USTUR-0570-20

# United States Transuranium and Uranium Registries

# Annual Report

April 1, 2019 – March 31, 2020

College of
Pharmacy and Pharmaceutical Sciences
WASHINGTON STATE UNIVERSITY

USTUR-0570-20

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# Annual Report

April 1, 2019 – March 31, 2020

Compiled and Edited

Maia Avtandilashvili and Sergei Y. Tolmachev

December 2020

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# USTUR

## A unique resource since 1968


**Learning from Plutonium and Uranium Workers**
United States Transuranium and Uranium Registries
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# Table of Contents

# Faculty and Staff

## Faculty

| | |
|---|---|
| Sergei Y. Tolmachev | Director, Research Professor |
| Maia Avtandilashvili | Assistant Research Professor |
| Stacey L. McComish | Associate in Research |
| Martin Šefl | Postdoctoral Research Associate |
| George Tabatadze | Assistant Research Professor |

## Emeritus and Adjunct Faculty

| | |
|---|---|
| Ronald L. Kathren | Professor, Emeritus |
| Anthony E. Riddell | Adjunct Faculty |
| Daniel J. Strom | Adjunct Faculty |

## Classified Staff

| | |
|---|---|
| Margo D. Bedell | Program Specialist II |
| Elizabeth M. Thomas | Laboratory Technician II |

## Part-time Employees

| | |
|---|---|
| Mark Gorelco | Professional Worker I |
| Warnick Kernan | Technical Assistant I |
| Florencio T. Martinez | Medical Technologist |
| Yulia Medvedchuk | Technical Assistant I |
| Alexander Tabatadze | Professional Worker I |

## Consultants

| | |
|---|---|
| Eric Kiesel | Forensic Pathologist |
| Minh Pham | IT Support |
| Mariya Tolmachova | Technical Editor |

## Student Employees

| | |
|---|---|
| Marianna Martinez | Technical Assistant I |
| Kenzie McNeel | Technical Assistant I |

# Advisory Committee

## Committee Chair

| | |
|---|---|
| Roger O. McClellan | Toxicology |

## Committee Members

| | |
|---|---|
| Janet Benson | Toxicology (*incoming*) |
| Luiz Bertelli | Health Physics |
| Timothy J. Ledbetter | Ethics |
| Thomas L. Rucker | Radiochemistry |
| Heather J. Hoffman | Epidemiology & Biostatistics |
| Arthur W. Stange | Occupational Health |

# Contact Information

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# Executive Summary

## Sergei Y. Tolmachev, *USTUR Director*

This report summarizes organization, activities, and scientific accomplishments for the United States Transuranium and Uranium Registries (USTUR) and the associated National Human Radiobiology Tissue Repository (NHRTR) for the period of April 1, 2019 – March 31, 2020. This is the third fiscal year (FY) of the USTUR's 5-year grant proposal (April 1, 2017 – March 31, 2022).

### WSU COVID-19 policy

On March 19, 2020, due to the COVID-19 pandemic, Washington State University (WSU) required employees to work remotely from home.

### National Council on Radiation Protection and Measurements

Dr. Tolmachev has been elected as a Council Member (2020–2026) for the National Council on Radiation Protection and Measurements. Dr. Tolmachev is the first College of Pharmacy and Pharmaceutical Sciences (CPPS), and the second WSU, representative who was ever elected to the Council.

### DOE Grant Renewal

The FY2021 grant renewal proposal to manage and operate the USTUR and the associated NHRTR, during April 1, 2020 – March 31, 2021 was submitted to the Department of Energy (DOE) Office of Health and Safety (AU-10). The approved FY2021 budget amounted to $1,200,000.

### Scientific Advisory Committee

The annual 2019 meeting of the USTUR's Scientific Advisory Committee (SAC) was held April 26–27, 2019, in Richland, WA. Dr. Janet Benson (Lovelace Biomedical Research Institute) was appointed as a new Scientific Advisory Committee (SAC) member. She will serve as a Toxicology Representative. Effective April 1, 2020, Dr. Roger McClellan will finish his nine-year service to the USTUR Scientific Advisory Committee.

### ACJ/USTUR Scholarship

The first Anthony C James/USTUR scholarship was awarded to Mikayla Kinsey, a WSU Tri Cities undergraduate student.

### New Hires

Anthony E. Riddell (Public Health England) was appointed by WSU CPPS as an adjunct faculty member with the USTUR. Dr. Martin Šefl joined the USTUR team as a postdoctoral research associate. His research will be focused on evaluation of uncertainties in radiation dose assessment for internally deposited radionuclides in support of radiation epidemiology.

### Organization and Personnel

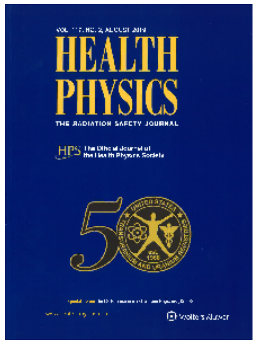
In FY2020, 7.6 full-time equivalent (FTE) positions, including one postdoctoral research associate at 0.7 FTE, one adjunct faculty at 0.2 FTE, and total of 1.0 FTE for temporary professional workers, were supported by the available funding. The organizational structure of the USTUR Research Center during FY2020 is provided in Appendix A.

### Registrant Donations

One whole-body and two partial-body donations were received by the USTUR in FY2020. As of March

31, 2020, the Registries had received 47 whole- and 312 partial-body donations.

## Special Issue of Health Physics Journal




The August, 2019 issue of *Health Physics* journal highlighting 50 years of research at the USTUR was published online. This issue includes an opening commentary by Patricia Worthington, Director of the U.S. DOE Office of Health and Safety (AU-10), a review of the USTUR history by Ronald L. Kathren and Sergei Y. Tolmachev, nine scientific manuscripts by USTUR faculty and national and international collaborators, as well as a forum article. For a complete list of papers, see *Publicaitons and Presentations* section.

## Scholar Activities

In total, USTUR faculty authored nine and co-authored six scientific papers. Four invited, five podium, and one poster presentations at national and international conferences were given by USTUR faculty and collaborators.

## NHRTR Inventory

As of March 31, 2020, 9,755 tissue samples from 46 whole-body and 113 partial-body donations were inventoried. These Registrants passed away between 1982 and 2018.

## Radiochemistry Operation

Four hundred fifty-five (455) tissue samples from four whole-body and eight partial-body donations were analyzed for plutonium and americium isotopes using $\alpha$-spectrometry. Radiochemical analyses of one whole-body and five partial-body cases were completed.

## Health Physics Database

Standardization of exposure records and bioassay data for 27 partial-body cases, including one living and 26 deceased Registrants, was completed. As of March 31, 2020, the database holds 140,029 data records from 242 deceased donors (47 whole-body and 195 partial-body), 27 living Registrants (five whole-body and 22 partial-body), and two special study cases.

## Institutional Review Board

The annual Institutional Review Board (IRB) review was completed and approved by the Central DOE IRB and is valid until September 11, 2020.

## Administrative

The annual USTUR Newsletter (USTUR-0535-19) was sent to the Registrants and/or their next-of-kin.

# Financial and Administrative Report

## Margo D. Bedell, *Program Specialist II*

On March 31, 2020, the USTUR completed the third grant year of the USTUR's 5-year grant proposal (April 1, 2017 – March 31, 2022). Fiscal year (FY) 2020 (April 1, 2019 – March 31, 2020) funding sources were:

### Federal Resources

#### Grant

U.S. Department of Energy Office of Health and Safety, Office of Domestic and International Health Studies (DOE/AU-13):

*Manage and Operate the United States Transuranium and Uranium Registries*

DE-HS0000073

Amount awarded: $1,200,000
Period: April 1, 2019 – March 31, 2020.

#### Operating budget

With a $2,354 positive carry-over from FY2019, the USTUR net operating budget for FY2020 was $1,202,354. Total operating expenses for FY2020 were $1,202,061 (Fig. 1) resulting in a positive balance of $293.

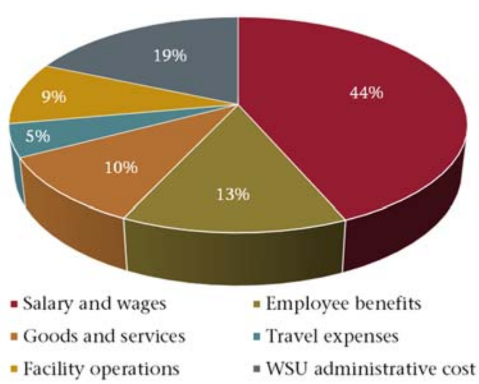



Fig.1. FY2020 operating budget breakdown.

### 50th Anniversary Funding

U.S. Department of Energy Office of Health and Safety (DOE/AU-10):

*USTUR: Five Decade Follow-up of Plutonium and Uranium Workers*

Amount awarded: $30,000
Period: October 1, 2016 – September 30, 2018 (one-year no-cost extension)
Available in FY2020: $9,492
FY2020 expenses: $9,492.

### Grant Administration

#### FY2021 Grant Renewal

On January 14, 2020, a grant renewal proposal to manage and operate the United States Transuranium and Uranium Registries and the associated National Human Radiobiology Tissue Repository (NHRTR) during FY2021 (April 1, 2020 – March 31, 2021) was submitted to the DOE/AU-13 through the WSU's Office of Research Support and Operations (ORSO). The requested FY2021 budget was $1,200,000.

### Reporting

The FY2019 annual report (USTUR-0501-19) for the DE-HS0000073 grant was published and electronically distributed. Four quarterly reports were submitted to the funding agency and the university.

# New Faces

## Sergei Y. Tolmachev, *Research Professor*

### Adjunct Faculty

On July 18, 2019, Anthony E. Riddell was appointed by the College of Pharmacy and Pharmaceutical Sciences as an adjunct faculty member with the USTUR. This is a three-year appointment. Mr. Riddell leads the Internal Dosimetry Group at Public Health England (PHE) and has more than thirty years of experience in internal dosimetry and also within related areas of research, such as radiation epidemiology and radiobiology.

Having shared research interests in areas such as radionuclide metabolism, dosimetry, and potential exposure risks, the USTUR has collaborated with Mr. Riddell and PHE over many years. In 2018, Mr. Riddell facilitated a Memorandum of Understanding (MOU) between the USTUR and PHE's Centre for Radiation Chemical and Environmental Hazards (CRCE) to help further this mutually beneficial relationship. Among other things, this MOU allowed PHE to share its newly developed internal dosimetry software, Taurus®, with the USTUR for research purposes. The base model of Taurus® is designed for operational dose assessment, but the USTUR will make use of an advanced version of the software to study the movement of actinides, such as plutonium, through the human body, and to calculate doses from intakes of those elements. The USTUR looks forward to continued collaboration with Mr. Riddell and PHE-CRCE.

### Postdoctoral Research Associate

On August 1, 2019, Dr. Martin Šefl joined the USTUR team as a postdoctoral research associate. This appointment is valid through March 31, 2022. Dr. Šefl earned his degree in Radiologic Physics at Czech Technical University in Prague (Czech Republic). His research at the USTUR will be focused on evaluation of uncertainties in radiation dose assessment for internally deposited radionuclides in support of radiation epidemiology. He will work on several biokinetic modeling projects in close collaboration with health physicists, biostatisticians, radiochemists, and radiation epidemiologists.

### ACJ/USTUR Scholar

The first Anthony C James/USTUR scholarship of $1,000 was awarded by WSU Foundation to Mikayla Kinsey, a WSU Tri Cities undergraduate student. She is majoring in biology with an interest in medicine.

# IRB Changes

## Stacey L. McComish, *Associate in Research*

In August 2019, the USTUR submitted both a continuing review (DOE000443) and a modification (DOE000444) to the Central Department of Energy Institutional Review Board (CDOEIRB). Both were approved in September 2019, and the USTUR's IRB approval is valid through September 11, 2020.

### Modified Collaboration Protocol

USTUR policy P106 "Scientific Collaboration and Data Access" was revised to better reflect the IRB protocol that was approved in 2017, and to include additional measures to protect Registrant data. Specific additions to P106 include: (i) collaborators who will receive biological samples must provide assurance that they are authorized to handle human samples, (ii) collaborator computers or servers that have Registrant information must have a firewall and be password-protected, (iii) Registrant data may not be stored on web-based backup systems, e.g., the cloud, (iv) any data containing potentially identifiable information must be destroyed or returned to the USTUR within one year of publication, or five years of receipt, whichever comes first, (v) tissue materials not destroyed during analysis must be returned to the USTUR within one year of analysis or three years of receipt, whichever comes first, and (vi) one-year extensions can be requested using the new F106a form "One-year extension: data and biological specimens".

### Modified Protocol for Record Requests

The USTUR receives two types of records requests: (i) to know if an individual is/was a USTUR Registrant, and (ii) to obtain a copy of a Registrant's file, or a part of a file. Registrant files typically contain internally-generated data (e.g. correspondence, permission forms, and radiochemistry results); autopsy reports; and copies of data obtained from Registrant worksites (e.g. medical, exposure, and industrial hygiene records).

In order to standardize our response to data requests, two new forms for routine data requests were created. Form F103a is used to request information about a living Registrant, and F103b to request information about a deceased Registrant. The Director must approve the release of information, and sign the request form.

Forms P106, F103a, and F103b are available as Appendix B.

### Other Modifications

In 2018, the IRB board recommended that the USTUR reexamine how to address "an aging population and the return of the Personal/Medical History form" due to concerns about the accuracy of information provided. In response to this concern, the Personal/Medical History questionnaire will no longer be sent in 5-year intervals to existing Registrants. Rather, it will only be sent with informed consent paperwork.

Martin Šefl was added to the IRB after signing DOE's HRP-422 checklist to verify that he had completed the DOE document review and Collaborative Institutional Training Initiative (CITI) training.

# Registrant Statistics

## Stacey L. McComish, *Associate in Research*

As of March 31, 2020, the Registries had 880 Registrants in all categories (Table 1). Of that number, 31 were living and 367 were deceased. The 31 living Registrants included five individuals who were registered for eventual whole-body donation, 22 for partial-body donation, and four for 'Special Studies,' i.e., a bioassay study with no permission for autopsy. There were also 482 Registrants in an inactive category, which includes those lost to follow-up and those whose voluntary agreements were not renewed.

Table 1. Registrant statistics as of March 31, 2020

| | |
|---|---|
| Total living and deceased Registrants | 398 |
| Living Registrants | 31 |
| Potential partial-body donors | 22 |
| Potential whole-body donors | 5 |
| Special studies | 4 |
| Deceased Registrants | 367 |
| Partial-body donations | 312 |
| Whole-body donations | 47 |
| Special studies | 8 |
| Total number of Registrants | 880 |

### Registrant Renewals

It was previously the USTUR's policy to offer all living Registrants an opportunity to renew their voluntary registrations every five years. However, under the 2018 approval from the Central DOE Institutional Review Board, Registrants are no longer required to renew their participation every five years. Instead, they are asked to sign the informed consent and other forms at the point of initial consent, and no additional consent is required. Registrants who have previously signed five-year agreements are sent one-time renewal paperwork shortly before their autopsy authorizations expire. The forms in this one-time renewal packet will remain valid unless terminated by action of the Registrant or the Registries.

During this fiscal year, five Registrants needed to complete a one-time renewal packet. Of these, four renewed and one withdrew from the program.

### Annual Newsletter

The USTUR distributes a newsletter to Registrants and their next-of-kin on a yearly basis. The 2019 letter was mailed in December (Appendix C). It featured a two-page summary of the USTUR's special issue of Health Physics, which included brief summaries of Patricia Worthington's introduction to the special issue, and ten scientific papers. Additionally, Dr. Tolmachev discussed collaboration with the Million Person Study, and Martin Šefl was welcomed to the USTUR team as a postdoctoral researcher.

### Registrant Deaths

During this fiscal year, the USTUR received one whole- and two partial-body donations. Each donor worked with actinides for approximately 40 years.

The whole-body donor was involved in three possible exposure incidents, which included personal contamination and elevated concentrations of plutonium in the air. However, no confirmed intake was recorded.

One partial-body donor was involved in two plutonium inhalation incidents, and received several minor wounds. Worksite personnel estimated that he had a systemic deposition of approximately 4 nCi.

