in USTUR's Annual Report for 2000. This whole body donation presents a uniquely comprehensive set of human data from which the mechanisms of action of chelation therapy can be analyzed in relation to outcomes predicted by the current ICRP lung and biokinetic models for the "untreated" person.

Figure 16 shows the ^{239}Pu-in-urine bioassay measurements. The points labeled "untreated" represent the "baseline" rates of urinary excretion that were measured between periods of chelation therapy, which are (presumably) relatively unaffected by previous therapy. From these data, it appears that (on the average) intravenous (I.V.) injection of CaEDTA increased the urinary excretion rate of plutonium approximately 8-fold. In contrast, I.V. injection of CaDTPA, which was tried at about 10,000 d after the intake, had the substantially greater effect, produced about a 50-fold enhancement of urinary excretion. Other treatments, including orally-administered agents, had little if any effect.

Figure 17 shows the ^{239}Pu-in-feces bioassay measurements. In this case, I.V. injection of CaEDTA yielded no measurable effect on fecal excretion of plutonium. However, I.V. injection of CaDTPA did appear to enhance fecal excretion somewhat, although the ranges of daily excretion rate overlap during and between periods of treatment.

The "untreated" urinary and fecal excretion data were analyzed by examining the resulting body organ contents at the time of death (38 y post intake) that were predicted by the currently recommended ICRP biokinetic model for plutonium (ICRP, 1993). In this case, the nature of the plutonium (bulk) material was known, but there was no information about the physical properties of the inhaled aerosol. The "default" assumption for a $^{239}Pu(NO_3)_4$ aerosol is the so-called moderately soluble "Type M" (ICRP, 1997). This assumes a 5-µm-AMAD aerosol, with 10% of the activity deposited in the respiratory tract absorbed rapidly (at the rate of 100 d^{-1}) and the remainder relatively slowly (at the rate of $5 \times 10^{-3}\ d^{-1}$). Figure 18 shows the result of simultaneously analyzing the urine and fecal excretion data, using the maximum likelihood method with the IMBA Expert™ USDOE-Edition (Phase II) software (James et al. 2004). The errors on each urinary and fecal data point were assumed to be lognormally distributed, with geometric standard deviations of 1.8 and 2.5 for urine and feces, respectively. The resulting "most likely" estimate of the total ^{239}Pu intake was 4.07×10^6 dpm (67.8 kBq). The resulting total weighted chi-square (χ^2) sum for the "fit" to the urinary and fecal data (shown in Figure 18) was 916.

By inspection, the resulting "fits" of the "Type M" predictions to the urinary and fecal bioassay data shown in the IMBA Expert™ "screen shot" (Figure 18) seem reasonable. However, in this case, there were critical additional data (the tissue analysis results) that can also be used to "test" these predictions. For example, the measured ^{239}Pu content of the lungs at death was 26.7 Bq, corresponding to the 1,602 "dpm" activity shown in Figure 18 (in the same unit as the urinary and fecal bioassay quantities). However, the predicted lung content for a 67.8 kBq intake of Type M plutonium at 38 y after intake is 3.5×10^{-29} Bq. This is effectively zero, *i.e.*, according to the Type M "default" absorption behavior for moderately soluble plutonium, there should have been no plutonium left in the lungs at the time of death. In fact, the donor's lungs contained over 1% of the total ^{239}Pu body burden at death.

Whereas the difference between a prediction of "zero" retention in the lungs and the measured 1% of the final body burden may appear to be trivial, in fact the measured lung retention indicates markedly different absorption behavior from that of Type M material. In order to retain the measured amount of plutonium in the lungs, the "controlling" absorption rate must have been substantially slower than the assumed $5 \times 10^{-3}\ d^{-1}$ (corresponding to a retention half-time of 138 d). It is necessary for some fraction of the initially deposited material to have been absorbed much more slowly, with an effective absorption rate about 50-fold slower, on the order of $10^{-4}\ d^{-1}$.

It could be hypothesized that the airborne material was more complex than assumed, and that it included some fraction of "insoluble" plutonium, *e.g.*, Type "S" material, either during the recorded incident or at some other time. However, this hypothesis can be rejected on two grounds: (i) the resulting "fit" to the urinary and fecal excretion data was substantially worsened, and (ii) a substantial amount of this "insoluble" plutonium would be expected to have been transferred to the pulmonary lymph nodes. The measured lymph node content was 1/155th of the lung content.

From the above observations, it was determined that, in this case, it was necessary to invoke the additional "bound material" compartment that was described by ICRP as part of the new "Human Respiratory Tract Model, HRTM" (ICRP, 1994). Figure 19 shows the full structure of the recommended lung model. It must be emphasized that ICRP has not previously found evidence of the significance of this "bound material" compartment, and has thus ignored this feature of the model in recommending "default" parameter values for the absorption model in the HRTM. However, IMBA Expert™ USDOE-Edition (Phase II) implements the full absorption model, and thus enabled derivation of appropriate parameter values to represent the measured amount of plutonium retained "long term" in the lung tissue.

Accordingly, a detailed re-analysis of the bioassay and tissue content data in this case was performed, including derivation of the "best fit" values of the "bound material" parameters, and the aerosol size. Details of this analysis will be submitted for journal publication. The resulting estimates were as follows:

- Intake = 268 kBq., *c.f.*, 8.5 kBq, the "historical" health physics estimate based on ICRP30 Class "W" plutonium assumptions.
- Aerosol AMAD = 15 µm.
- Gut absorption fraction (f_1) = 0.0005 (the ICRP "default" for plutonium Type M).
- Fraction of deposited material absorbed rapidly = 2%.
- Rapid (initial) absorption rate = 100 d^{-1}.
- Final, slow (direct) absorption rate = 0.05 d^{-1}.
- Fraction of deposited material "bound" to lung tissue = 3%.
- Absorption rate of "bound" fraction = $10^{-4}\ d^{-1}$.

With this more appropriate deposition and absorption model, the total weighted χ^2 sum obtained by comparing the predicted and measured urinary and fecal excretion rates decreased from 916 (for the default Type M assumptions) to 790. More strikingly, however, the measured lung content at death was accurately represented. Table 20 compares the predicted body organ contents with the measured values.

Comparison of modeled body organ contents at death (38y post intake) with measured values.

Body organ	^{239}Pu Content		
	Measured, Bq	Predicted, Bq	Difference, %
Whole body	2,290	2,866	+25
Lungs	26.7	26.4	-1.1
Liver	936	862	-8.1
Skeleton	1,177	1,663	+41
Other (soft) tissues	150	315	+110

These predictions were made with the currently recommended parameter values in the ICRP Publication 67 biokinetic model for "systemic" translocation and excretion of plutonium (ICRP, 1993). From the starting point of the measured urinary and fecal bioassay data, it is seen that the whole body retention at 38 y post intake was overestimated, but by only 25%. This overestimate arose largely from over-estimation of the skeletal uptake and retention. A similar observation was made from detailed analysis of the whole body donation Case 0259 (James et al., 2003), involving an acute intake of ^{238}Pu in ceramic particle form and followed for 18 y. In that case, the "standard" ICRP67 biokinetic model predicted 54% higher skeletal content at death than the measured value. Also, in Case 0259, the liver content at death was underestimated by 19%, *c.f.*, an approximately 8% underestimation in this case [for "soluble" $^{239}Pu(NO_3)_4$]. It can, therefore, be expected that the modified parameter values for liver and skeletal uptake rates derived from the Case 0259 tissue data will also improve the "fit" of predicted and measured liver and skeletal retention in this case. The Case 0269 model predictions will be analyzed further, including an evaluation of whether the chelation therapy succeeded in reducing the concentrations of ^{239}Pu in various soft tissues, as indicated by the preliminary data of Table 20.

Figures 20 and 21 show the resulting "fits" of the predicted urinary and fecal excretion rates, respectively, to the measured data. Figure 20 (urinary excretion) shows that both the early excretion (up to a few weeks post intake) and later excretion (beyond about 1 y post intake) were reasonably well represented. The urinary excretion rate measured over the intervening period was systematically underestimated, by a factor of about 3. These samples were collected between repeated courses of short-term I.V. CaEDTA chelation therapy. It is possible that the higher measured urinary excretion rate over this period may reflect a "carry-over" effect from the actual periods of chelation. These data and model predictions will be analyzed further to elucidate this observation.

Figure 21 (fecal excretion) shows that after the first few weeks post intake, the measured fecal excretion rate ws reasonably well represented by the assumed lung model parameters, and later by the standard ICRP67 biokinetic model parameters which define the long-term endogenous fecal excretion for this "soluble" material. This is a critical, satisfactory prediction of the ICRP67 plutonium biokinetic model as a whole (ICRP, 1993).

Further Studies

- This whole body donation provides a well defined data set (for a known acute exposure) with which to derive values of several key plutonium biokinetic model transfer rates that are specific to this individual person, as was done for Case 0259 (James et al., 2003). Thus, any substantial deviations of tissue doses in this case from the "standard" predictions for Type "M" plutonium will be identified. Clearly, in this case, there was a long-term lung dose, whereas none is predicted for Type "M" material. There may also be a substantial effect of the chelation therapy regimes in reducing retention in various soft tissues.

- The observed urinary excretion rates in terms of the modeled effect of the I.V. CaEDTA and CaDTPA therapy regimes on the rate of elimination of plutonium from circulating blood to the kidney excretion pathway will be examined and the amount of dose "saved" by the therapy will be estimated.

- For this whole body donation, there are detailed measurements of ^{241}Am tissue contents, together with a known ^{241}Pu:^{239}Pu isotopic ratio for the inhaled material. The IMBA Expert™ USDOE-Edition (Phase II) software enables the in-growth of ^{241}Am within the lungs to be modeled (for an "insoluble" particle matrix). The ^{241}Am tissue data available in this case should serve to test ICRP's current assumptions about ^{241}Am "progeny" in-growth and subsequent retention in organs of translocation.

References

International Commission on Radiological Protection. Age-dependent doses to members of the public from intake of radionuclides: Part 2 Ingestion dose coefficients. Oxford: Elsevier Science Ltd; *ICRP Publication 67*; Ann ICRP 23(3/4); 1993.

International Commission on Radiological Protection. Human respiratory tract model for radiological protection. Oxford: Elsevier Science Ltd; *ICRP Publication 66*; Ann ICRP 24(1-3); 1994.

International Commission on Radiological Protection. Individual monitoring for internal exposure of workers. Replacement of *ICRP Publication 54*. Elsevier Science Ltd; *ICRP Publication 78*; Ann ICRP 27(3/4); 1997.

James AC, Filipy RE, Russell JJ, McInroy JF. USTUR Case 0259 whole body donation: A comprehensive test of the current ICRP models for the behavior of inhaled $^{238}PuO_2$ ceramic particles. Health Phys. 84:2-33; 2003.

James AC, Birchall A, Marsh JW, Puncher M. User manual for IMBA Expert™ USDOE-Edition (Phase II). Richland, WA: ACJ & Associates, Inc.

United States Transuranium and Uranium Registries. Annual Report February 1, 2000 – January 31, 2001. USTUR-0177-01. Richland, WA:Washington State University; 2001.

Figure 16

^{239}Pu excretion rate in urine measured during and between various periods and types of chelation therapy

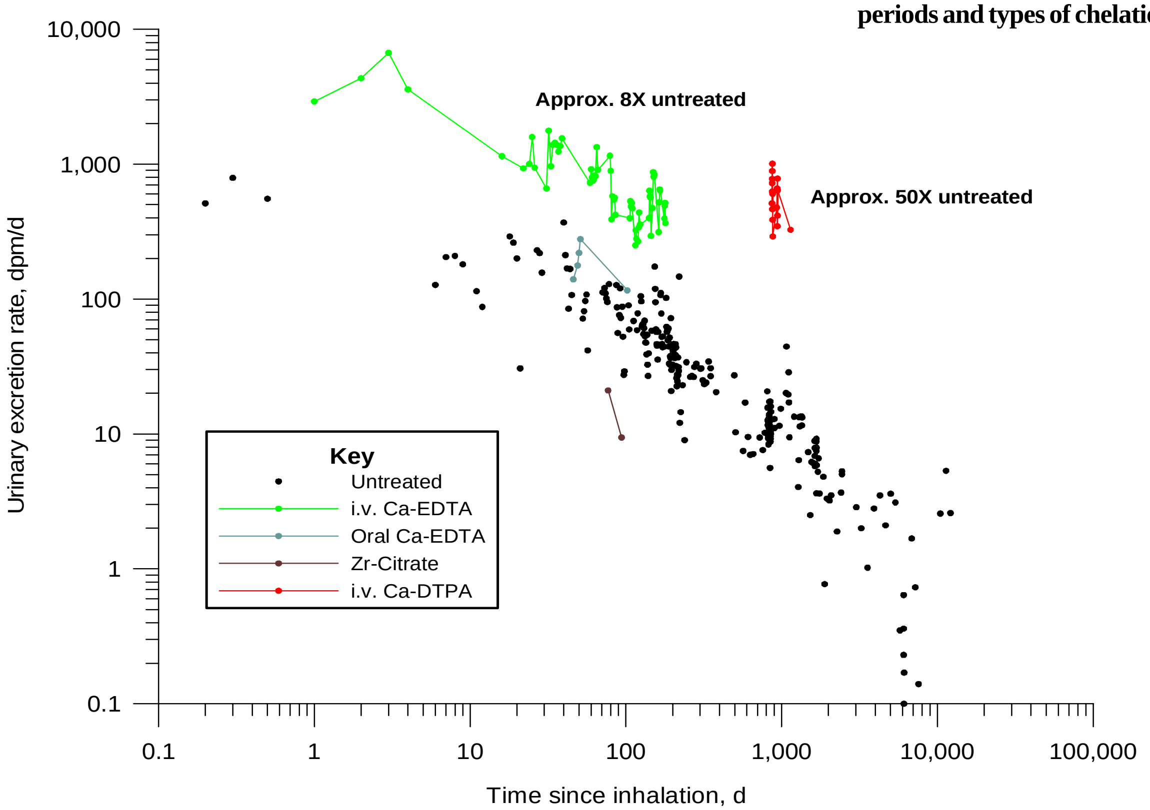
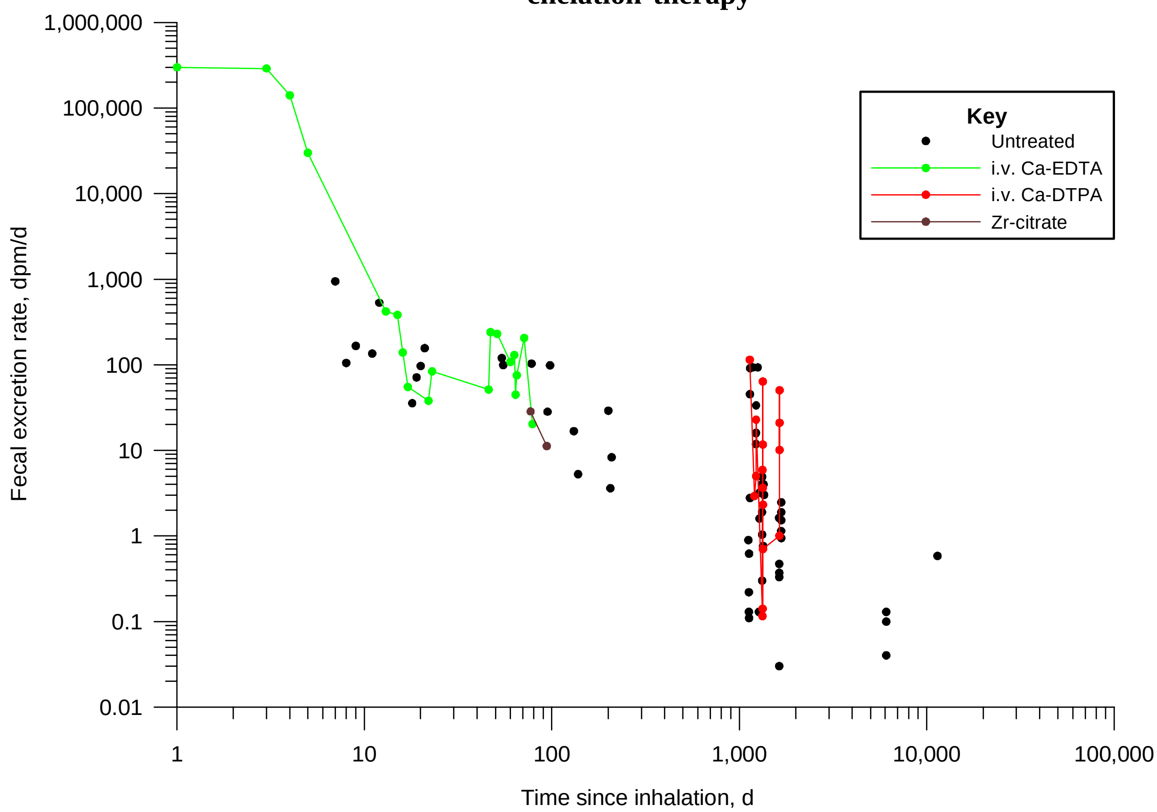