The other partial-body donor was involved in three possible plutonium contamination incidents, and was extensively monitored for uranium. However, this individual had no confirmed intakes of plutonium, and worksite personnel estimated his systemic deposition to be less than 2 nCi of initially soluble $^{239}Pu$.

## Registrant Status

The average age of living whole- and partial-body Registrants was 81.3±10.0 years and 82.7±12.4 years, respectively. The average age at death for the USTUR's 359 deceased whole- and partial-body Registrants was 69.9±13.3 years.

The number of donations by calendar year, as well as the average age of donors by year, is shown in Figure 2.

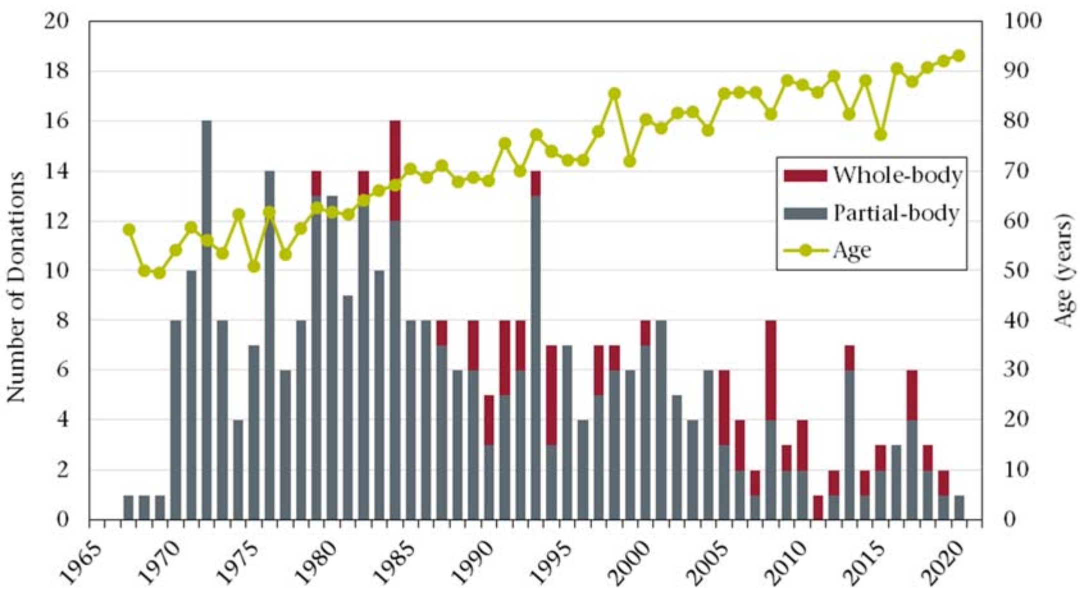



Fig. 2. Number of whole- and partial-body donations by calendar year and average age.

# Health Physics Database

## Maia Avtandilashvili, *Assistant Research Professor*

The USTUR Internal Health Physics Database is designed to standardize extensive sets of health physics data from USTUR donors and provide access to detailed incident, contamination, *in vitro* and *in vivo* bioassay, air monitoring, work site assessment, external dosimetry, and treatment information for scientists who are interested in studying the distribution and dosimetry of actinides in the human body.

The USTUR currently retains documents containing health physics and bioassay records for 47 whole-body and 312 partial-body tissue donors, as well as 27 living potential donors and 12 special study cases (four living and eight deceased).

As of March 31, 2020, standardization of health physics records and bioassay data was completed for 27 living potential donors (five whole-body and 22 partial-body), and 242 deceased donors (47 whole-body and 195 partial-body). In total, 139,525 health physics records from deceased and living Registrants have been entered into the database. In addition, data entry was completed for two special study cases with a total of 504 records. Figure 3 shows FY2020 progress toward population of the database.

Figure 4 shows the FY2008 – FY2020 progress and the overall status of the health physics database as of March 31, 2020.

The summary statistics of all completed cases, categorized based on the type of intake, primary radionuclide of exposure, and material type (solubility class), are presented in Figure 5.

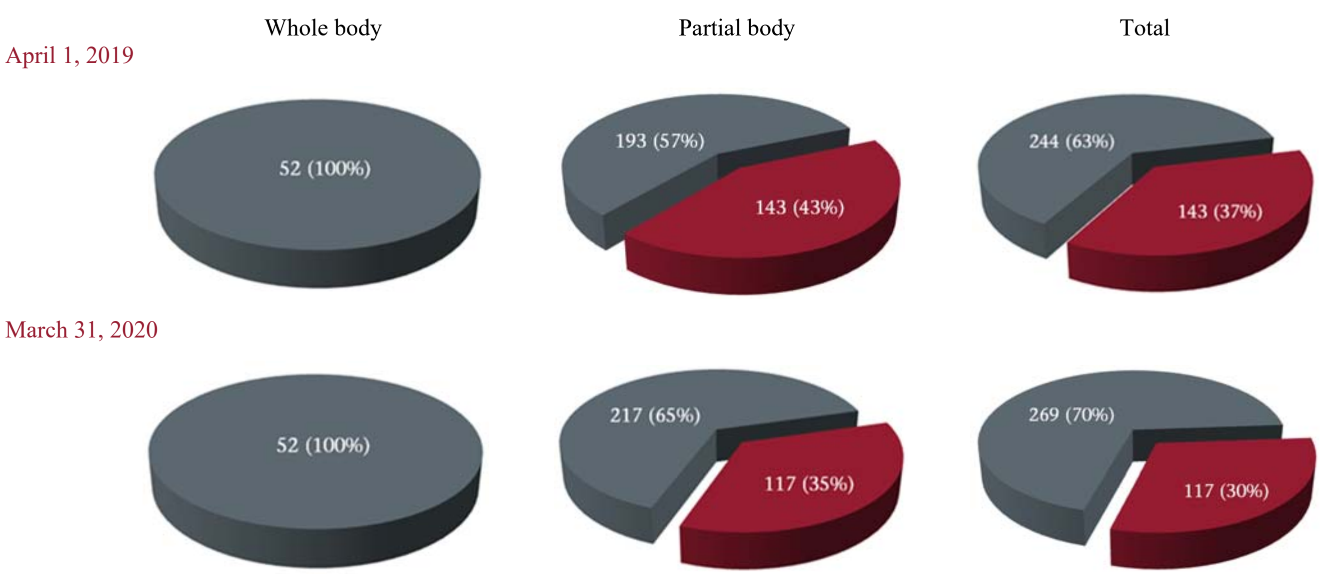



Fig. 3. FY2020 health physics database progress: ■ complete cases; ■ incomplete cases.

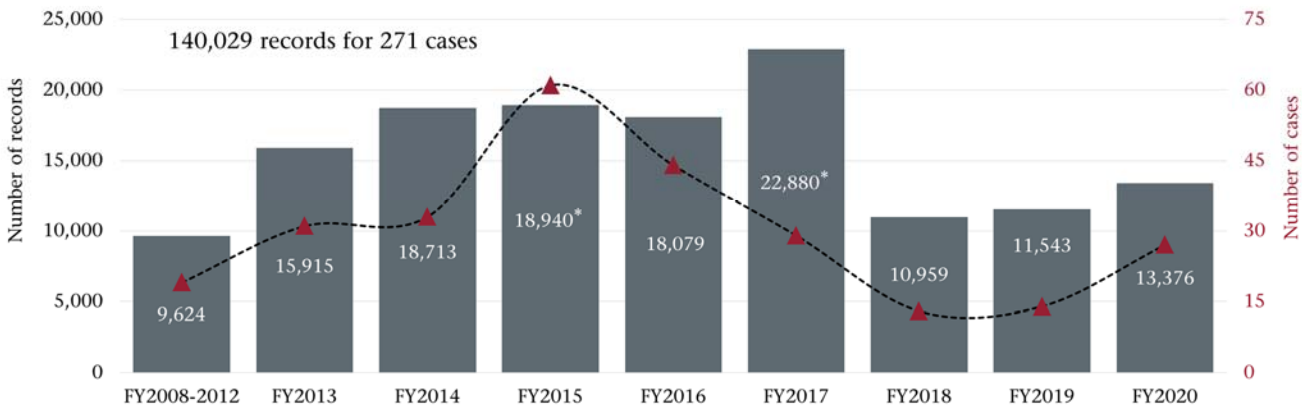



Fig. 4. FY2020 status of the USTUR health physics database. Includes two special study cases completed in FY2015 and FY2017 (*)

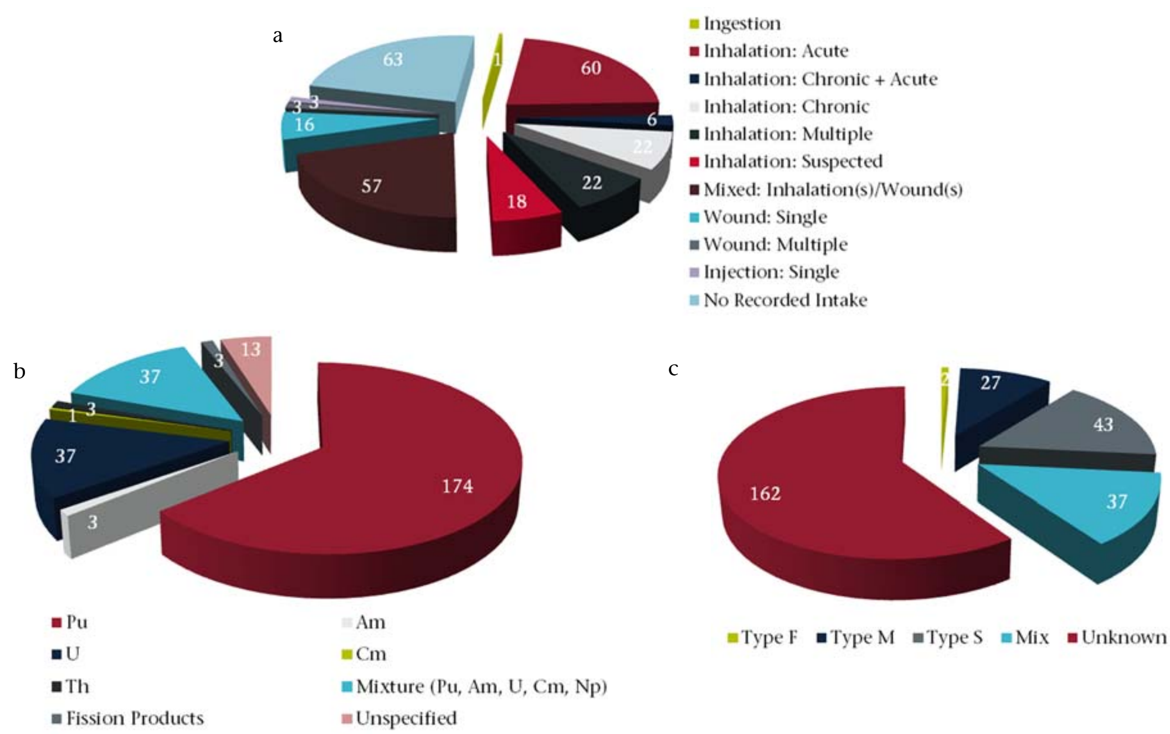



Fig. 5. Summary statistics of the health physics database: completed Registrant cases by intake (a); primary radionuclide (b); material type (c).

# National Human Radiobiology Tissue Repository

Stacey L. McComish, *Associate in Research*

The National Human Radiobiology Tissue Repository (NHRTR) houses several collections of tissues and related materials from individuals with intakes of actinide elements and radium. These collections include tissues from USTUR donations, acid dissolved tissues from the Los Alamos Scientific Laboratory's (LASL) population studies, and tissues from the terminated radium worker and plutonium injection studies, which were received from Argonne National Laboratory (ANL).

Three primary activities, related to USTUR tissue donations, were carried out at the NHRTR: autopsies, dissection of donated tissues, and radiochemical analysis of tissues. Each of these activities generated specific samples, which were either stored for future use, or consumed during the radiochemical process. Table 2 summarizes these laboratory activities and the fate of the resulting USTUR samples.

## THEMIS Inventory Status

The USTUR uses The Management Inventory System (THEMIS) to electronically inventory NHRTR samples. The USTUR's ultimate aim is to inventory all samples housed at the NHRTR facility. Most samples originating from USTUR tissue donations have already been inventoried. Projects to inventory USTUR tissues, acid solutions, and histology slides were completed during FY2015 – FY2016. These projects are in a maintenance phase, where samples are inventoried as they are received and/or generated. Projects to inventory USTUR planchets, LASL acid solutions, and ANL tissues have been initiated; however, due to limited resources, laboratory personnel focused their efforts toward completing the planchet inventory during FY2020.

Table 2. USTUR samples generated at the NHRTR facility

| Laboratory operation | NHRTR samples generated | THEMIS inventory | Storage |
|---|---|---|---|
| Autopsy | Paraffin-embedded tissue blocks | no | yes |
| | Histopathology slides | yes | yes |
| Dissection | Frozen and/or formalin-fixed tissues | yes | yes |
| Radiochemical analysis of tissues | | | |
| Drying/Ashing | Ashed tissues | no | no† |
| Digestion/Dissolution | Acid solutions | yes | yes |
| Actinide separation | Acid solution aliquots | yes | no† |
| Alpha spectrometry | α-counting sources (planchets) | yes | yes |

† Sample is consumed during radiochemical analysis.

Table 3. Inventory status of NHRTR materials

| NHRTR samples | Collection | | |
|---|---|---|---|
| | USTUR | ANL | LASL |
| Frozen and/or formalin-fixed tissues | Maintenance | Deferred | — |
| Histology slides | Maintenance | Deferred | — |
| Acid solutions | Maintenance | — | Deferred |
| Planchets | Active | — | — |

Each inventory project has been assigned a status. *Maintenance* indicates that all historical samples have been inventoried, and new samples will be entered into THEMIS as they are produced or received. *Active* indicates that the inventory of historical samples is ongoing. *Deferred* indicates that laboratory personnel commenced inventorying historical samples, but the project was placed 'on hold' until high-priority projects are completed and/or additional student workers are available. Table 3 summarizes the status of inventory projects.

### Tissue Dissection

During FY2020, Florencio Martinez completed the dissection of one whole-body donation and one partial-body donation. Warnick Kernan and Kenzie McNeel assisted Mr. Martinez and carried out vacuum packaging of tissue samples.

### THEMIS Inventory

As of March 31, 2020, 24,559 parent samples and 12,232 subsamples had been inventoried using the THEMIS database (Table 4). Parent samples best represent the number of unique tissues available at the USTUR; therefore, the following discussions about tissues and acid solutions exclude subsamples.

Table 4. Inventoried samples as of March 31, 2020

| Tissue type | Samples | | |
|---|---|---|---|
| | Parent | Sub- | Total |
| USTUR donations | | | |
| Soft tissue samples | 5,008 | 425 | 5,433 |
| Bone samples | 4,747 | 83 | 4,830 |
| Histology slides | 1,398 | 2,116 | 3,514 |
| Acid solutions | 6,805 | 1,193 | 7,998 |
| Planchets | 0 | 7,667 | 7,667 |
| Paraffin blocks | 0 | 45 | 45 |
| ANL tissues & slides | 1,450 | 434 | 1,884 |
| LASL solutions | 4,447 | 92 | 4,538 |
| Blank and QC acids | 431 | 50 | 481 |
| Miscellaneous | 273 | 127 | 400 |
| Total | 24,559 | 12,232 | 36,791 |

#### USTUR Tissue Samples

Information on 242 parent samples from recent tissue donations was entered into THEMIS during FY2019. This placed the total number of inventoried USTUR tissues at 9,755 samples from 46 whole-body cases, 113 partial-body cases, and one living case (surgical specimens). The six most common types of USTUR tissues are skeletal, muscle/skin/fat, alimentary, circulatory, nervous, and respiratory/tracheobronchial. Tissues are typically stored in a frozen state. Skeletal samples are most common due to the large number of bones in the human body, as well as the dissection protocol. On average, whole-body cases had 152±96 tissue samples per case and partial-body cases had 24±20 tissue samples per case.