Figure 17

^{239}Pu excretion rate in feces measured during and between various periods and types of chelation therapy



^{239}Pu excretion rates in urine and feces predicted for Type M plutonium compared with measured values. Red points were excluded from the analyses.

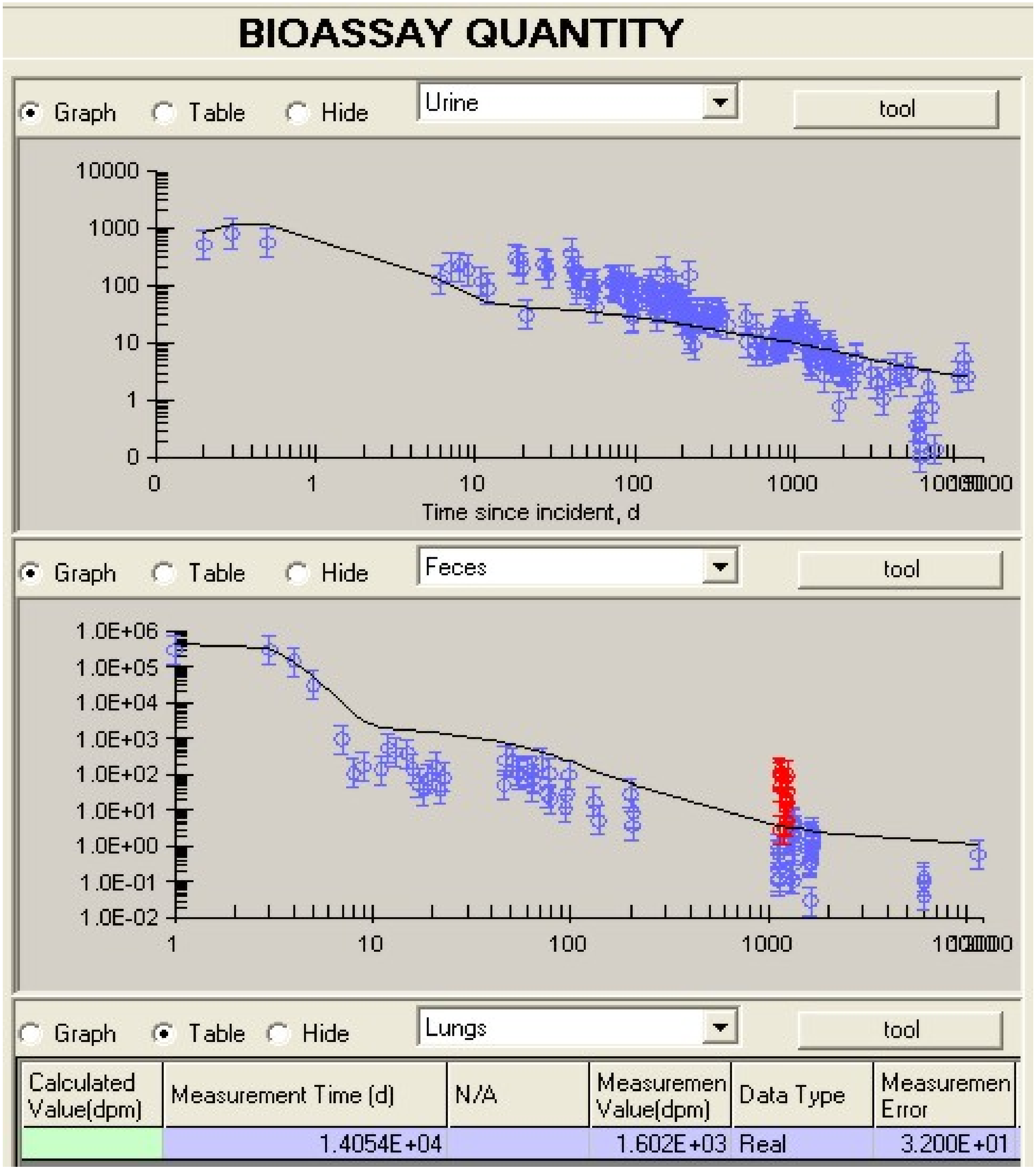


Figure 19

The ICRP Publication 66 compartment model of particle dissolution and absorption from each region of the respiratory tract