Project status – *maintenance*.

### USTUR Acid Solutions

In addition to frozen and formalin-fixed tissues, the NHRTR holds thousands of acid-digested tissue samples (acid solutions) that were previously analyzed for actinides. All historical acid samples have been inventoried; however, the number of acid solutions steadily increased, because each time a tissue was dissolved in the radiochemistry lab, the corresponding sample in the THEMIS was changed from a tissue to an acid solution. As of March 31, 2020, the THEMIS inventory contained 6,805 acid-dissolved tissues, as well as 431 acid solutions from blanks and quality control samples.

Project status – *maintenance*.

### USTUR Histology Slides

The USTUR holds thousands of microscope slides that were provided by pathologists following USTUR Registrant autopsies. Inventory of new microscope slides is completed as they are received. During FY2019, no new slides were inventoried.

Project status – *maintenance*.

### USTUR Planchets

The NHRTR holds several thousand α-spectrometric counting sources (planchets), accumulated by the Registries. A planchet is the final product of an actinide tissue analysis. It is a stainless-steel disk (diameter = 5/8") onto which α-radioactivity was electrodeposited following radiochemical actinide separation. An individual planchet has electroplated activity from one of the following actinide elements: plutonium (Pu), americium (Am), uranium (U), or thorium (Th). Planchets are placed in coin holders for storage. Each coin holder can hold up to eight planchets.

During FY2020, information on 2,408 planchets was entered into THEMIS, bringing the total number of inventoried planchets to 7,667. Each sample was also linked to the planchets database using the sample's unique barcode. The planchets database works alongside THEMIS to store detailed information about individual planchets.

Project status – *active*.

### Los Alamos Scientific Laboratory Acid Solutions

The NHRTR houses a collections of acid solutions from population studies carried out by LASL. No progress has been made toward inventorying the LASL collection due to limited personnel. Thus, the LASL acid solution inventory's project status was changed from *active* to *deferred*.

Project status – *deferred*.

### Argonne National Laboratory Samples

The NHRTR houses an existing collection of tissue materials obtained from the terminated radium worker study at ANL and the historical plutonium injection studies. The ANL collection consists of frozen and dried tissues, histological slides, and plastic and paraffin-embedded tissues. This collection was acquired by the NHRTR/USTUR in 1992.

No progress has been made toward inventorying the ANL collection due to limited personnel.

Project status – *deferred*.

## Inventory Progress

Figure 6 shows the cumulative number of inventoried samples at the end of each calendar year from 2010 to 2019. It can be seen that initial efforts focused on inventorying USTUR tissues and acids. More recently, laboratory personnel focused on LASL acids and USTUR planchets inventories.

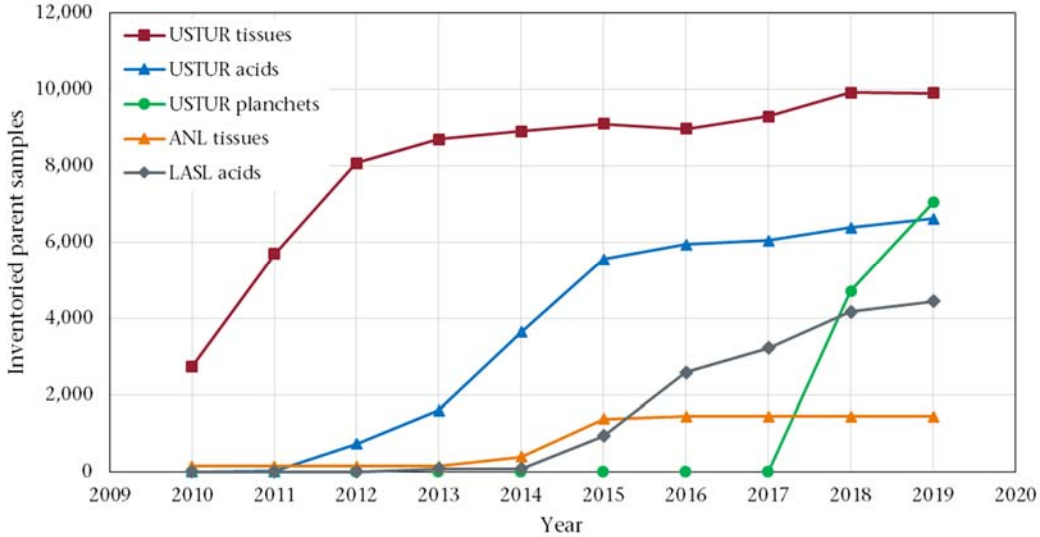



Fig. 6. Cumulative number of inventoried NHRTR samples at the end of each calendar year.

# Radiochemistry Operations

## George Tabatadze, *Assistant Research Professor*

This section describes specific activities and achievements of the Radiochemistry Group during FY2020.

### Personnel

As of April 1, 2020, operation of the radiochemistry laboratory was supervised by Dr. Tolmachev (Principal Radiochemist) with two full-time personnel – Dr. George Tabatadze (Assistant Research Professor) and Ms. Elizabeth Thomas (Laboratory Technician II).

### FY2020 Tissue Sample Analysis

Tissue sample analysis is a multi-step process. During the analysis, a tissue undergoes five different analytical steps: (i) drying and ashing, (ii) digestion and dissolution, (iii) radiochemical actinide separation, (iv) preparation of an α-counting source (planchet), and (v) measurement of individual actinides – plutonium ($^{238}$Pu and $^{239+240}$Pu), americium ($^{241}$Am), uranium ($^{234}$U, $^{235}$U, and $^{238}$U), and/or thorium ($^{232}$Th).

During FY2020, analyses of 455 tissue samples for $^{238}$Pu, $^{239+240}$Pu, and $^{241}$Am, including 152 bone and 303 soft tissues from 11 donations and one biopsy sample from a living Registrant (Case 0820) were completed. This includes two miscellaneous tissues from two partial-body donations, cases 0743 and 0787. Additionally, 89 tissue samples, including 53 bones and 36 soft tissues from two donations, were submitted for analysis.

#### Whole-body Donations

In FY2020, analyses of 226 tissue samples from four whole-body donations, received between 2008 and 2018, were completed. Analyzed cases included 0303 (87 samples), 0471 (35), 0634 (44), and 0674 (60).

Eighty-eight tissue samples, including 53 bone and 35 soft tissues from one whole-body donation, Case 0846, were submitted for analysis. In addition, a cerebral lobe sample from Case 0740 was submitted for analysis.

#### Partial-body Donations

In FY2020, analyses of 226 tissue samples from five partial-body donations, received between 2017 and 2018, were completed. Analyzed cases included 0287 (51), 0317 (40), 0332 (47), 0641 (51), and 0765 (37). A total of 57 bone samples and 169 soft tissues were analyzed for $^{238}$Pu, $^{239+240}$Pu, and $^{241}$Am. In addition, brain samples from two partial-body donations, cases 0743 and 0787, were analyzed.

## FY2015 – FY2020 Tissue Sample Analysis

Figure 7 shows FY2015 – FY2020 tissue analysis progress.

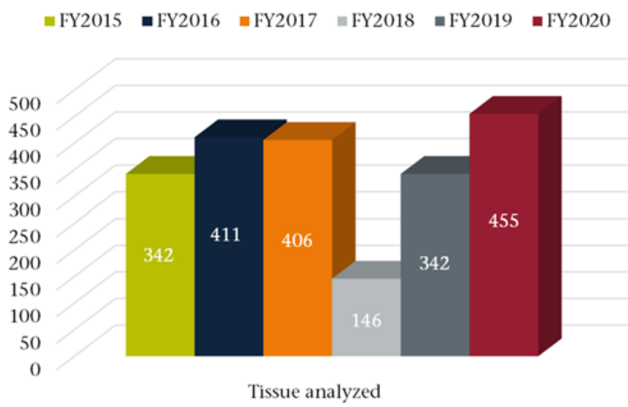



Fig. 7. USTUR tissue analysis progress in FY2015 – FY2020.

## FY2020 Radiochemistry Case Analysis

As of April 1, 2020, the USTUR had received 47 whole- and 312 partial-body donations, including one whole- and two partial-body donations accepted during FY2020.

Cases are categorized as 'Intact,' 'Incomplete,' 'Surveyed', or 'Complete'. 'Intact' means that no tissue samples have been analyzed. 'Incomplete' typically denotes that analysis of a selected sub-set of tissues is in progress. 'Surveyed' denotes that only analysis of selected tissue samples that provides key scientific information to determine the level of exposure has been completed, and can be used for biokinetic modeling. More tissue samples from 'Surveyed' cases are available for analysis. 'Complete' denotes that a full selection of tissue samples was analyzed and results were reported.

In FY2020, analyses of tissue samples from one previously 'Surveyed' whole-body donor were completed. Radiochemical survey analyses of three 'Incomplete' whole-body case are now complete. Their radiochemistry statuses were changed to 'Surveyed'. (Table 5).

Full analyses of five partial-body cases were completed. Table 6 summarizes partial-body case analysis progress. Figure 8 shows FY2015 – FY2020 case analysis progress.

Table 5. FY2020 whole-body case analysis progress

| Case No | Year of donation | Radiochemistry status | |
|---|---|---|---|
| | | FY2019 | FY2020 |
| 0303 | 2008 | Surveyed | Complete |
| 0471 | 2018 | Incomplete | Surveyed |
| 0634 | 2017 | Incomplete | Surveyed |
| 0674 | 2017 | Incomplete | Surveyed |

Table 6. FY2020 partial-body case analysis progress

| Case No | Year of donation | Radiochemistry status | |
|---|---|---|---|
| | | FY2019 | FY2020 |
| 0317 | 2017 | Intact | Complete |
| 0641 | 2018 | Intact | Complete |
| 0287 | 2017 | Incomplete | Complete |
| 0332 | 2017 | Incomplete | Complete |
| 0765 | 2018 | Incomplete | Complete |

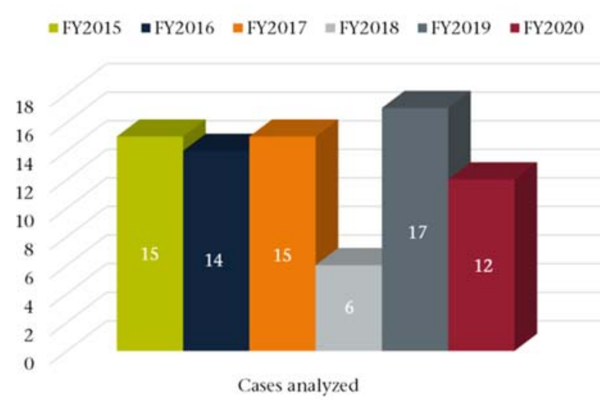



Fig. 8. USTUR case analysis progress in FY2015 – FY2020.

The status change of case analyses from FY2019 to FY2020 is shown in Figure 9.

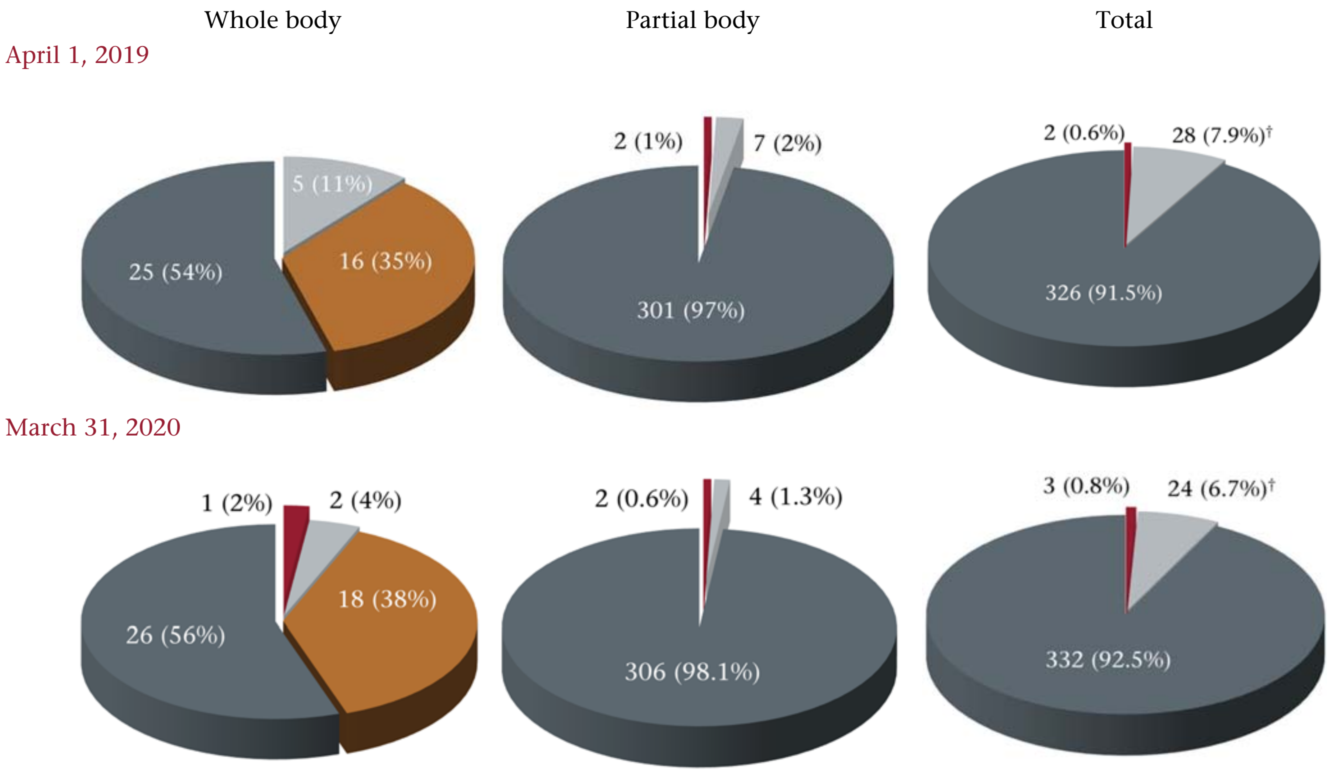



Fig. 9. Radiochemistry case analysis status: ■ Intact; ■ Incomplete; ■ Surveyed; ■ Complete.
† Includes 'Surveyed' whole-body cases.

## Tissue Sample Backlog

The USTUR/NHRTR retains a tissue backlog of 2,168 samples from 27 whole- and partial-body cases. They remain 'Incomplete' as of April 1, 2020. This includes 1,994 tissue samples from 20 whole-body cases, and 174 tissues from seven partial-body cases. Of 2,168 backlog samples, 1,703 (79%) need to be analyzed for plutonium, 213 (10%) for americium, and 252 (11%) for uranium (Fig. 10).

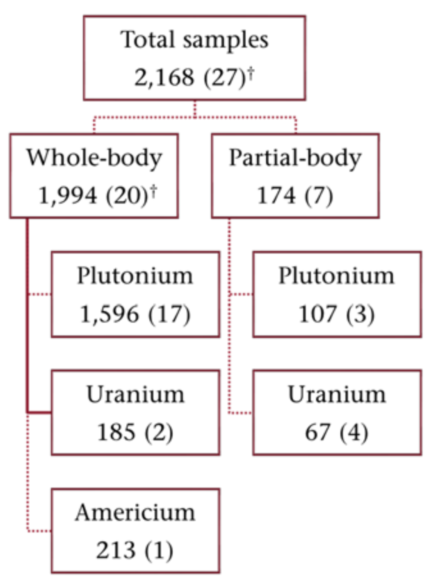



Fig. 10. USTUR tissue sample backlog at the end of FY2020. † Excluding two Thorotrast cases.

# Database Harmonization

Stacey L. McComish, *Associate in Research*

An effort is underway to harmonize the USTUR's database system, which includes seven databases that have been purchased or developed in-house over the course of more than 25 years. Most of these databases started out as standalone databases; however, links have been forged between them on an *ad hoc* basis (Fig. 11). The resulting information structure involves both automated communication between databases and hand-copied movement of data. The database harmonization project will integrate the individual THEMIS, RADCHEM, and planchets databases such that they function as a single database (Fig. 12). The aims of this project are: (i) to eliminate the need to hand-copy data, by improving the links between databases; (ii) to improve data integrity such that when information is changed in one database, the other databases immediately reflect that change; and (iii) to automate data entry in order to reduce the amount of time that laboratory personnel spend updating/entering sample information.