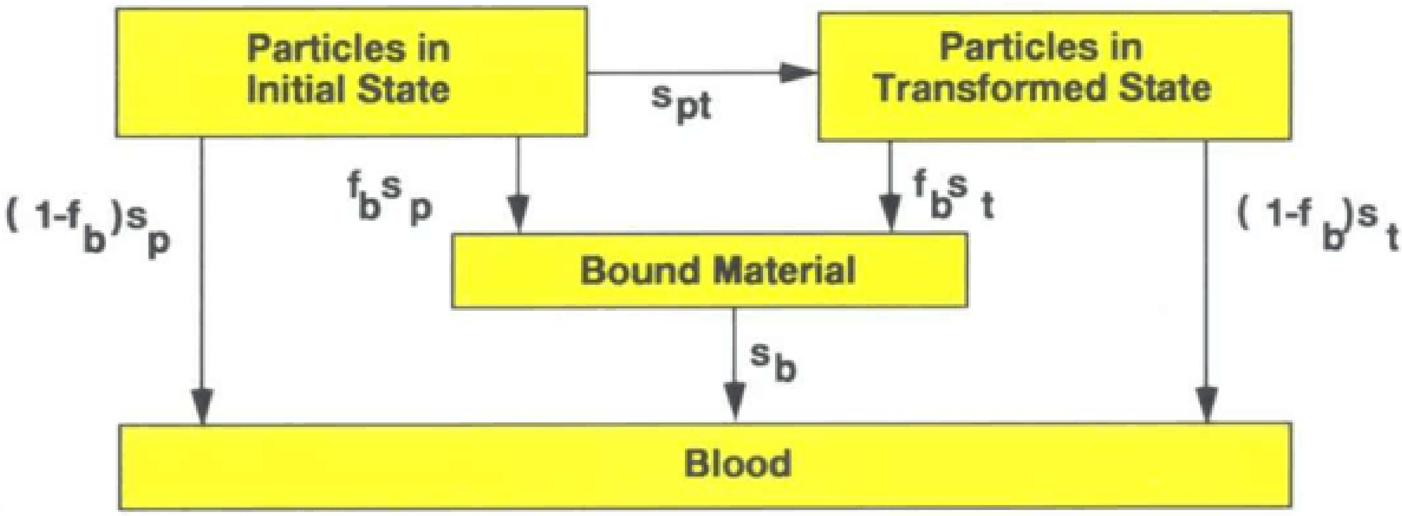
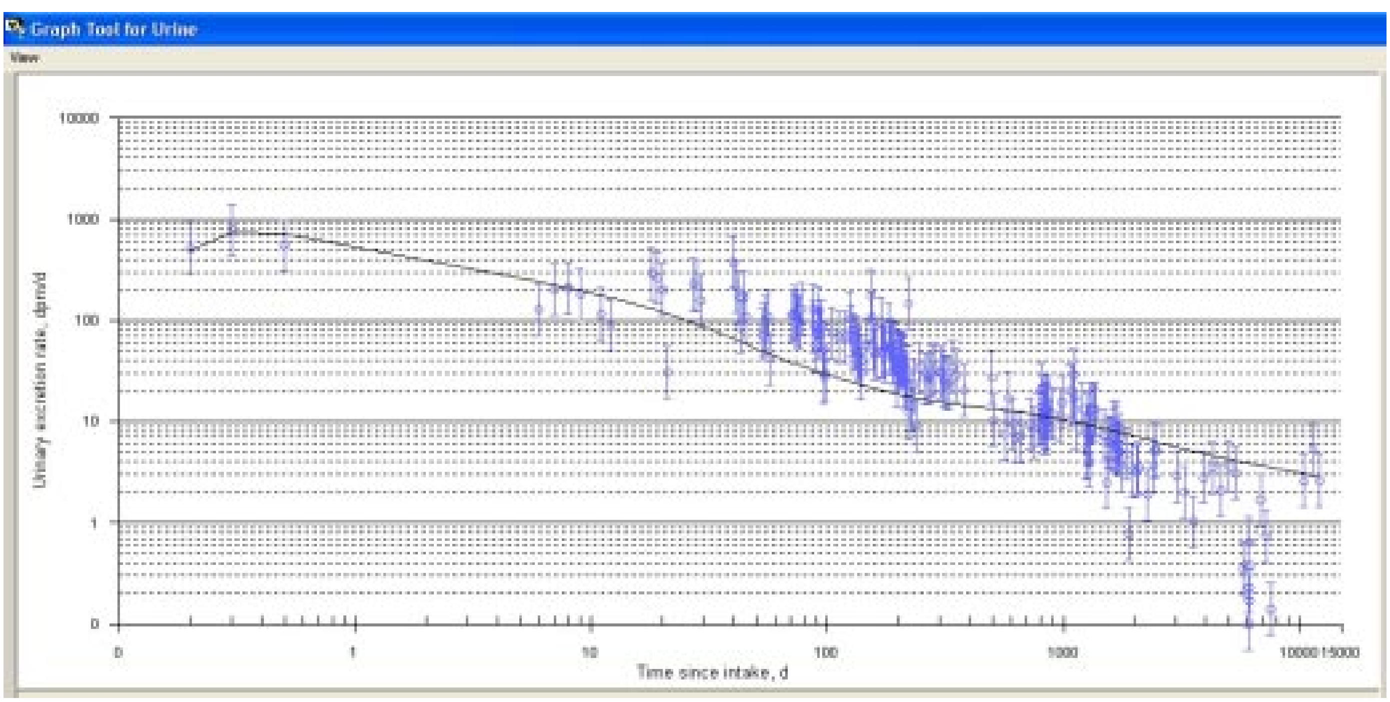
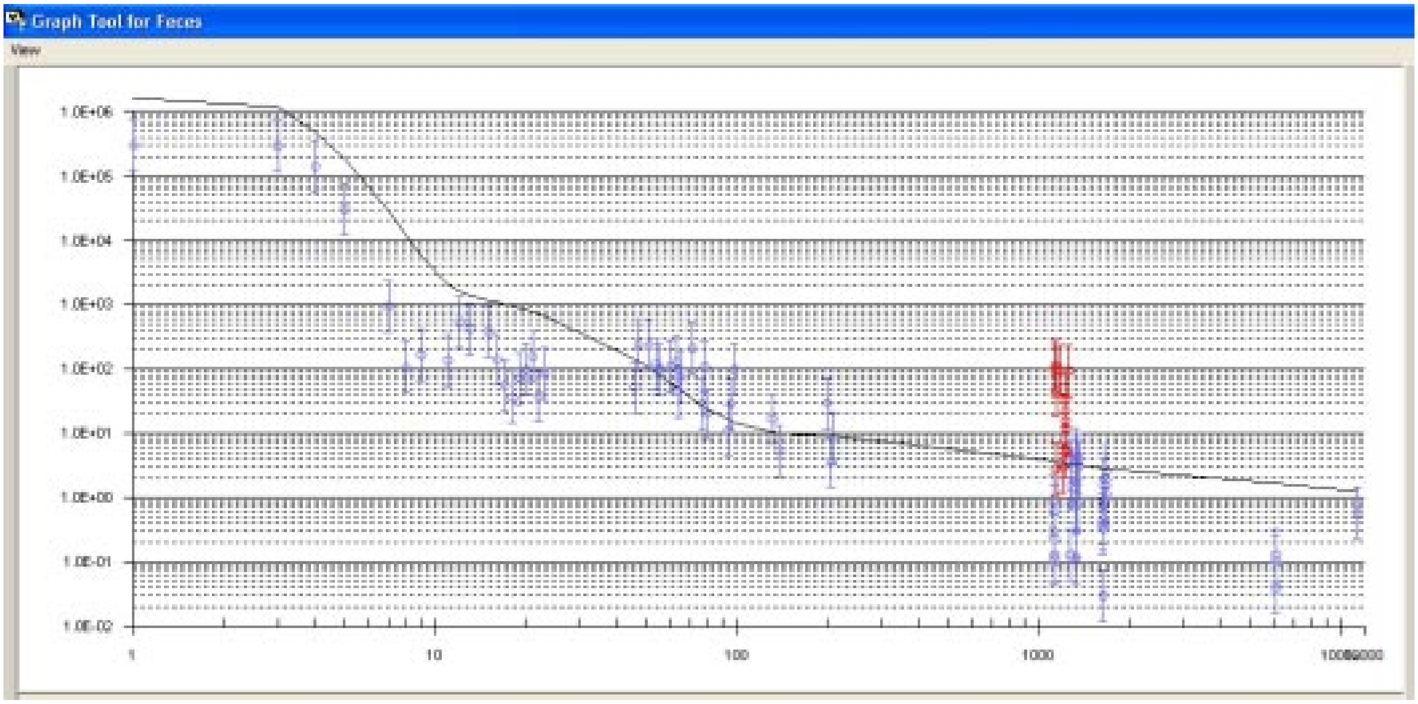