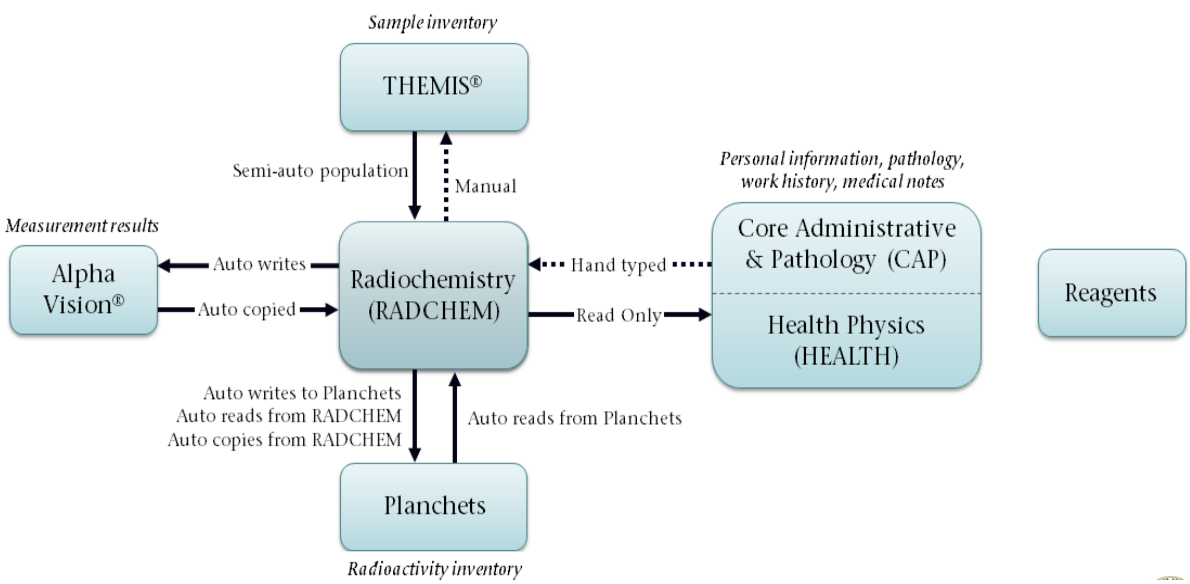



Fig. 11. Current system of USTUR databases and their relationship.

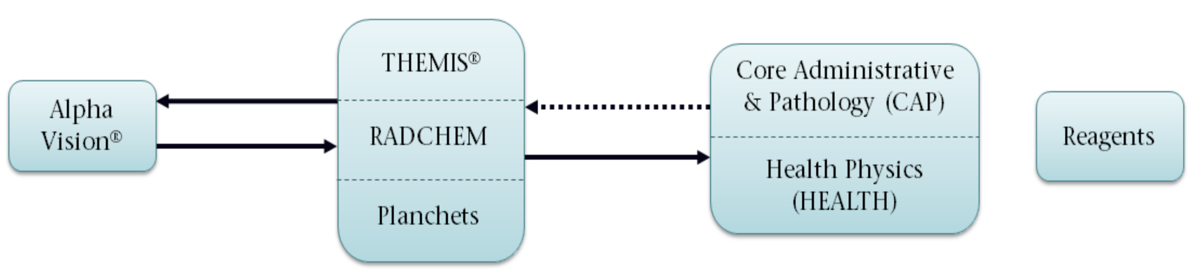



Fig. 12. Integrated USTUR database system.

THEMIS must be redesigned to allow it to communicate with the RADCHEM and planchets databases. There are four steps associated with this process: (i) restructure data tables; (ii) migrate existing data to the new tables, such that nothing is lost; (iii) redesign the user interface and integrate it into the RADCHEM front end; and (iv) verify that the data was properly migrated and the new user interface works correctly.

Alex Tabatadze has been hired part time to complete the database harmonization project. He has already begun to familiarize himself with the THEMIS database structure, so that he can develop a useful structure for the future. Mr. Tabatadze has also added security to RADCHEM in anticipation of integrating the redesigned inventory database into the RADCHEM user interface. This includes creating user logins that can be assigned permission to access different parts of the database.

# 2019 Advisory Committee Meeting Summary

## Roger O. McClellan, *Chair*

The annual meeting of the USTUR's Scientific Advisory Committee (SAC) was held April 11–12 at the Hampton Inn, Richland, WA. This year's meeting emphasized current and future collaborative research and specifically, collaboration with the DOE Million Person Study, and included presentations by John Boice, Keith Eckerman, Elizabeth Ellis, and Ashley Golden. The meeting agenda is available in Appendix D.

### Meeting Attendees

Overall, forty-two individuals attended 2019 USTUR SAC meeting, including USTUR faculty and staff.

#### Advisory Committee

- Roger McClellan, *Toxicology (Chair)*
- Luiz Bertelli, *Health Physics*
- Heather Hoffman, *Epidemiology*
- Thomas Rucker, *Radiochemistry*
- Arthur "Bill" Stange, *Occupational Health*
- Unable to attend: Timothy Ledbetter, *Ethics*

#### Department of Energy

- Joey Zhou, *USTUR Program Manager*
- Daniela Stricklin, *Beryllium-Associated Worker Registry (BAWR) Program Manager*
- Wesley Boyd, *Richland Operations Office*

#### Washington State University

- Antone Brooks, *Adjunct Professor, Environmental Sciences*
- Ron Kathren, *Professor Emeritus*
- Mikayla Kinsey, *Student /ACJ Scholarship recipient*
- Kathryn Meier, *Associate Dean for Faculty and Student Development, College of Pharmacy and Pharmaceutical Sciences*

#### USTUR

- Sergei Tolmachev, *Director*
- Stacey McComish, *Associate in Research*
- Maia Avtandilashvili, *Assistant Research Professor*
- George Tabatadze, *Assistant Research Professor*
- Elizabeth Thomas, *Laboratory Technician II (Radiochemistry)*
- Margo Bedell, *Program Specialist II*
- Dan Strom, *Adjunct Faculty*
- Florencio Martinez, *Medical Technologist*

#### Invited Guests

- Cheryl Antonio, *NV5*
- John Boice, *Million Person Study/NCRP/Vanderbilt University*
- Bryce Breitenstein, *USTR Director (retired)*
- John Brockman, *University of Missouri Research Reactor*
- Keith Eckerman, *Oak Ridge National Laboratory (retired)*
- Elizabeth Ellis, *Oak Ridge Institute for Science and Education (ORISE)*
- Darrell Fisher, *Versant Medical Physics and Radiation Safety*
- Robert Ford, *Pacific Northwest National Laboratory (PNNL)*
- Elizabeth Friedman, *University of Washington, Occupational & Environmental Medicine Resident*
- Jillian Gardner-Andrews, *Hanford History Project*

- Wayne Glines, *Herbert M. Parker Foundation*
- Ashley Golden, *ORISE*
- Neil Henson, *PNNL*
- Warnick Kernan, *PNNL*
- Tim Lynch, *NV5*
- Jay McClellan, *PNNL (retired)*
- Bruce Napier, *PNNL*
- Richard Pierson, *PNNL*
- Sandy Rock, *HPM Corporation (HPMC) Occupational Medical Services (OMS)*
- Margery Swint-Yegge, *USTR Director (retired)*

## Presentations

### WSU/CPPS News – Meier, K.

Dr. Meier discussed news from WSU Spokane's campus and the College of Pharmacy and Pharmaceutical Sciences. Topics included administrative changes within the college and university, student numbers, and research funding at CPPS.

### 2019 Financial & Administrative Development – Bedell, M.

Ms. Bedell summarized administrative and financial information including: personnel support, the FY2019 budget vs. spending, the FY2020 budget, and salary increases. Additionally, the WSU foundation awarded the first A.C. James scholarship this year.

### 2018 SAC Recommendations & 2019 Overview – Tolmachev, S.

Dr. Tolmachev described the USTUR's response to each of the SAC's recommendations from last April's meeting. This was followed by an overview of FY2019 activities, which included: a funding increase for FY2020, Dr. Dumit's PhD defense, professional services, the health physics and NHRTR databases, radiochemistry progress, and the USTUR's research activities.

### Registrant Statistics and IRB Changes – McComish, S.

Ms. McComish briefly summarized Registrant statistics and recent donations. This was followed by a discussion on topics related to a proposed records request form, and an overview of changes made to the USTUR's scientific collaboration and data access policy.

### Radiochemistry Progress Report – Tabatadze, G.

Dr. Tabatadze described operation of the radiochemistry laboratory. Topics included analytical methods, status of tissue analyses, new equipment, and new functionality of the USTUR's in-house radiochemistry database.

### Million Person Study, USTUR and Mission Mars – Boice, J.

Dr. Boice discussed types of radiation that astronauts would encounter during a mission to Mars, including heavy ions traveling at high speed (HZE particles). Our understanding of the potential impact of HZE particles on human health is limited to animal studies. However, the Million Person Study aims to use the alpha dose to former nuclear workers as a surrogate for HZE dose.

### ACJ/USTUR Scholar – Kinsey M.

The first recipient of the AC James memorial scholarship shared some information about herself and her educational goals.

### A Long and Winding Road DOE Worker Studies – Ellis, E.

Dr. Ellis discussed the sources and management of data used for the Million Person Study's epidemiological research. The worksites collected medical and exposure information out of concern for the health and safety of workers. The links between these data, early epidemiological studies, DOE's Comprehensive Epidemiological Data Resource (CEDR), and MPS were discussed.

### The Intersection of Epidemiology, Dosimetry & Biostatistics: Optimal Approaches in the Million Person Study – Golden, A.

Dr. Golden used a recently-published study of uranium workers from Mallinckrodt Chemical Works as an example of the epidemiological approach used by the Million Person Study. She discussed vital status, dosimetry, and biostatistical methods, as well as the results of the study.

### Dosimetry: Radiation Protection to Health Effects – Eckerman, K.F.

Dr. Eckerman discussed topics relevant to calculating tissue doses for the Million Person Study. He gave an overview of past and current biokinetic models for internal emitters, discussed absorbed dose to individual tissues from external radiation, and shared what they have learned about developing feasible exposure scenarios.

### WSU-PNNL Nuclear Science and Technology Institute – Henson, N.

Dr. Henson introduced the Nuclear Science and Technology Institute (NSTI). NSTI facilitates multi-disciplinary research by moving from one-to-one collaborations between WSU and Pacific Northwest National Laboratory (PNNL) to a strong network of collaborations.

### Research Plan and Operation in FY2020 – Tolmachev, S.Y.

Dr. Tolmachev summarized the USTUR's research and operational goals for the coming year. He discussed funding and personnel, radiochemistry, plans to hire a postdoctoral researcher, and the importance of collaboration.

### Comments

Specific comments included:

1. We are pleased with progress in demonstrating value to DOE officials through publication of papers and presentations. Continued progress and expansion is encouraged.
2. We are pleased with the development of the confidentiality policy.
3. The USTUR has shown significant effort toward identifying and developing collaboration opportunities with outsiders this year.
4. We believe the Data Quality Objectives (DQO) document draft is a good start but it needs to be completed with improved links to Measurement Quality Objectives (MQO).
5. Maintaining a high degree of sensitivity for release of samples and use of data is encouraged.

### Recommendations

1. Continue and increase publication of papers and presentations, and work toward improving credentials (e.g. certifications) of the staff.
2. Increase interactions with WSU at its several campuses including participation in seminars and lectures. Gain recognition as research professors by units beyond the College of Pharmacy (e.g. Chemistry, Nuclear Science, etc.) to develop collaborative research projects and student involvement.
3. Complete a Quality Assurance Plan/DQO Document to include: (i) measurement of all analytes/matrices performed onsite and offsite, (ii) Measurement Quality Objectives (accuracy, precision, sensitivity, selectivity, completeness,

etc.), linked to the DQO decision needs, (iii) quality tolerance limits for the different quality measurement parameters that monitor and control the MQOs linked to the Measurement Quality Indicators, and (iv) data verification and validation objectives/practices for verifying MQOs are met. Include all MQOs and tolerance limits in the Statement of Work used for contracted offsite analyses.

4. Complete implementation of an initiative for collecting bioassay monitoring data from living Registrants.
5. Develop specific objectives for the goals presented in the 5-year and 10-year plans and establish benchmark completion dates for stated goals.
6. Include in the operating procedure for control, release, and potential return of data and tissues a developed policy that provides limitations on use/reuse.
7. Review and update policy and procedures for pre-publication review with collaborators to make sure the USTUR has active involvement in the review and approval of publications and acknowledgement as a co-author.

## SAC Membership

Thomas Rucker's first term on the advisory committee ended in March of 2019, and he was renewed for another three-year term.

## Note of Appreciation

The assistance of Stacey McComish in preparing the meeting summary is gratefully appreciated.

Roger O. McClellan

SAC Chair

# Uncertainties in Predictions of $^{239}Pu$ Systemic Activity

Martin Šefl, *Postdoctoral Research Associate*

*The following sections highlight four major research studies conducted at the USTUR in FY2020, including two postdoctoral projects, an internal study on beryllium, and a collaboration with Los Alamos National Laboratory.*

Systemic deposition and retention of radionuclides in an occupationally exposed individual's body and, consequently, the resulting radiation doses are usually estimated from the worksite documentation and/or bioassay measurements.

The unique data resource available at the USTUR combines work history, chemical and radiation exposure records, bioassay measurements, and post-mortem tissue analysis results from 312 partial- and 47 whole-body tissue donors with documented intakes of actinides. The post-mortem tissue analysis results can be used to evaluate the accuracy of the standard dosimetry for radiation epidemiology.

For this study, individuals with $^{239}Pu$ intakes were pre-selected based on the following criteria: (i) there was no extensive chelation and at least five $^{239}Pu$ urine measurements exceeded the contemporary maximum detectable activity (MDA) (Fig.13); and (ii) $^{239}Pu$ concentrations in the skeleton and liver measured post-mortem were equal to or greater than 0.1 Bq kg$^{-1}$ and 1 Bq kg$^{-1}$, respectively (Fig. 14). The selection process resulted in a set of 42 individuals.

A subset of 12 Registrants (nine whole-, and three partial- body tissue donors) was further selected for the preliminary study. Worksite estimates of systemic deposition of $^{239}Pu$ for these individuals ranged from 30 to 3,700 Bq. The assumed route of intakes were inhalations of $Pu(NO_3)_4$ and refractory $PuO_2$, or $^{239}Pu$ contaminated wounds. The objective of this preliminary study was to compare the predicted $^{239}Pu$ activities in the skeleton and liver, based upon urine bioassay and in-vivo chest counts, with measured post-mortem activities.

The latest biokinetic models including the International Commission on Radiological Protection (ICRP) Publication 130 human respiratory tract model[1], ICRP Publication 141 plutonium systemic model[2], and National Council on Radiation Protection and Measurements (NCRP) Report 156 wound model[3] were implemented for calculations.

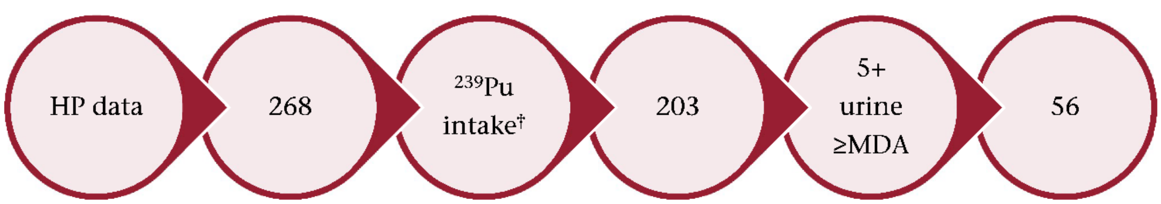



Fig. 13. Case selection process from Health Physics database (HP data) based on criterion (a). † – no extensive chelation.

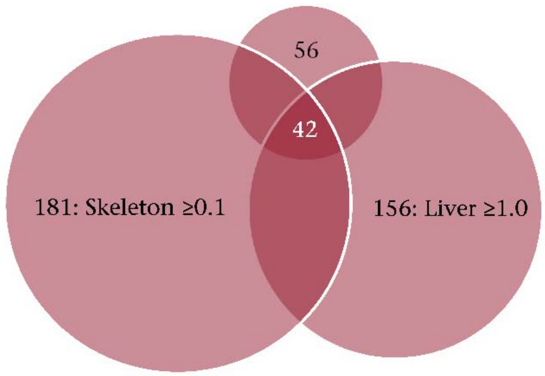
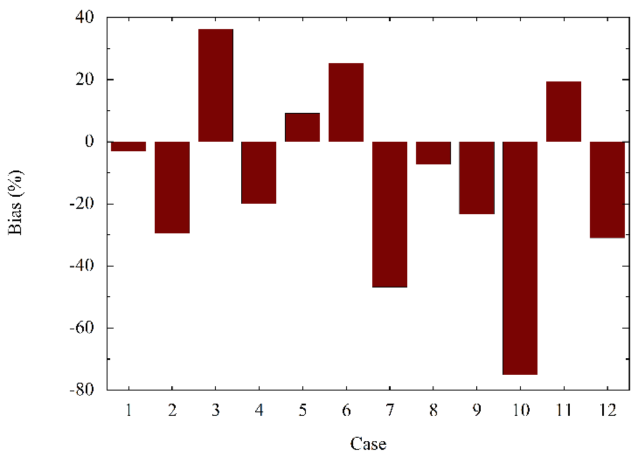



Fig. 14. Intersection of the pools of cases selected based on criteria (a) and (b).

IMBA Professional Plus® was used to fit the bioassay data to estimate plutonium intakes and predict activities in the skeleton and liver at the time of death. Predicted ($A_p$) and measured ($A_m$) post-mortem skeleton and liver activities were used to calculate the bias according to the equation:

$$\text{Bias}(\%) = (A_p - A_m)/A_m \times 100\%. \quad (1)$$

The results are presented on Figure 15. The predicted skeleton and liver activities at the time of death differed from the measured values on average (absolute bias) by 27±32%, and 37±43% respectively.



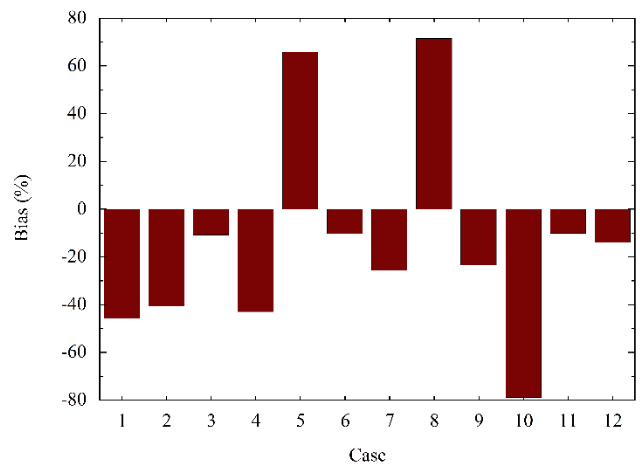




Fig. 15. Bias in the post-mortem activities in skeleton (left) and liver (right).

## References

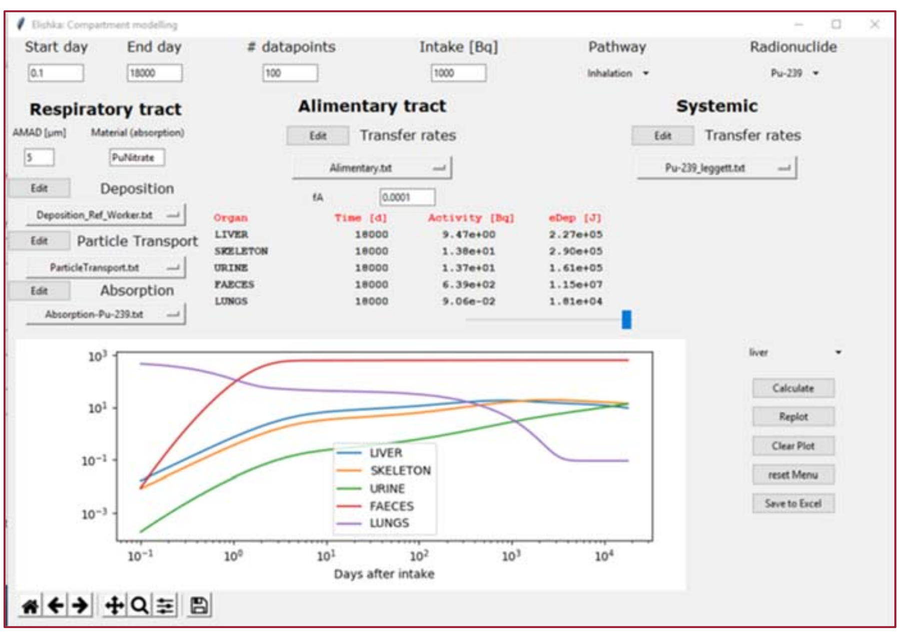

1. International Commission on Radiological Protection. Occupational intakes of radionuclides: Part 1. ICRP Publication 130; Ann ICRP 44(2); 2015.
2. International Commission on Radiological Protection. Occupational intakes of radionuclides: Part 4. ICRP Publication 141; Ann ICRP 48(2–3); 2019.
3. National Council on Radiation Protection and Measurements. Development of a biokinetic model for radionuclide-contaminated wounds and procedures for their assessment, dosimetry and treatment. NCRP Report 156; 2006.

# Software for Biokinetic Modeling & Dose Calculation

Martin Šefl, *Postdoctoral Research Associate*

Given a need for biokinetic modeling software compatible with the latest ICRP biokinetic and dosimetric models, the USTUR initiated development of a new, flexible, adaptable computer code for radiation dosimetry following intakes of actinides. Python 3.7[1] was chosen as programming language since it is a modern, multi-platform, well-documented language supporting object-oriented development and offering a broad range of libraries for advanced math, optimization, plotting and building a graphical user interface (GUI). The ICRP Publication 141 systemic model for plutonium[2], the ICRP 130 human respiratory tract model[3], the ICRP 100 human alimentary tract model[4], and the NCRP 156 contaminated wound model[5] have been implemented in a new code. Calculations are based on analytical solutions of the systems of first-order linear differential equations in the various models. The plutonium systemic model has been validated alone, as well as in conjunction with the NCRP 156 wound model, against IMBA Professional Plus internal dosimetry software predictions. The development of a graphical user interface (GUI) is ongoing. The prototype GUI was built using *tkinter*, a python interface to the *Tk* GUI toolkit.

The prototype supports multiple intakes via inhalation, injection, ingestion, and wound. The user can adjust parameters of all models, plot the time evolution of activity, and export calculations into an Excel file. The intake prediction from the fit of bioassay data and the equivalent and effective dose calculation are the priorities for the future development.




*GUI prototype for biokinetic modeling of plutonium intakes.*

## References


1. The SciPy Community; 2015. https://docs.scipy.org/doc/scipy-0.15.1/reference/
2. International Commission on Radiological Protection. Occupational intakes of radionuclides: Part 4. ICRP Publication 141; Ann ICRP 48(2–3); 2019.
3. International Commission on Radiological Protection. Occupational intakes of radionuclides: Part 1. ICRP Publication 130; Ann ICRP 44(2); 2015.
4. International Commission on Radiological Protection. Human alimentary tract model for radiological protection. ICRP Publication 100. Ann ICRP 36(1–2); 2006.
5. National Council on Radiation Protection and Measurements. Development of a biokinetic model for radionuclide-contaminated wounds and procedures for their assessment, dosimetry and treatment. NCRP Report 156; 2006.

# Beryllium in Tissues of Former Nuclear Workers

Maia Avtandilashvili, *Assistant Research Professor*
Sergei Y. Tolmachev, *Research Professor*

Beryllium and beryllium compounds widely used in nuclear power industry and weapons production are known to be human carcinogens. Currently, there is limited published data on beryllium concentrations and distribution in the human body. Out of 358 deceased USTUR Registrants, 89 self-reported working with beryllium, but only 71 individuals reported years of beryllium work ranging from 1 to 45 years with the average of 17±13 years. Beryllium concentrations were measured using inductively-coupled plasma mass spectrometry in tissue samples from nine USTUR cases with beryllium exposure duration ranging from 3 to 38 years. A total of 127 tissues was analyzed including 105 tissues from a whole-body donor who was potentially exposed to beryllium for six years. The highest concentrations were measured in thoracic lymph nodes with the range of 6–248 µg $kg^{-1}$ (median: 15.0 µg $kg^{-1}$). For other tissues, beryllium median concentration followed the order: kidney (0.51 µg $kg^{-1}$) > liver (0.46 µg $kg^{-1}$) > lung (0.16 µg $kg^{-1}$) > skeleton (0.10 µg $kg^{-1}$). For this whole-body donor, the total beryllium content was estimated to be 57.6 mg, including 5.0 mg retained in the respiratory tract 22 years post-exposure. It was found that systemic beryllium primarily accumulated in the skeleton (30.2 mg), followed by the liver (11.8 mg) and other soft tissues (10.6 mg). Beryllium concentration in the liver (10.2 mg $kg^{-1}$) was three times higher than the average concentration in the skeleton (3.4 mg $kg^{-1}$) and 42 times higher than that in other soft tissues (0.24 µg $kg^{-1}$). This finding does not support the upcoming biokinetic model for beryllium to be published in Part 5 of ICRP's Occupational Intakes of Radionuclides (OIR) series[1], where the liver is included in the '*Other soft tissue*' compartment, in which beryllium is assumed to be uniformly distributed (Fig. 16).

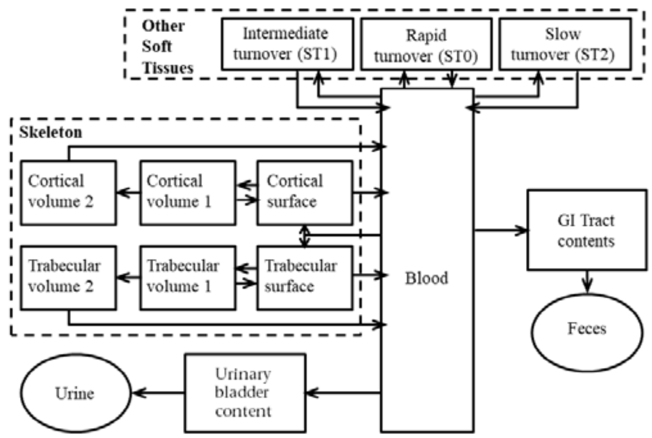



Fig. 16. Systemic model for beryllium.

## References

1. Personal communication with R W Leggett; January 15, 2019.

# Estimation of Bound Fraction

## Deepesh Poudel, *Health Physicist, Los Alamos National Laboratory*

Certain parameters of the Human Respiratory Tract Model (HRTM) such as the 'bound fraction' can have a profound impact on the retention of plutonium in the lung tissues and the radiation doses to different parts of the respiratory tract. Confidence in this parameter is important to ensure confidence in our biokinetic and dosimetric models, and consequently the epidemiological and dose-response models.

In order to accurately determine the value of bound fraction, one would need data on retention in individual dosimetry compartments of the respiratory tract. Such datasets were obtained for two USTUR whole-body tissue donors: cases 0631 and 0745.

Comparison of the long-term retention of plutonium in different compartments of the respiratory tract against the predictions of the ICRP biokinetic models showed higher-than-expected activity in the upper respiratory tract. Although the materials inhaled by both cases was described as plutonium nitrate, our analysis of the activity concentration in lungs and the thoracic lymph nodes indicated that the materials inhaled by both workers were found to have solubilities in between those of nitrates and oxides.

Markov-Chain Monte Carlo was used to calculate the posterior distribution of the HRTM parameters including the bound fraction. The data from two individuals was explained by a bound fraction of 1% and 4% for cases 0631 and 0745 respectively, without having to significantly alter the particle clearance parameters. These values were found to be higher than those reported in the literature using data from inhalation of plutonium nitrate in dogs and humans, and that (0.2%) recommended by the ICRP in its latest publication[1](Fig. 17).

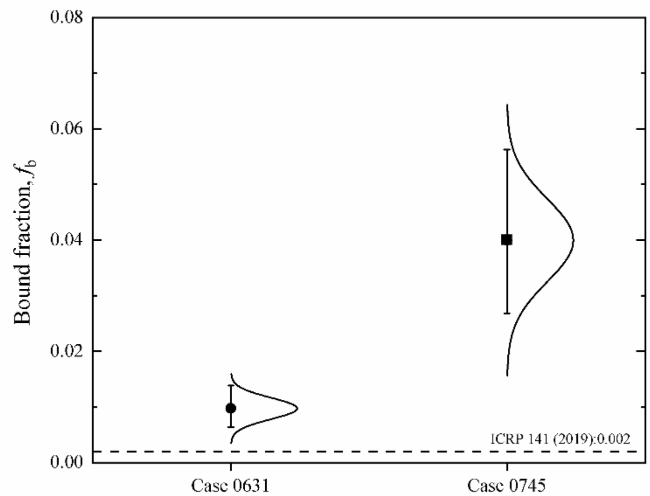



Fig. 17. Posterior distribution of bound fraction for two USTUR cases.

The methods of analysis and the findings of the paper are summarized in a paper currently published online ahead of print in Health Physics[2].

### References

1. International Commission on Radiological Protection. Occupational intakes of radionuclides: Part 4. ICRP Publication 141; Ann ICRP 48(2–3); 2019.

2. Poudel D, Avtandilashvili M, Bertelli L, Klumpp JA, Tolmachev SY. Long-term retention of plutonium in the respiratory tracts of two acutely-exposed workers: estimation of bound fraction. Health Phys; Ahead of Print; 2020. doi: 10.1097/HP.0000000000001311.

# Professional Activities and Services

During FY2020, the USTUR staff was actively involved in professional and academic activities nationally and internationally.