Figure 20

Modeled ^{239}Pu-in-urine excretion rate compared with measured values



Modeled ^{239}Pu-in-feces excretion rate compared with measured values. Points shown in red were excluded from the analysis. They were influenced by chelation therapy



Dennis Mahlum, *Chairman*

Advisory Committee Report

The annual Advisory Committee meeting of the United States Transuranium and Uranium Registries was held September 19-20, 2003 in Spokane, Washington at the Ridpath Hotel. The following is the report that was issued by the Committee in December 2003. Serving on the USTUR Advisory Committee for the 2003 annual meeting was Robert Thomas, Chairman; Joe Aldrich, Ronald Brosemer, Isabel Fisenne, Kathryn Paxton-George, Bruce Lawson, and Dennis Mahlum.

Executive Summary

The annual meeting of the United States Transuranium and Uranium Registries (USTUR) Scientific Advisory Committee (SAC) was held in Spokane, Washington, on September 19 and 20, 2003. The Committee met with most of the USTUR administrative and scientific staff. These meetings were informative, interactive, incisive, and cordial. The format introduced last year which allowed small group discussions was used again this year. These informal discussions permitted wide-ranging and vigorous exploration of topics of interest.

The Committee concluded that the USTUR is discharging its role as a depository and disseminator of information on radiation exposure and related health effects in a responsible and effective manner.

Administration

With the retirement of Mr. John Russell, USTUR Associate Director, the Committee discussed the hiring of Dr. Robert Thomas as a consultant, to help fill the void and assist the USTUR Director in a variety of tasks. Dr. Thomas will take a leave of absence from the Committee while he is consulting with USTUR. Dr. Mahlum will serve as Acting Chairman during Dr. Thomas's leave.

Substantial progress has been made in a number of areas. Two efforts that particularly stand out are the archiving of records on CDs and completion of the inventory of samples in the freezers. These accomplishments will ensure that information is preserved and that information and samples are more readily accessible.

A major topic of discussion was the ability to handle a plethora of samples should many donors die during a short time period. This is a very real concern as the Registrants age and the Committee urges the USTUR to find additional ways to free up more freezer space. The Committee recommended that the USTUR computer system be upgraded to use Microsoft Structured Query Language. Also, the recommendation was made to integrate USTUR efforts with the WSU Information Technology group.

2003 Meeting Proceedings

The meeting brought together: 1) the Directorship for the Transuranium and Uranium Registries; 2) the Program Manager from the United States Department of Energy Headquarters; 3) faculty from Washington State University; 4) active researchers from the Registries scientific staff in Richland and Pullman, WA; and 5) all members of the SAC.

Administration

The presentations began on September 19, 2003, by Dr. Filipy. He reviewed the recommendations that the Committee made in 2002 and described the USTUR response to each.

Recommendation 1: Complete inventory of stored tissues and materials of the National Radiobiological Archives (NRA).

Response: The inventory is partially complete. Three options are being considered. These include continuing the effort at $55K/year, reducing the effort to $30K, or disposing of materials. A large amount of material is available including some radioactive samples. In addition to the radioactive samples, Dr. Filipy estimated that there are about 400 cubic feet of microscope slides and tissue blocks and about 175 banker's boxes of paper. USTUR could store the material for $20K. It should be noted that material usage in 2003 has been zero.

Recommendation 2: Complete the NHRTR inventory.

Response: The inventory has been completed and includes the following information:

1. Lists of tissue types with Rad/Chem description;
2. Identification by USTUR case number;
3. Location indicated by freezer number and sample number for frozen samples;
4. Location (room number and box number) of tissue solutions; and
5. Slides and blocks identified by case number.

This method of inventory allows retrieval of administrative data, tissue analytical data, radiation exposure and bioassay data, cause of death and medical data (anecdotal). Medical data include radiation exposure, chemical exposure, smoking, employment, and family history.

Recommendation 3: Examine radiation exposure, medical, and work histories before autopsy to insure the most appropriate tissue sampling and analysis.
Response: This is currently done informally by a USTUR staff member. USTUR concurs with the need for a formal protocol.

Recommendation 4: Studies on interactions of plutonium and foreign substances such as asbestos should be considered.

Response: Such studies are very costly. Moreover, it is difficult to get a sufficient number of cases to assure validity of the data obtained. Therefore, such studies have been given low priority.

Recommendation 5: Only cases with the most useful occupational records should be accepted in order to maximize use of facilities and staff.

Response: The USTUR agrees with this recommendations and generally follows it. This has led to Category 3 (lowest exposures cases) being dropped and Category 2 registrants to be examined on individual merits. All Category 1 cases are being used.

Recommendation 6: Use National Institute of Standards and Technology (NIST) bone samples which are currently on hand. Purchase no additional NIST samples.

Response: The recommendation was followed.

Recommendation 7. Establish and maintain a backup set of recods at geographically dispersed locations. This was one of the most critical recommendations made by the Committee.

Response: This recommendation was implemented and is nearly completed. USTUR purchased a high-quality scanner, plus a high-capacity computer and software. Paper files were scanned, converted to PDF files, and burned onto CDs. Each case has its own CD so that they can be easily updated as new records are obtained.

Recommendation 8: Construct a list of quantifiable measures to address a DOE mandate for Performance Goals.

Response: Goals were formulated and linked to the President's Management Agenda. However, additional effort needs to be directed toward providing the DOE Program Manager with meaningful goals. Other recommendations directed toward increased visability and outreach are being addressed in several ways, including presentations and publications. Additions have been made to the WSU Cancer Prevention and Research Center.

The SAC is pleased to see the response of the USTUR to the Committee's recommendations. This is further evidence of the seriousness with which the USTUR views its charge. Further evidence of this is the openness of the informal discussions the USTUR had with the various SAC members. The breakout sessions, instituted last year, were used again this year and again proved to be an effective method of information exchange.

The Committee recommended that the computer system be upgraded to MS-Structured Query Language (MS-SQL). The Committee also felt that the USTUR would benefit by working closely with the University's Information Technology staff.