## Professional Services

### NCRP Council

Dr. Tolmachev has been elected as a Council Member for the National Council on Radiation Protection and Measurements (NCRP). This is a six-year appointment (2020–2026). Dr. Tolmachev will serve for the Program Area Committee 6 on Radiation Measurements and Dosimetry. Dr. Tolmachev is the second WSU member who was elected to the NCRP Council.

https://ncrponline.org/about/members/council-members/

### NCRP Council Committee 2

Dr. Tolmachev continued to chair the Radio- and Nuclear Chemistry Sub-committee of the National Council on Radiation Protection and Measurement (NCRP) Council Committee 2 (2017–2020).

https://ncrponline.org/program-areas/cc-2/

### NCRP Scientific Committee 6-12

Dr. Tolmachev and Dr. Avtandilashvili continued to serve on the NCRP scientific committee (SC 6-12) on the Development of Models for Brain Dosimetry for Internally Deposited Radionuclides. Dr. Tolmachev is a vice-chairman of the committee (2018–2020).

https://ncrponline.org/program-areas/sc-6-12/

### Herbert M. Parker Foundation

Dr. Tabatadze has been appointed to serve as a member (2019 – present) of the Board of Trustees for the Herbert M. Parker Foundation. Dr. Tolmachev continued to serve as a member (2016 – present) of the Board.

https://tricities.wsu.edu/parkerfoundation/

### Health Physics Society International Collaboration Committee

Dr. George Tabatadze continued to serve as a member (2016–2019) of the International Collaboration Committee of the Health Physics Society.

https://hps.org/aboutthesociety/organization/committees/committee9.html

### Columbia Chapter of Health Physics Society

Dr. Tabatadze continued to serve as the *ex-officio* president (2018–2020) of the Columbia Chapter of the Health Physics Society.

https://www.cchps.org/executive-council

### WSU Radiation Safety Committee

Dr. Tabatadze has been appointed to serve as a member (2019–2022) of the WSU Radiation Safety Committee (RSC). The RSC establishes and ensures compliance with radiation protection policies, reviews applications for, and approves use of, radioactive materials and radiation-producing machines, and audits Radiation Safety Office records.

https://rso.wsu.edu/radiation-safety-committee/

### Kyushu Environmental Evaluation Association

Dr. Tolmachev was re-appointed as a Technical Advisor (2020–2022) at the Kyushu Environmental Evaluation Association (Fukuoka, Japan).

http://www.keea.or.jp/

## Scientific Meetings

USTUR faculty attended and participated in the following scientific meetings:

- 55th Annual Meeting of the National Council on Radiation Protection and Measurements (NCRP), Bethesda, MD, April 1–2, 2019
- 3rd International Conference on Dosimetry and its Applications (ICDA-3), Lisbon, Portugal, May 27–31, 2019
- 6th Workshop of the Million Person Study, Oak Ridge Associated Universities (ORAU), Oak Ridge, TN, June 5–7, 2019
- 74th Northwest Regional Meeting of the American Chemical Society, Portland, OR, June 16–19, 2019
- 64th Health Physics Society Meeting, Orlando, FL, July 7–11, 2019
- The Million Person Study's dosimetry team meeting, Hilton Orlando Resort, Orlando, FL, July 9, 2019
- Teleconference meeting on collaborations for radium brain dosimetry, August 6, 2019
- NCRP Scientific Committee 6-12 teleconference meeting. September 13, 2019
- 7th Workshop of the Million Person Study, Oak Ridge Associated Universities (ORAU), Oak Ridge, TN, October 16–18, 2019
- 65th Annual Meeting of Radiation Research Society, San Diego, CA, November 3–6, 2019
- 5th International Symposium on the System of Radiological Protection (ICRP 2019), Adelaide, Australia, November 17–21, 2019
- European Radiation Dosimetry Group (EURADOS) Annual Meeting 2020, Florence, Italy, January 27–30, 2020
- 8th Workshop of the Million Person Study, Oak Ridge Associated Universities (ORAU), Oak Ridge, TN, February 11–14, 2020
- Idaho State University Internal Dosimetry Collaboration Workshop, March 4, 2020
- Virtual meeting of the NCRP Program Area Committee 6 (PAC 6): Radiation Measurements and Dosimetry, March 22, 2020
- NCRP 2020 Annual Business Meeting, March 24, 2020.

### Japanese Journal of Health Physics

Dr. Sergei Tolmachev continued to serve as a member of the Editorial Board for the *Japanese Journal of Health Physics* (JJHP) for his 4th term from August 2019 to July 2021.

### Austin Biometrics and Biostatistics

Dr. Maia Avtandilashvili continued to serve as a member (2016–2020) of the Editorial Board for the journal of *Austin Biometrics and Biostatistics*.

## Professional Affiliations

USTUR personnel are active members of numerous national and international professional organizations:

- Radiation Research Society (USA)
- Health Physics Society (USA)
- European Radiation Dosimetry Group (EURADOS), Working Group 7 (WG7) on Internal Dosimetry (EU).

# Publications and Presentations

The following manuscripts and presentations were published or presented during the period of April 2019 to March 2020. In August, 2019, the *fourth* USTUR special issue of the *Health Physics* journal was published including an introductory note, 10 research papers, and one forum article.

Previous manuscripts and abstracts are available on the USTUR website at:
ustur.wsu.edu/Publications/index.html

Abstracts of published peer-reviewed manuscripts and scientific presentations are included in Appendix E of this report.

### Published

#### *USTUR Special Issue of Health Physics Journal*

USTUR-0528-19

Worthington PR. Introduction to the U.S. Transuranium and Uranium Registries (USTUR) special issue. Health Physics 117: 117; 2019.

USTUR-0427-16

Kathren RL, Tolmachev SY. The United States Transuranium and Uranium Registries (USTUR): A five-decade follow-up of plutonium and uranium workers. Health Physics 117: 118–132; 2019.

USTUR-0436-16

Birchall A, Puncher M, Hodgson A, Tolmachev SY. The importance and quantification of plutonium binding in human lungs. Health Physics 117: 133–142; 2019.

USTUR-0434-16

Goans RE, Toohey RE, Iddins CJ, McComish SL, Tolmachev SY, Dainiak N. The Pseudo-Pelger Huët Cell as a retrospective dosimeter: Analysis of a radium dial painter cohort. Health Physics 117: 143–148; 2019.

USTUR-0430-16

Avtandilashvili M, Tolmachev SY. Modeling the skeleton weight of an adult Caucasian man. Health Physics 117: 149–155; 2019.

USTUR-0431-16

Dumit S, Avtandilashvili M, Tolmachev SY. Evaluating plutonium intake and radiation dose following extensive chelation treatment. Health Physics 117: 156–167; 2019.

USTUR-0435-16

Breustedt B, Avtandilashvili M, McComish SL, Tolmachev SY. USTUR Case 0846: Modeling americium biokinetics after intensive decorporation therapy. Health Physics 117: 168–178; 2019.

USTUR-0432-16

Tabatadze G, Miller BW, Tolmachev SY. Mapping $^{241}Am$ spatial distribution within anatomical bone structures using digital autoradiography. Health Physics 117: 179–186; 2019.

USTUR-0433-16

Zhou JY, McComish SL, Tolmachev SY. A Monte Carlo t-test to evaluate mesothelioma and radiation in the U.S. Transuranium and Uranium Registries. Health Physics 117: 187–192; 2019.

USTUR-0437-16

Lopez MA, Nogueira P, Vrba T, Tanner RJ, Ruhm W, Tolmachev SY. Measurements and Monte Carlo simulations of $^{241}Am$ activities in three skull phantoms: EURADOS–USTUR collaboration. Health Physics 117: 193–201; 2019.

USTUR-0429-16

Tolmachev SY, Avtandilashvili M, Kathren RL. Estimation of total skeletal content of plutonium and $^{241}$Am from analysis of a single bone. Health Physics 117: 202–210; 2019.

USTUR-0515-19

Tolmachev SY, Swint MJ, Bistline RW, McClellan RO, McInroy JF, Kathren RL, Filipy RE, Toohey RE. USTUR special sessions roundtable: United States Transuranium and Uranium Registries (USTUR): A five-decade follow-up of plutonium and uranium workers. Health Physics 117: 211–222; 2019.

*Other Publications*

USTUR-0531-19

Dumit S, Breustedt B, Avtandilashvili M, McComish SL, Strom DJ, Tabatadze G, Tolmachev SY. Response to the Letter to the Editor, 'Comments on "Improved modeling of plutonium-DTPA decorporation," (Radiat Res 2019; 191:201–210) by Gremy and Miccoli'. Radiation Research 182: 682–683; 2019.

USTUR-0506-18A

Avtandilashvili M, McComish SL, Tolmachev SY. The United States Transuranium and Uranium Registries: Fifty-year history of actinide biokinetic research. BIO Web of Conferences 14: 05001; 2019.

USTUR-0507-18A

Avtandilashvili Tolmachev SY. Biokinetics of soluble plutonium after wound injury treated with Ca-DTPA. BIO Web of Conferences 14: 02008; 2019.

USTUR-0508-18A

Tolmachev SY, McComish SL, Avtandilashvili M. Expanding horizons for actinide biokinetics and dosimetry. BIO Web of Conferences 14: 08003; 2019.

USTUR-0509-18A

Leggett RW, Tolmachev SY, Boice JD. Case studies in brain dosimetry for internal emitters: Is more detail needed for epidemiology? BIO Web of Conferences 14: 03008; 2019.

USTUR-0519-19A

McComish SL, Zhou JY, Martinez F, Tolmachev SY. Limitations of cause of death data among autopsied population in the United States Transuranium and Uranium Registries. Health Physics 117 (Suppl 1): 62; 2019.

USTUR-0520-19A

Tolmachev SY, Leggett RW, Avtandilashvili M, Boice JD. Case studies in brain dosimetry for internally deposited radionuclides. Health Physics 117 (Suppl 1): 80–81; 2019.

USTUR-0521-19A

Strom DJ, Dumit S, Avtandilashvili M, McComish SL, Tabatadze G, Tolmachev SY. Cylindrical representations of recycling biokinetic models. Health Physics 117 (Suppl 1): 78; 2019.

USTUR-0522-19A

Avtandilashvili M, Tolmachev SY. Macrodistribution of plutonium among dosimetric compartments of the human respiratory tract. Health Physics 117 (Suppl 1): 20–21; 2019.

USTUR-0525-19A

Tolmachev SY, Leggett RW, Avtandilashvili, M, Boice JD. Plutonium in human brain: Is more biokinetic detail needed for dosimetry? 3rd International Conference on Dosimetry and its Applications (ICDA-3), Lisbon, Portugal, May 26–31, 2019; eBook of Abstracts: e01.01; 2019.

USTUR-0526-19A

Tolmachev SY, Avtandilashvili, M, Kathren RL. Uranium content, distribution, and biokinetics in human body. 74th Northwest Regional Meeting of the American Chemical Society (NORM2019), Portland, Oregon, USA, June 16–19, 2019: Book of Abstracts: 211–212; 2019.

USTUR-0527-19A

Wegge DL, Tolmachev SY, Brockman JD. A method to measure U, Pu, and Am in human keratinous samples using extraction chromatography and ICP-MS. Proceedings of SciX 2019 Conference; 2019.

USTUR-0529-19A

Tolmachev SY, Paunesku T, Woloschak GE, Boice JD, Jr. From autopsies to synchrotrons to Mars – why the brain matters. 65th Annual Meeting of the Radiation Research Society, San Diego, California, USA, November 3–6, 2019: eBook of Abstracts: ePage; 2019.

USTUR-0536-19

Avtandilashvili M, Tolmachev SY. United States Transuranium and Uranium Registries Annual Report: April 1, 2018 – March 31, 2019. United States Transuranium and Uranium Registries; USTUR-0536-19, Richland, WA, 2019.

## Presented

### Invited

USTUR-0526-19A

Tolmachev SY, Avtandilashvili M, Kathren RL. Uranium content, distribution, and biokinetics in human body. Podium presentation at the 74th Northwest Regional Meeting of the American Chemical Society, Portland, OR, June 16–19, 2019.

USTUR-0529-19A

Tolmachev SY, Paunesku T, Woloschak GE, Boice JD. From autopsies to synchrotrons to Mars – Why the brain matters. 65th Annual Meeting of Radiation Research Society, San Diego, CA, November 3–6, 2019.

USTUR-0544-20P

Tolmachev SY, Avtandilashvili M, Leggett RW, Boice JD. Brain Dosimetry for Internally Deposited Radionuclides. Podium presentation at the EURADOS Annual Meeting 2020, Florence, Italy, January 27–30, 2020.

USTUR-0545-20P

Tolmachev SY. USTUR Today: January 2020 Edition. Podium presentation at the EURADOS Annual Meeting 2020, Florence, Italy, January 27–30, 2020.

### Podium

USTUR-0525-19A

Tolmachev SY. Avtandilashvili M, Leggett RW, Boice JD. Plutonium in human brain: Is more biokinetic detail needed for dosimetry? 3rd International Conference on Dosimetry and its Applications (ICDA-3), Lisbon, Portugal, May 27–31, 2019.

USTUR-0519-19A

McComish SL, Zhou J, Martinez FT, Tolmachev SY. Limitations of cause of death data among autopsied population in the United States Transuranium and Uranium Registries. 64th Health Physics Society Meeting, Orlando, FL, July 7–11, 2019.

USTUR-0520-19A

Tolmachev SY, Leggett RW, Avtandilashvili M, Boice JD. Case studies in brain dosimetry for internally deposited radionuclides. 64th Health

Physics Society Meeting, Orlando, FL, July 7–11, 2019.

USTUR-0521-19A

Strom DJ, Dumit S, Avtandilashvili M, McComish SL, Tabatadze G, Tolmachev SY. Cylindrical representations of recycling biokinetic models. 64th Health Physics Society Meeting, Orlando, FL, July 7–11, 2019.

USTUR-0522-19A

Avtandilashvili M, Tolmachev SY. Macrodistribution of plutonium among dosimetric compartments of the human respiratory tract. 64th Health Physics Society Meeting, Orlando, FL, July 7–11, 2019.

Poster

USTUR-0527-19A

Wegge DL, Tolmachev SY, Brockman JD. A method to measure U, Pu, and Am in human keratinous samples using extraction chromatography and ICP-MS. Poster presentation at the SciX 2019 Conference, Palm Springs, CA, October 13–18, 2019.

# Bibliographic Metrics

## Stacey L. McComish, *Associate in Research*

Since its inception in 1968, the USTUR has published 276 papers in conference proceedings and peer-reviewed journals, 24 books/book sections, 97 abstracts in journals, and 22 editorial journal publications such as letters to the editor. These publications were authored by USTUR staff, SAC members, and/or emeritus/adjunct faculty.

Peer-reviewed papers by USTUR authors have appeared in 43 different journals, with a highest impact factor of 9.727 (Cancer Research). Four journals account for 75% of these papers: Health Physics (0.853), Radiation Protection Dosimetry (0.773), the Journal of Radioanalytical and Nuclear Chemistry (1.137), and Radiation Research (2.657).

The USTUR's publications profile was tracked online through the Publons bibliographic service. Publons generates citation metrics for journal articles in the Web of Science collection. In the past, the USTUR has used Publons to track all publication types. However, Publons is better suited to track citation metrics for journal articles, and the following information applies only to peer-reviewed journal articles. Publons has citation data for 222 USTUR publications. These articles were cited 3,884 times, and the USTUR has an *h*-index of 32. It is clear from these numbers that the USTUR's research continues to have an important impact on our understanding of actinides in humans. Figure 18 displays the number of USTUR journal articles published per year, and number of times articles were cited each year. To explore the USTUR's publications on Publons, visit:

https://publons.com/researcher/2623846/ustur-cpps-wsu/

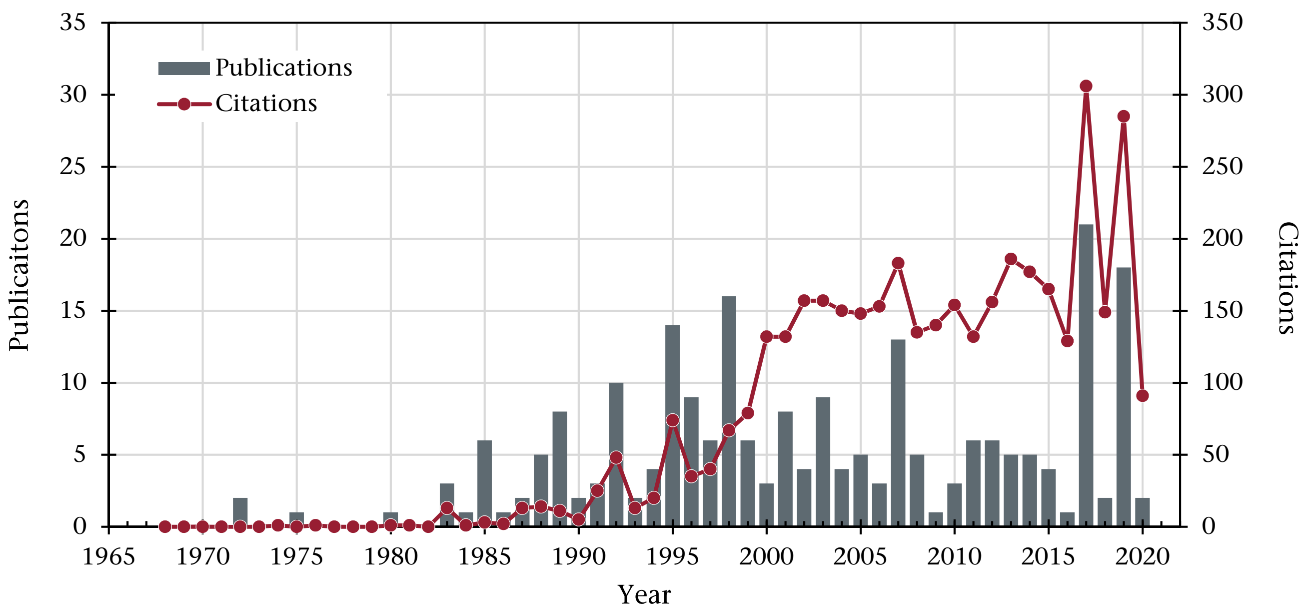
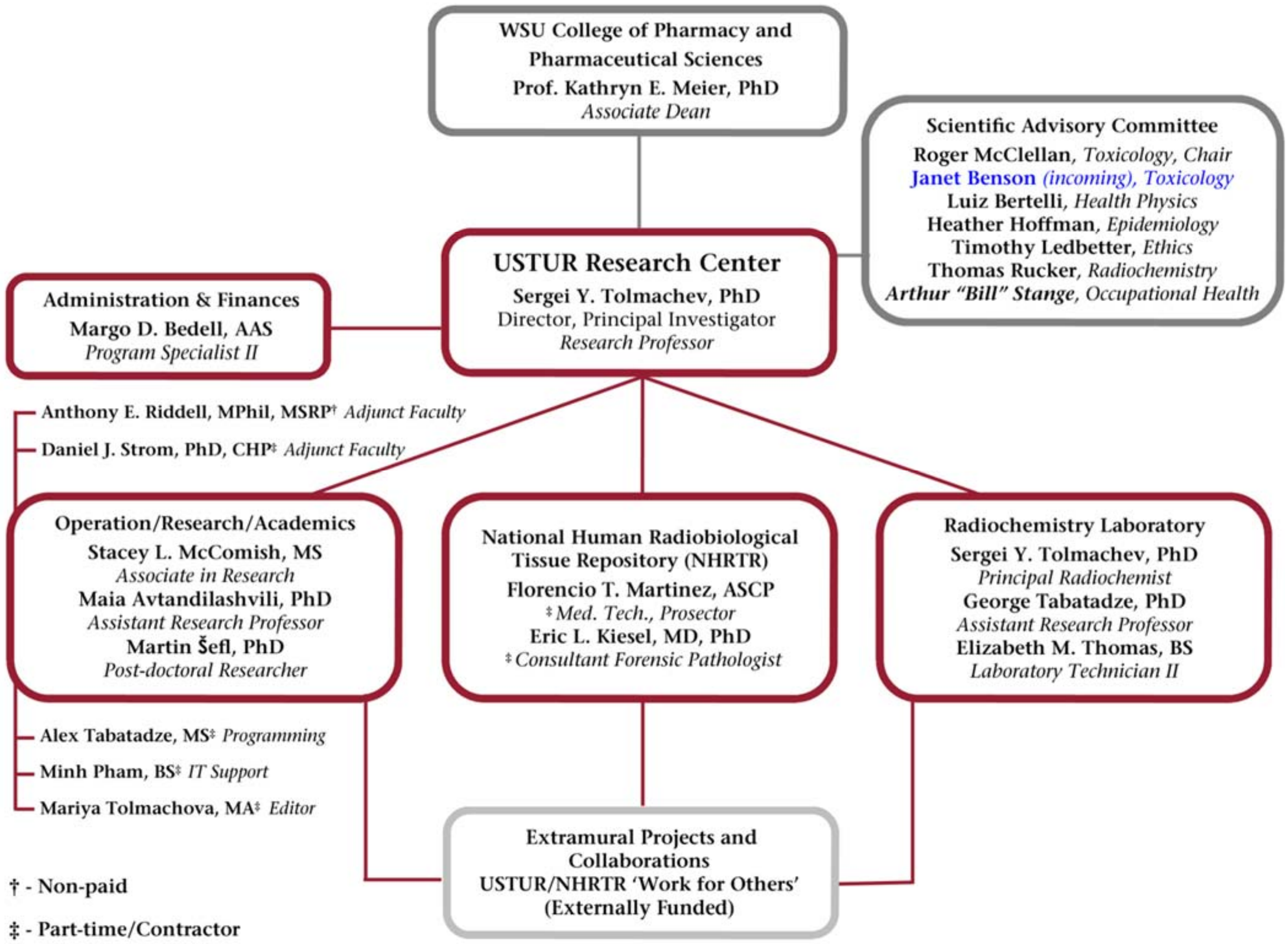



Fig 18. The number of USTUR journal publications per year, and the number of times articles were cited in each year.

# Appendix A




USTUR Research Center organization structure during FY2020.

# Appendix B

**F103a**

Created 09/19
Revised n/a

## Data Request: Living Registrant

Approved by Sergei Y. Tolmachev, Director
September 2019

*To protect your information, we require proof of your identity. To request information by mail, your signature on this form must be notarized OR the person requesting information must provide a photocopy of two identifying documents bearing your name and signature, one of which shall bear your current home or business address and date of birth (e.g. driver's license). To request information in person, you must present one identifying document bearing your photograph and signature (i.e. driver's license or passport).*

*To request information on behalf of a living individual, the requestor must have an appropriate medical power-of-attorney authorizing such an action, and provide a copy of the signed power-of-attorney document.*

**Part A: Individual for Whom Data is Requested**

Full Name ______ Telephone Number ______

Current Address ______ City ______ State ______ Zip Code ______

Social Security Number ______ Date of Birth ______

**Part B: Individual Making Request**

Do you have medical power of attorney for the Registrant? Yes No n/a

Full Name ______ Telephone Number ______

Mailing Address ______ City ______ State ______ Zip Code ______

Relationship to individual in Part A ______

**Part C: Determine Registrant Status**

*To determine if you are a USTUR Registrant (i.e if you are registered to donate tissues when you pass away)...*

☐ Is the individual in Part A registered to donate tissues to the USTUR when he/she passes away?

______

Facilities where you worked with or around plutonium, americium, uranium, or other actinides





**Part D: Records Request**

☐ Please send a copy of the following records:

______

______

**Part E: Checklist and Signature**

Please confirm that you have included the following items:

☐ Medical power of attorney document (if applicable)

☐ Notarized signature on this form (if submitting request by mail)

OR

☐ Photocopy of identifying document bearing your name, signature, current home or business address, and date of birth (e.g. driver's license or passport)

☐ Photocopy of identifying document bearing your name and signature

I hereby certify that I am the individual named in Part B of this request, and that all information on this form is true and correct.

Full Name ______ Date ______

Signature ______

**Administrative Use Only**

☐ Approved

☐ Not Approved Reason: ______

Director's Signature ______ Date ______

# F103b

Created 09/19
Revised n/a

## Data Request: Deceased Registrant

Approved by Sergei Y. Tolmachev, Director
September 2019

*To request information on behalf of a deceased individual, the requestor must be next of kin and provide a copy of the death certificate.*

*To protect our Registrants' information, we require proof of your identity. To request information by mail, your signature on this form must be notarized OR the person requesting information must provide a photocopy of two identifying documents bearing your name and signature, one of which shall bear your current home or business address and date of birth (e.g. driver's license). To request information in person, you must present one identifying document bearing your photograph and signature (i.e. driver's license or passport).*

**Part A: Individual for Whom Data is Requested**

Full Name

Most Recent Address City State Zip Code

Social Security Number Date of Birth Date of Death

**Part B: Individual Making Request**

*To request information on behalf of a deceased Registrant, the requestor must be next of kin.*

Full Name Telephone Number

Mailing Address City State Zip Code

Relationship to individual in Part A

**Part C: Determine Registrant Status**

☐ Did the above individual in Part A donate tissues to the USTUR?

Facilities where the individual worked with or around plutonium, americium, uranium, or other actinides





**Part D: Records Request**

☐ Please send a copy of the following records:

**Part E: Checklist and Signature**

Please confirm that you have included the following:

☐ Death Certificate

☐ Notarized signature on this form (if submitting request by mail)

OR

- ☐ Photocopy of identifying document bearing your name, signature, current home or business address, and date of birth (e.g. driver's license or passport)
- ☐ Photocopy of identifying document bearing your name and signature

I hereby certify that I am the individual named in Part B of this request, and that all information on this form is true and correct.

Full Name Date

Signature

**Administrative Use Only**

☐ Approved

☐ Not Approved Reason: ____________

Director's Signature Date

# P106 Scientific Collaboration and Data Access

Created 06/92
Revised 09/19

*Approved by* Sergei Y. Tolmachev, Director
September 2019

*This policy applies to research collaboration with other scientists and institutions, and to sharing Registries' data and materials with others.*

**Collaboration with other institutions is encouraged**

To maximize the scientific worth and output of the unique materials and data under its purview, the Registries encourages and actively seeks collaboration with other investigators and institutions. Collaboration is sought to compliment rather than duplicate the capabilities of the Registries, and to facilitate the efforts of the Registries in achieving its primary goal. Collaboration may take the form of joint evaluations of data, tissues, or other Registries materials, preparation of articles for peer-reviewed literature, or preparation of joint research proposals to a potential sponsor.

**Confidentiality**

USTUR data shall be held in the highest confidence and every possible precaution will be taken to protect Registrants. These data include, but are not limited to: worksite medical, radiation dosimetry, and industrial hygiene histories; correspondence; and autopsy findings.

**Definition of collaborative researchers**

Data, tissues, and other unique materials collected or generated by the Registries may be made available to other scientists under the following conditions:

1. Potential research collaborators must submit to the Registries a written proposal that describes the specific materials requested, and includes a clear scientific hypothesis for the proposed usage of the requested materials.
2. Research collaborators must provide written assurance that the Registries' policies with respect to human subjects and privacy of the Registrants and their next-of-kin will be followed as agreed in Form 106.
3. Research collaborators who will receive biological samples from deceased Registrant(s) must provide assurance that they are authorized to handle human samples.

Materials from the National Human Radiobiological Tissue Repository are available only to those researchers who qualify as collaborative researchers, as described above.

**Dissemination of Registries' data and tissue materials**

The USTUR director must approve each individual who will have access to USTUR data and/or tissue materials by signing the administrative portion of F106 (USTUR Statement of Confidentiality).

Registries' data are classified into three levels, based on the potential for identification of the donors and dissemination of the data to other researchers. Access to the data will be restricted as follows:

<u>Level 1</u>: Data include direct personal identifiers and specific dates of events with specific sites of employment. These data are available, by written request, to medical and radiation protection groups from the worksites of the Registrants. Access to these





data is restricted by site. For example, medical and radiation protection personnel at a work site may access data of Registrants only from that site. Signed confidentiality statements (Form 106) must be received from the responsible person(s) at the sites requesting data.

<u>Level 2</u>: Data include no direct personal identifiers; however, specific dates of events and general descriptions of the sites of employment are included. These data are available to collaborative researchers as defined above.

<u>Level 3</u>: Data include no direct personal identifiers, only general times of employment and radiologic events, and general information regarding worksites.

Registrant data shall be sent to collaborators as PDFs that have been redacted of direct personal identifiers (name, SSN, address, phone number, fax number, email address, worker identification numbers, medical record numbers), encrypted using 256AES technology (password protected), and copied to a removable storage device (e.g. CD/DVD, USB drive, etc.). The removable storage device shall be shipped overnight, signature required, for receipt to the researcher, and the password will be sent to the researcher by a different means (e.g. email). Correspondence regarding Registrants shall be limited to their unique four-digit case number.

Tissues shall be shipped, for overnight delivery, in compliance with all applicable shipping regulations.

**Data Storage**

Paper and electronic files containing Registrant information must be kept in a secure location. Computers or servers that have Registrant information must have a firewall and be password protected. Registrant data may not be stored on web-based backup systems, e.g. the cloud.

**Additional Researchers or Collaborators**

USTUR data and tissue materials are shared with approved collaborators for specific research purposes. Tissue materials may not be analyzed for purposes beyond the scope of research agreed upon prior to receipt of specimens. Data recipients may not share the materials with other researchers or perform research outside the agreed upon scope without prior approval from the Registries.

Each individual who will have access to Registries data must:

1. read USTUR procedures P106 (USTUR Scientific Collaboration and Data Access Policy) and P107 (USTUR Publications Policy); and
2. sign USTUR form F106 (USTUR Statement of Confidentiality).

**Return or Disposal of Registries' data and tissue materials**

All original printed and/or electronic files sent by the USTUR, as well as any secondary files created by the recipient that contain potentially identifiable information, must be destroyed or returned to the USTUR within 1 year of publication, or within 5 years of receipt, whichever comes first. Extensions may be requested in 1-year increments if additional time is needed.

Tissue materials that are not destroyed during analysis must be returned to the USTUR within 1 year of analysis or 3 years of receipt, whichever comes first. Extensions can be requested in 1-year increments if additional time is needed.

**Publication of data and results from collaborative research**

No publicly available or open-literature publication, or presentation, shall be made in which Registrants are identified without the prior consent of the Registrant, or the legally responsible party, unless legally required by law, regulation, or court order.

Scientific manuscripts and technical reports based on collaborative research involving previously unpublished Registries' data, tissue samples, or other materials, or which involve collaborative effort by Registries staff, shall include, as appropriate, one or more Registries staff members as co-authors. If the Registries' involvement has been limited to a loan or provision of tissues or other materials, and the resulting manuscript or technical report has been prepared exclusively by other investigators without consultation with the Registries staff, or inclusion of unpublished Registries' data or evaluation, no Registries staff need be included as co-authors. Instead, a written acknowledgement of the Registries as the source of the tissue or other materials shall be included.

# Appendix C

*in this photo >>>*

Front: Daniel Strom, Elizabeth Thomas, Stacey McComish, Maia Avtandilashvili, Florencio Martinez. Back: Sergei Tolmachev, Martin Šefl, George Tabatadze, Margo Bedell

*the* **USTUR** Newsletter

USTUR-0535-19
Issue 25

## Direct from the Director

Dear Registrants and Families,

This is the time of the year when you receive the USTUR annual newsletter where we give you updates on what happened at the Registries during the year. Let me begin….

I am glad to tell you that in April the U.S. DOE renewed the USTUR program, and our annual budget increased by ~10%. This allowed us to hire a new member of the USTUR research team – Dr. Martin Šefl, who joined us as a postdoctoral fellow in August. Another change in the USTUR personnel is the move of the McComish family to Idaho in November. But no worries, Stacey will continue to be available to answer your questions, as she will be working remotely for a half of a week .

It gives me great pleasure to tell you that, in addition to the funding increase, 2019 was very productive scientifically. The USTUR's fourth special issue of the Health Physics Journal, dedicated to the USTUR's research, was published in August. It contained ten scientific papers and a roundtable discussion. You will find more about each paper in this newsletter. The Registries continued fruitful collaboration with the DOE Million Person Study (MPS), providing the study personnel with a unique opportunity to validate radiation dose assessment methods for internally deposited plutonium. This year, a group of MPS scientists lead by Professor John Boice, Jr, presented at the Scientific Advisory Committee's meeting. In his presentation, Professor Boice stressed the importance of the USTUR's research not only for biokinetic modeling and internal dosimetry, but also in support of radiation epidemiology studies, and emphasized the uniqueness of materials and data available to scientists at the Registries. USTUR faculty continued to serve as members of the National Council on Radiation Protection and Measurements' scientific committee that is focused on the development of a biokinetic model of the brain.

It is my privilege and honor to express my gratitude to our Registrants, who participate in the USTUR's research, and their family members. I wish you all good health and joy over this holiday season, and continued good health in the years to come.

Sergei Tolmachev

*in this issue >>>*

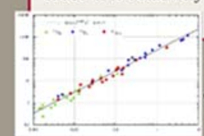
# *Special Issue: The United States Transuranium & Uranium Registries*

The August 2019 issue of the Health Physics journal was dedicated to the USTUR's research. It served as a written summary of presentations from the USTUR's special session at the 2016 Health Physics Society meeting, and it included an introduction, ten journal articles, and a summary of the roundtable discussion. Both the special session and the special issue were organized to commemorate 50 years of the USTUR's research. Below are brief summaries of each paper.

Patricia Worthington (DOE) ***introduced the special issue*** by discussing the USTUR's mission and the scope of its impact on our understanding of plutonium, americium, and uranium in humans.

Bastian Breustedt (Germany) used data from a USTUR donor who inhaled americium to ***test a method*** for mathematically describing the removal of americium from the human body during treatment with chelation drugs. The method was developed by Europe's Coordinated Network on Radiation Dosimetry. The study's findings indicated that ***chelation agents remove americium from the blood, extracellular fluids, and liver***.