Several aspects of enhancing communication with the scientific and lay communities were discussed. The use of a descriptor slogan on stationery and the website was encouraged. A pamphlet to improve the visibility of NHRTR and NRA resources should be prepared and distributed. It was suggested that members of the Radiation Research Society might be receptive to use of these resources.

There is a collaborative project underway in which excretion data from four individuals exposed at each of four DOE nuclear laboratories will be sent to health protection personnel at the four laboratories to perform analysis using their own dosimetry models and computer software to estimate body and organ burdens using the excretion date. The object is to determine how the computed whole body and organ burdens will be compared to actual radiochemical analyses done on these 16 registrants by the USTUR. At this time, the USTUR is to select the excretion data to be sent to each of the four participating laboratories which are: Savannah River, Rockey Flats, Hanford, and Los Alamos. This project is considered of great importance and efforts should be made to complete it done as soon as possible.

Staffing

On the staffing side, there is good and bad news. The good news is that the radiochemistry group is back up to four full-time staff who are working hard to maximize sample output while maintaining good quality control (QC). The bad news is that the Associate Director, John Russell, retired and has not been replaced although a search committee has been formed and are actively seeking a replacement. Compounding the staffing problem was the announcement by the Director, Dr. Filipy, that he plans to retire within a year and a half. It is the feeling of the Committee that the USTUR staff has made progress in meeting the objectives of the Registries. However, with the anticipated changes, extra effort will be needed to insure that the new Director and Associate Director inherit a situation where they can easily mesh with the incumbent staff.

Radiochemistry

The radiochemistry group is back up to four full-time members. The newest members seem well-integrated into the overall function of the group. This has resulted in a noticeable increase in analytical data output. The entire staff should be congratulated on the smooth way in which the staff changes have been implemented.

Concern was expressed by several of the Committee members about how samples are processed and tracked through the chemistry laboratory. It was not clear to the Committee if the location of a given sample could be established along the pipeline. Part of this is cost. For example, the question has been raised several times about the cost per sample and the Committee doesn't feel that they have received an adequate answer.

It is essential for the USTUR, as well as the committee, to get a better understanding of the process by which samples are processed and tracked through the chemistry lab. It might emerge that it is a simple sample tracking issue, but it is also possible that it is more of an equipment or utilization of laboratory space issue. This is an area that Dr. Thomas may wish to devote some effort.

Of major concern to the SAC were a number of safety issues associated with the Pullman Laboratory. The poor condition of one of the fume hoods and duct work was especially noted. An issue driving this concern is the possible contamination of samples by materials dripping from the duct work. There is further concern about the corrosion of an electrical supply next to the most recent hood additions.

The USTUR needs to review all of their regular and preventive maintenance requirements, upgrades, and equipment replacement needs, and then categorize and prioritize them based on their impact on the program. The staff are being proactive but additional focus is warranted.

It was also noted that a muffle furnace needs to be replaced as well as a hotplate. While the hotplate can be purchased on operating funds, the muffle furnace is a capital equipment item. A plea for capital equipment needs to be made. It was suggested that a letter from the DOE Program Manager would be helpful. The small amount of freezer space available for sample storage is of considerable concern to the Committee. Twelve freezers are full and only seven freezers are partly full. If a number of registrants come to autopsy during 2004, there is not enough space available for all of the tissues. No conclusions have been made regarding solution of this problem. Finding a new home for some of the samples or purchasing more freezers are the two options given consideration.

National Radiobiology Archives

The NRA was established to maintain an inventory of animal tissues from various research programs carried out for decades under support of the USDOE and it's predecessor organizations. These tissues, primarily in the form of preserved solutions or of paraffin or methacrylate blocks, are available for research. A substantial effort has been made to inventory all of the tissues in the NRA. That task is nearly complete and the USTUR should be congratulated for their effort.

The NRA has been funded by the USDOE Office of Science. There are indications that a lack of interest may jeopardize that funding. The USTUR was instructed by SAC to approach the DOE Office of Science about continuing funding at a relatively low level so that the scientific community does not lose this valuable resource. Another approach to saving this material would be to work vigorously to find a new home for these samples and associated reference material. The same concern exists for the tissues for the Radium Dial Painters and NHRTR. If no new home is found, the Committee's recommendation is discard this material after six years.

Acknowledgments

The Committee wishes to extend their appreciation for the excellent job done by the USTUR staff. All were well prepared and all added immeasurably to the various topics of discussion. Special thanks go to Susan Ehrhart for arranging such good facilities for the meeting as well as for the production of a packet of information that was informative and easy to follow.

The Acting Chairman also wishes to thank Ron Brosemer for the extensive editorial help provided in this report.

2003 Advisory Committee Meeting Agenda

Friday, September 19th, 2003

0800-0830	Breakfast
0830-0900	Executive Session for Committee Members
0900-0915	Welcome and Introduction of New Members
0915-0945	Report from DOE
0945-1015	Review of 2002 Committee Recommendations
1015-1030	Break
1030-1130	Overview of Program Activities
1130-1200	Future Directions
1200-1300	Lunch
1300-1700	Topical Subjects for Discussion
	-Administration and Communication
	-Collaborative Projects
	-Data Management
	Break
	-NHRTR/NRA
	- Radiochemistry
	- Estimation of Systemic Deposition
1830-1930	No Host Social Hour
1930-2100	Dinner

Saturday, September 20th, 2003

0800-0830	Breakfast
0830-1030	Discussion Groups
	-Administrative
	-NHRTR/NRA
	-Radiochemistry
	Break
1100-1200	Discussion Summary
1200-1300	Lunch
1300-1500	Executive Session
1500-1515	Break
1515-1700	Debriefing

PUBLICATIONS/PRESENTATIONS

The following manuscripts and presentations were published, submitted for publication, presented or in progress for the period February 1, 2003 to January 31, 2004. Previous manuscripts and abstracts are available on the USTUR website at www.ustur.wsu.edu.

Abstracts of open peer-reviewed published manuscripts are included in Appendix A of this report.

Published

Ehrhart, S.M. and R.E. Filipy. United States Transuranium and Uranium Registries Annual Registrant Newsletter. Issue #10. USTUR-0192-03; 2003. College of Pharmacy, Washington State University, Richland, WA.

Ehrhart, S.M. and R.E. Filipy. United States Transuranium and Uranium Registries Annual Report: February 1, 2002 – January 31, 2003. USTUR-0191-03; 2003. College of Pharmacy, Washington State University, Richland, WA.

Filipy, R.E. and J.J. Russell. The United States Transuranium and Uranium Registries as a Resource for Actinide Dosimetry and Bioeffects. Rad. Prot. Dos. 105(1-4):185-187; 2003.

Filipy, R.E. and R.G. Thomas. The U.S. Transuranium and Uranium Registries: Resources for Radiation Dosimetry and Biological Effects (Brochure). USTUR-0193-03; 2003. College of Pharmacy, Washington State University, Richland, WA.

Kathren, RL, Lynch, TP, Traub, RJ. Six-year Follow-up of an Acute ^{241}Am Inhalation Uptake. Health Physics 84(5):576-581; 2003.

Russell, J.J., M.R. Sikov, and R.L. Kathren. Plutonium Content of Human Placental Tissues Twelve Years after Occupational Exposure. Rad. Prot. Dos. 104(3):231-236; 2003.

Russell, J.J. and R.L. Kathren. Uranium Deposition and Retention in a USTUR Whole Body Case. Health Physics 86:273-284; 2004.

Sikov, M.R. Potential Exposure of Pregnant Women to Multiple Hazards Resulting from the Explosion of a 'Dirty Bomb. Proceedings of the 36th Midyear Health Physics Topical Meeting, January 26-29, 2003, San Antonio, TX. 147-151; 2003.

Sikov, M.R., J.J. Russell. Implications of Radiological Exposure of Children and Pregnant Women. Proceedings of the 36th Midyear Health Physics Topical Meeting, January 26-29, 2003, San Antonio, TX. 140-146; 2003.

Submitted

Elliston, J.T., S.E. Glover and R.H. Filby. Comparison of Direct Kinetic Phosphorescence Analysis and Recovery Corrected Kinetic Phosphorescence Analysis for the Determination of Natural Uranium in Human Tissues. Submitted for publication in the Journal of Radioanalytical and Nuclear Chemistry.

Jacobson, B.S. Cataracts in Retired Actinide-Exposed Radiation Workers. Submitted to Health Phys.

Miller, S.C., Krahenbuhl, M., Lloyd, R.D., Bruenger, F., Bowman, B.M., Polig, E., Filipy, R.E., Nifatov, A.P., and Romanov, S.A. A Tale of Two "Nuclear Cities": Plutonium Contamination in an American and a Soviet Early Plutonium Worker. Anatoliy P. Nifatov,

Sergei A Romanov. Submitted to Science.

In Preparation

Elliston, J. T., Glover, S. E., Deckert, G., Stuit, D. B., Filby, R. H., and Filipy, R. E Bone Calcium Content as a Validation of the Ashing Protocol for Human Bone.

USTUR-0082-97

Plutonium Content of Human Fetal and Placental Tissue

John J. Russell, Ronald L. Kathren, Cheryl L. Love

*United States Transuranium and Uranium, Registries, Washington State University,
2710 University Drive, Richland, WA 99352-1671*

Although a number of studies have been made in animals (Sikov and Mahlum 1968; Weiss, Walburg and McDowell 1980; Morgan, Haines and Harrison 1991; Finkel 1947; Weiss and Walbur 1978), data on human placental transfer and accumulation of plutonium and other actinides is sparse. Overall, these results demonstrate that actinides do cross the placental barrier and enter the fetus and when compared to a reference female value of, ~1.17 mBq/kg for Pu, suggests a concentration factor of about three relative to the mother. However, in a more recent paper (Prosser et al. 1994) using fetal tissues from second trimester terminations, have found placenta and fetus sample concentrations of the same order of magnitude, viz. a few tens of uBq/kg, suggesting the absence of a concentration factor.

Published in the journal of Health Physics, Vol. 104(3):231-236.

USTUR-0150-99

Uranium Deposition and Retention in a Whole Body Donation to the USTUR

J. J. Russell and R. L. Kathren

Washington State University, Richland, WA

This report characterizes the U content in the tissues of a whole body donated to the USTUR along with implications for modeling and possible biological; effects of U intake. USTUR case 1002 was an adult male who expired at a nursing home from an acute cerebellar infarct at the age of 83. He worked as a power operator, utility operator, and metal operator for 28 years in a plant facility that processed and handled radioactive materials. During his employment, the highest single urinary U value measured was ~ 30 ug L^{-1} recorded in November 1949. The mean annual urinary U concentration calculated from the employee's bioassay records covering the first eleven years of monitoring averaged less than 2 mg/L. The ration of $^{234/238}$U in the lung tissue was about 1, same as that found in natural uranium. The highest concentration of U was found in the tracheobronchial lymph node. In addition, the U content in the various tissues of the body followed a slightly different rank order than that reported by various authors in the literature. The concentration of U in the kidney tissue was ~1.98 ng/g which is about 3 orders of magnitude less than the generally accepted threshold level for permanent kidney damage of 3 ug U/g. Autopsy results disclosed findings not uncommon in the aged. Based on the data on hand, this worker incurred his U body burden from chronic long-term low-level inhalation of

slightly soluble U in the workplace, and suffered no apparent ill effects from his intake.

Published in the journal of Health Physics, Vol. 86:273-284; 2003.

USTUR-0184-02

The United States Transuranium and Uranium Registries As Sources For Actinide Dosimetry and Bioeffects

R.E. Filipy and J.J. Russell

U.S. Transuranium and Uranium Registries, Washington State University Tri-Cities, 2710 University Drive, Richland, Washington 99352

The United States Transuranium and Uranium Registries (USTUR) has analyzed tissues collected at autopsies of over 300 former radiation workers from actinide processing sites throughout the US, in addition to collecting the medical and radiation exposure histories of those workers. These data are included in a large USTUR database and they are available to research scientists throughout the world, either as public records or through collaborative projects with the USTUR. The USTUR also operates the National Human Radiobiological Tissue Repository (NHRTR), in which portions of tissue samples collected at autopsy are kept. These samples, frozen at -70 C, may be used for molecular studies of the effects of radiation. Medical and radiation exposure histories of the tissue donors are available, as are the results of radiochemical analyses of adjacent portions of the samples. These materials are available to researchers who have collaborative agreements with the USTUR, which can be established by accessing USTUR staff members through the website, http://www.ustur.wsu.edu.

Published in the journal of Radiaiton Protection Dosimetry, Vol. 105(1-4): 185-188; 2003.

USTUR-0186-02A

Implications of Radiological Exposure of Children and Pregnant Women

*M.R. Sikov and J.J. Russell**

** U.S. Transuranium and Uranium Registries, Washington State University Tri-Cities, 2710 University Drive, Richland, Washington 99352*

Authorities agree that undue concern and apprehension would be elicited by information that a population might be or had been exposed to ionizing radiation of radioactive materials (NCRP 2001). Agencies are providing guidance and training to emergency responders and disseminating information about radiation effects to health care facilities. The potential for exposure of children and the embryo/fetus warrants special consideration because they tend to be more sensitive to the effects of radiation and many toxic agents than are adults while exposures can produce unique responses. Moreover, reports of accidental or deliberate events that harm children or pregnant women and their embryo/fetus elicit especially great emotional responses in our

society.

Publications, including papers in this volume, propose scenarios under which populations might be exposed to radiation or radioactive materials (NCRP 2001). Three of these scenarios seem most relevant for exposure of populations that include children or the embryo/fetus. There is a need to establish perspective because there might be an elevated psychosocial reaction when children and pregnant women are members of the exposed population. This paper will briefly review radiation effects that are relevant for these age groups, indicate the dose levels at which the effects might be observed, summarize special features associated with internal radionuclide exposure, and examine how these factors pertain and/or interact under the conditions pertaining to the pertinent exposure scenarios.

Published in the Proceedings of the 36th Midyear Topical Meeting of the Health Physics Society, pp.140-146; 2003.

USTUR-0188-03

Potential Exposure of Pregnant Women to Multiple Hazards Resulting from the Explosion of a 'Dirty Bomb'

*J.J. Russell and M.R. Sikov**

** U.S. Transuranium and Uranium Registries, Washington State University Tri-Cities, 2710 University Drive, Richland, Washington 99352*

Some scenarios suggest the possibility of exposure of populations to an explosive device or 'dirty bomb' containing radioactive material while attending a public event in an enclosed facility such as an indoor stadium or shopping wall by a terrorist group. A variety of hazardous substances might be included in the device or generated by interactions of the explosives - these could exacerbate the effects of the radiation or the internalized radionuclides. Moreover, such populations might include children and pregnant women, groups that have shown special sensitivities to induction of early and delayed radiation effects. The combination of radionuclides mixed with hazardous substances from a 'dirty bomb' explosion might result in potential additive or synergistic effect far greater than either alone and have an impact because of the sensitivity of particular populations.

Some carcinogens and co-carcinogens have been found to interact with radiation exposure and other substances have been shown to be especially toxic in the perinatal peria Another concern is that worker exposures could arise from simultaneous or sequential internal exposure to radioactive materials, infectious agents, carcinogens and or co-carcinogens while performing a variety of duties in the cleanup of mixed hazardous waste at such a disaster site and that these way act synergistically. There is an extensive literature documenting bioeffects of radiation exposures, infectious agents and a variety of chemicals. 'Mere is not yet a complete description of the impact of such complex mixtures of environmental insults interacting among themselves or on potentially sensitive populations but there is sufficient information to identify first level protective measures and or public responses.

Published in the Proceedings of the 36th Midyear Topical Meeting of the Health Physics Society, pp.147-151; 2003.

USTUR-0195-04

Six-Year Follow-Up Of An Acute ^{241}Am Inhalation Intake

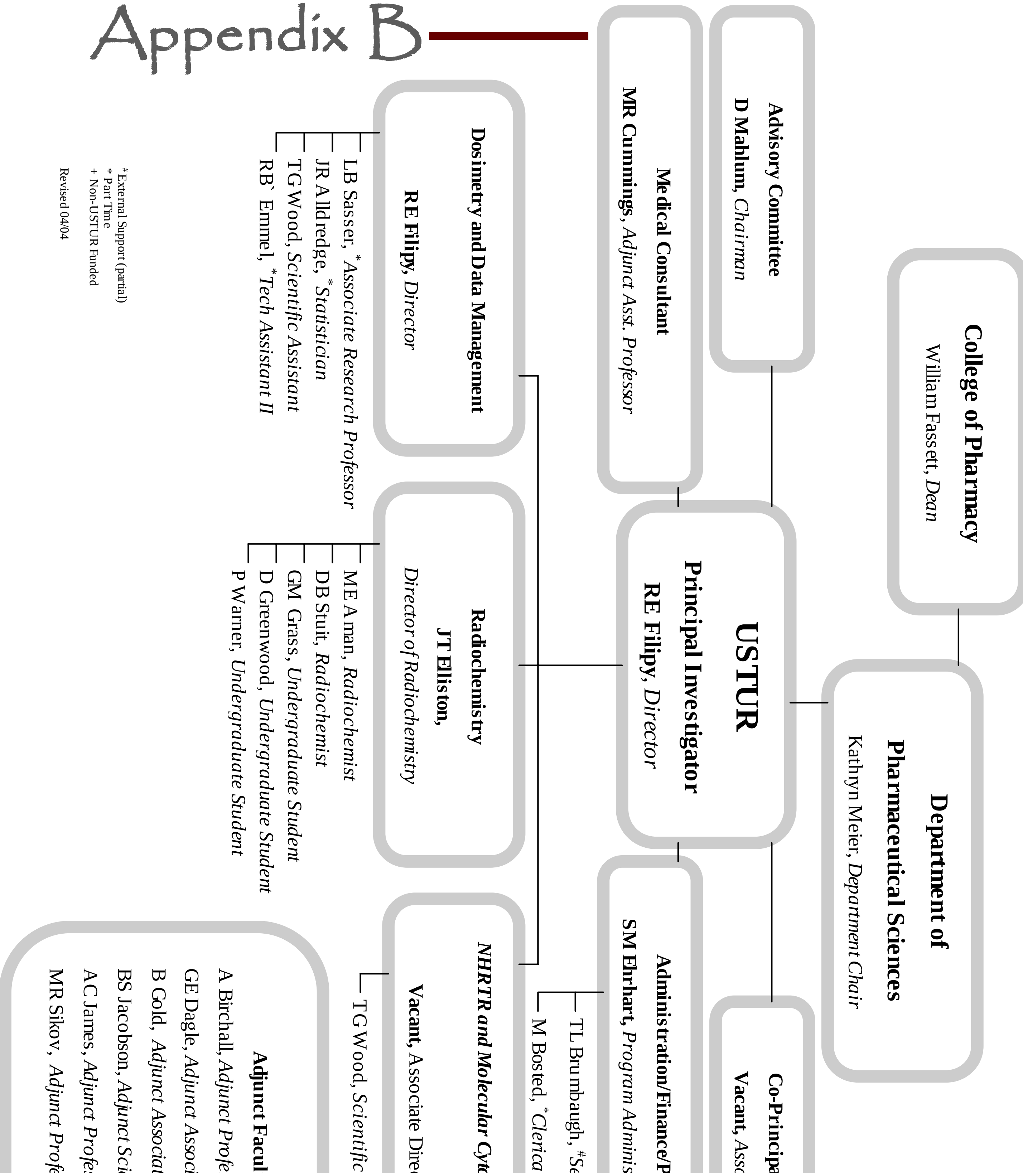
Ronald L. Kathren, Timothy P. Lynch+, and Richard J. Traub+*

**Department of Pharmaceutical Sciences, Washington State University, Richland, WA 99354; +Pacific Northwest National Laboratory, Richland, WA 99352*

A 38-y-old Caucasian male who suffered an acute accidental inhalation intake of 6.3 kBq of 241Am was monitored over 2,135 d using periodic in vivo measurements of the activity in the lungs, liver, and skeleton. Lung clearance was described by a two-compartment exponential model with half-times of 110 d and 10,000 d. The observed uptake of 241Am in the liver (72 Bq) and skeleton (170 Bq) was significantly greater than predicted by the ICRP models for liver (5 Bq) and skeleton (8 Bq). The half-time in the liver was approximately 850 d. Estimates of skeletal activity based on head, wrist, and knee counts generally agreed within 25% over the course of the monitoring period. The half-time in the skeleton was approximately 20,000 d.

Published in the journal of Health Physics, Vol. 84(5): 576-581; 2003.

Appendix B



College of Pharmacy
William Fasset, Dean
Department of Pharmaceutical Sciences
Kathryn Meier, Department Chair
Advisory Committee
D Mahlum, Chairman
Medical Consultant
MR Cummings, Adjunct Asst. Professor
USTUR
Principal Investigator
RE Filipy, Director
Dosimetry and Data Management
RE Filipy, Director
LB Sasser, *Associate Research Professor
JR Alldredge, *Statistician
TG Wood, Scientific Assistant
RB Emmel, *Tech Assistant II
Radiochemistry
JT Elliston,
Director of Radiochemistry
ME Aman, Radiochemist
DB Stuit, Radiochemist
GM Grass, Undergraduate Student
D Greenwood, Undergraduate Student
P Warner, Undergraduate Student
Administration/Finance/
SM Ehrhart, Program
TL Brumbaugh,
M Bosted,
Co-
Vacant,
NHRTR and Molecular
Vacant, Associate
TG Wood,
Adjunct
A Birchall, Adjunct
GE Dagle, Adjunct
B Gold, Adjunct
BS Jacobson, Adjunct
AC James, Adjunct
MR Sikov, Adjunct
#External Support (partial)
* Part Time
+ Non-USTUR Funded
Revised 04/04