Sergei Tolmachev (USTUR) developed a ***simple equation for calculating the amount of plutonium or americium in a Registrant's entire skeleton*** from the activity in just the patella (aka kneecap). The patella is ideal for this, because it is relatively unaffected by osteoporosis.



The activity in the patella is a good predictor of the skeletal activity.

Maria Antonia López (Spain) coordinated an ***intercomparison of americium-241 counting systems*** in Europe, the US, and Canada using the USTUR 0102 skull phantom, and two other phantoms. The USTUR skull phantom consists of tissue-equivalent plastic in the shape of a life-sized head. Embedded in this plastic are the skull bones from the USTUR's first whole body donor.

Head, torso, leg, and arm phantoms. These were made using bones from a USTUR Registrant, and are used to calibrate detectors for monitoring workers.

"This special issue is dedicated to the USTUR Registrants and their families who have voluntarily and selflessly participated in this postmortem study."

~ Patricia Worthington, Director of DOE's Office of Environment, Health, Safety, and Security

Ronald Kathren (USTUR) provided a ***thoughtful history*** of the USTUR, starting with Glenn Seaborg's opinion that initiation of ***"a program to trace the course of plutonium in the body...should have the very highest priority"***. Glenn Seaborg and his colleagues discovered plutonium in 1940.

Ronald Goans (ORAU) studied 40+ year-old blood slides from the radium dial painter studies. These slides revealed an ***anomaly in white blood cells*** (called pseudo-Pelger Huet) that can be used to determine the ***dose to the blood marrow*** from radium. Argonne National Laboratory shipped its collection of materials from the historical radium dial painter studies to the USTUR in 1992.

Radium watch dial

George Tabatadze (USTUR) used a ***digital detector*** to determine the ***distribution of americium in bones*** from a USTUR Registrant. The detector was able to "see" that there was a higher concentration of americium in trabecular bone than in cortical bone.

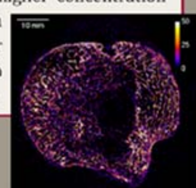


Image of americium detected in a cross section of the humerus bone.

Sara Dumit (USTUR) estimated the dose ***to a USTUR Registrant*** who was exposed to plutonium during a glove-box explosion, and studied ***how effective chelation agents were at removing plutonium*** from the worker's body.

Alan Birchall (England) analyzed data from a USTUR Registrant and from the Pacific Northwest National Laboratory's beagle dog studies. He concluded that the data could only be explained if ***a small amount of plutonium remained "bound" to lung tissues for a very long time***.

Joey Zhou (DOE) ***studied the association of mesothelioma and external radiation*** by matching Registrants who died from mesothelioma to Registrants with similar demographics, such as employment duration, who died from other causes. When the groups were compared, no statistically significant differences were found between the cumulative external radiation doses to those who died from mesothelioma and those who died from other causes.

Maia Avtandilashvili (USTUR) used data from USTUR whole-body donations to derive equations that ***estimate the weight of a person's entire skeleton*** from his or her height, body weight, and/or age. These equations improve equations that were previously published by the International Commission on Radiological Protection.

# Welcome to Post-Doctoral Researcher!

Last August, Martin Šefl joined the USTUR as a post-doctoral researcher. Dr. Šefl will use data from 20+ USTUR Registrants who were exposed to plutonium, and calculate the best-possible estimate of dose for each person. He will then compare these estimates to the plutonium doses that would be calculated with methods used by epidemiological studies.

This work is important because epidemiological studies are as good as the data that they rely on. For example, if workers' doses are underestimated, risk will be overestimated, and vice versa. Dr. Šefl's research will help us understand whether there is a bias in methods used in epidemiological studies, since these studies are typically unable to calculate best-possible doses for each individual.

## A Bit of Background...

USTUR donations are incredibly unique! Not only have Registrants donated their tissues (or whole bodies) for research, they have also shared their radiation exposure records with the USTUR. When scientists combine measurements taken while the worker was alive (such as the amount of plutonium in a worker's lungs or urine) with post-mortem measurements of plutonium in a donor's organs, the result is the best -possible estimate of a worker's intake and plutonium dose.

The USTUR is the only place worldwide, that can conduct this type of research, using both in-depth radiation dosimetry records and post-mortem tissue measurements.

Attendees of the 2019 Scientific Advisory Committee meeting.

U.S. Transuranium & Uranium Registries | Washington State University
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# Appendix D

## UNITED STATES TRANSURANIUM AND URANIUM REGISTRIES

College of Pharmacy and Pharmaceutical Sciences
Washington State University

2019 Scientific Advisory Committee Meeting

Hampton Inn, Riverview Room, Richland, April 11-12, 2019

**Thursday, April 11, 2019**

| | | |
|---|---|---|
| ***07:45 – 08:30*** | ***Breakfast*** | |
| 08:30 – 08:40 | Welcome & Introductions | S. Tolmachev, *USTUR Director* |
| 08:40 – 08:50 | Opening Remarks | R. McClellan, *SAC Chair* |
| 08:50 – 8:55 | Updates from DOE/AU-13. Guidance for FY2020 | J. Zhou, *DOE Manager* |
| 08:55 – 09:10 | WSU/CPPS News | K. Meier, *Associate Dean* |
| 09:10 – 09:25 | Administrative & Financial Developments | M. Bedell, *Program Specialist I* |
| 09:25 – 10:10 | 2018 SAC Recommendations & 2019 USTUR Overview | S. Tolmachev, *Director* |
| 10:10 – 10:30 | USTUR Registrant Statistics and IRB | S. McComish, *Associate in Research* |
| ***10:30 – 11:00*** | ***Coffee Break*** | |
| 11:00 – 11:30 | Radiochemistry Progress Report | G. Tabatadze, *Assist. Res. Professor* |
| 11:30 – 12:15 | MPS, USTUR and Mission Mars | J. Boice, *NCRP* |
| ***12:15 – 13:30*** | ***Lunch*** | |
| 13:30 – 13:40 | ACJ/USTUR Scholar | M. Kinsey, *WSU* |
| 13:40 – 14:00 | DOE Worker Health Studies | E. Ellis, *ORAU* |
| 14:00 – 14:20 | Radiation Epidemiology, Dosimetry, and Biostatistics | A. Golden, *ORAU* |
| 14:20 – 14:40 | Dosimetry: Radiation Protection to Health Effects | K. Eckerman, *ORNL-retired* |
| 14:40 – 15:00 | WSU-PNNL Nuclear Science and Technology Institute | N. Henson, *PNNL* |
| ***15:00 – 15:30*** | ***Coffee Break*** | |
| 15:30 – 16:00 | Research & Operation: Plan for FY2020 | S. Tolmachev, *Director* |
| 16:00 – 16:30 | Discussion and Q & A | USTUR, DOE, SAC, Guests |
| ***18:00 pm*** | ***Social Hour*** | |
| ***18:30 – 21:30*** | ***Dinner at Anthology, 706 Williams Blvd, Richland, WA*** | |

Meetings, breakfast, and lunch will be held in the Riverview Room at the Hampton Inn, 486 Bradley Blvd, Richland, WA

# UNITED STATES TRANSURANIUM AND URANIUM REGISTRIES

College of Pharmacy, Washington State University

2019 Scientific Advisory Committee Meeting

Hampton Inn, Riverview Room, Richland, April 11-12, 2019

**Friday, April 12, 2019 – SAC, DOE and USTUR Management**

| | | |
|---|---|---|
| ***08:00 – 09:00*** | ***Breakfast*** | |
| 09:00 – 09:10 | SAC Membership | S. Tolmachev, *USTUR Director* |
| 09:10– 09:30 | SAC Q & A | R. McClellan, *SAC Chair* |
| 9:30 – 13:00 | SAC Executive Session | R. McClellan, *SAC Chair* |
| *9:30 – 13:00* | *Tour to USTUR Laboratory Facility, Richland Airport* | *USTUR/Guests* |
| ***13:00 – 14:00*** | ***Lunch*** | |
| 14:00 – 16:00 | SAC Debriefing | R. McClellan, *SAC Chair* |

**Friday, April 12, 2019 – All**

***17:30 Social time***

***18:30 – 21:30 Dinner Buffet – Columbia Pointe Room, Hampton Inn***

# Appendix E

USTUR-0427-16

## The United States Transuranium and Uranium Registries (USTUR): A five decade follow-up of plutonium and uranium workers

R. L. Kathren, S.Y. Tolmachev

*U.S. Transuranium and Uranium Registries, College of Pharmacy, Washington State University, Richland, WA*

Dedication: The research of the US Transuranium and Uranium Registries relies heavily upon postmortem autopsy findings and radiochemical analysis of tissues. The enormous debt owed to those now-deceased registrants who unselfishly voluntarily participated in the US Transuranium and Uranium Registries program through postmortem donation of their tissues and to those still-living registrants who have volunteered to be future postmortem tissue donors is hereby acknowledged with gratitude. The scientific findings derived from postmortem analysis of these tissues have been instrumental in advancing our understanding of the actinide elements in humans and have led to refinement, validation, and confidence in safety standards for those who work with these elements as well as for the general public. To these generous and anonymous persons who made this ultimate contribution, this paper is dedicated with great thanks and admiration.

*Health Physics* 117 (2): 118–132; 2019.

USTUR-0436-16

## The importance and quantification of plutonium binding in human lungs

A. Birchall [1], M. Puncher[2], A. Hodgson [2], S.Y. Tolmachev[3]

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[3]*U.S. Transuranium and Uranium Registries, 1845 Terminal Dr., Suite 201, Richland, WA, USA*

Epidemiological studies have shown that the main risk arising from exposure to plutonium aerosols is lung cancer, with other detrimental effects in the bone and liver. A realistic assessment of these risks, in turn, depends on the accuracy of the dosimetric models used to calculate doses in such studies. A state-of-the-art biokinetic model for plutonium, based on the current International Commission on Radiological Protection biokinetic model, has been developed for this purpose in an epidemiological study involving the plutonium exposure of Mayak workers in Ozersk, Russia. One important consequence of this model is that the lung dose is extremely sensitive to the fraction ($f_b$) of plutonium, which becomes bound to lung tissue after it dissolves. It has been shown that if just 1% of the material becomes bound in the bronchial region, this will double the lung dose. Furthermore, $f_b$ is very difficult to quantify from experimental measurements. This paper

summarizes the work carried out thus far to quantify $f_b$ Bayesian techniques have been used to analyze data from different sources, including both humans and dogs, and the results suggest a small, but nonzero, fraction of < 1%. A Bayesian analysis of 20 Mayak workers exposed to plutonium nitrate suggests an $f_b$ between 0 and 0.3%. Based on this work, the International Commission on Radiological Protection is currently considering the adoption of a value of 0.2% for the default bound fraction for all actinides in its forthcoming recommendations on internal dosimetry. In an attempt to corroborate these findings, further experimental work has been carried out by the United States Transuranium and Uranium Registries. This work has involved direct measurements of plutonium in the respiratory tract tissues of workers who have been exposed to soluble plutonium nitrate. Without binding, one would not expect to see any activity remaining in the lungs at long times after exposure since it would have been cleared by the natural process of mucociliary clearance. Further supportive study of workers exposed to plutonium oxide is planned. This paper ascertains the extent to which these results corroborate previous inferences concerning the bound fraction.

*Health Physics* 117 (2): 133–142; 2019.

USTUR-0434-16

### The pseudo-Pelger Huët cell as a retrospective dosimeter: Analysis of a Radium Dial Painter cohort

R. E. Goans[1], R. E. Toohey[2], C. J. Iddins[3], S. L. McComish[4], S. Y. Tolmachev[4], N. Dainiak[3,5]

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[2]*M.H. Chew and Associates, 7633 Southfront Rd., Suite 170, Livermore, CA 94551*
[3]*Radiation Emergency Assistance Center/Training Site (REAC/TS), P.O. Box 117, MS-39, Oak Ridge, TN 37831*
[4]*U.S. Transuranium and Uranium Registries, College of Pharmacy, 1845 Terminal Dr., Suite 201, Richland, WA 99354*
[5]*Radiation Emergency Assistance Center/Training Site (REAC/TS), P.O. Box 117, MS-39, Oak Ridge, TN 37831*

Recently, the pseudo-Pelger Huët anomaly in peripheral blood neutrophils has been described as a new radiation-induced, stable biomarker. In this study, pseudo-Pelger Huët anomaly was examined in peripheral blood slides from a cohort of 166 former radium dial painters and ancillary personnel in the radium dial industry, 35 of whom had a marrow dose of zero above background. Members of the radium dial painter cohort ingested $^{226}Ra$ and $^{228}Ra$ at an early age (average age 20.6±5.4 y; range 13–40 y) during the years 1914–1955. Exposure duration ranged from 1–1,820 wk with marrow dose 1.5–6,750 mGy. Pseudo-Pelger Huët anomaly expressed as a percentage of total neutrophils in this cohort rises in a sigmoidal fashion over five decades of red marrow dose. Six subjects in this cohort eventually developed malignancies: five osteosarcomas and one mastoid cell neoplasm. The pseudo-Pelger Huët anomaly percentage in these cases of neoplasm increases with marrow dose and is best fit with a sigmoid function, suggestive of a threshold effect. No sarcomas are seen for a marrow dose under 2 Gy. These results indicate that pseudo-Pelger Huët anomaly in peripheral blood is a reasonable surrogate for the estimation of alpha dose to bone marrow in historic radiation cases. Hypotheses are discussed to explain late (months to years), early (hours to days), and intermediate (weeks to months)

effects of ionizing radiation, respectively, on the expression of genes encoding inner nuclear membrane proteins and their receptors, on the structure and function of nuclear membrane proteins and lipids, and on cytokinesis through chromatin bridge formation.

*Health Physics* 117 (2): 143–148; 2019.

USTUR-0430-16

## Modeling skeleton weight of an adult Caucasian man

M. Avtandilashvili, S.Y. Tolmachev

*U.S. Transuranium and Uranium Registries, College of Pharmacy, Washington State University, Richland, WA*

The reference value for the skeleton weight of an adult male (10.5 kg) recommended by the International Commission on Radiological Protection in Publication 70 is based on weights of dissected skeletons from 44 individuals, including two US Transuranium and Uranium Registries whole-body donors. The International Commission on Radiological Protection analysis of anatomical data from 31 individuals with known values of body height demonstrated significant correlation between skeleton weight and body height. The corresponding regression equation, $W_{skel}$ (kg) = −10.7 + 0.119 × $H$ (cm), published in International Commission on Radiological Protection Publication 70 is typically used to estimate the skeleton weight from body height. Currently, the US Transuranium and Uranium Registries holds data on individual bone weights from a total of 40 male whole-body donors, which has provided a unique opportunity to update the International Commission on Radiological Protection skeleton weight vs. body height equation. The original International Commission on Radiological Protection Publication 70 and the new US Transuranium and Uranium Registries data were combined in a set of 69 data points representing a group of 33- to 95-y-old individuals with body heights and skeleton weights ranging from 155 to 188 cm and 6.5 to 13.4 kg, respectively. Data were fitted with a linear least-squares regression. A significant correlation between the two parameters was observed ($r^2$ = 0.28), and an updated skeleton weight vs. body height equation was derived: $W_{skel}$ (kg) = −6.5 + 0.093 × $H$ (cm). In addition, a correlation of skeleton weight with multiple variables including body height, body weight, and age was evaluated using multiple regression analysis, and a corresponding fit equation was derived: $W_{skel}$ (kg) = −0.25 + 0.046 × $H$ (cm) + 0.036 × $W_{body}$ (kg) − 0.012 × $A$ (y). These equations will be used to estimate skeleton weights and, ultimately, total skeletal actinide activities for biokinetic modeling of US Transuranium and Uranium Registries partial-body donation cases.

*Health Physics* 117 (2): 149–155; 2019.

USTUR-0431-16

## Evaluating plutonium intake and radiation dose following extensive chelation treatment

S. Dumit, M. Avtandilashvili, S.Y. Tolmachev

*U.S. Transuranium and Uranium Registries, College of Pharmacy, Washington State University, Richland, WA*

A voluntary partial-body donor (US Transuranium and Uranium Registries case 0785) was accidentally exposed to 239Pu via inhalation and wounds. This individual underwent medical treatment including wound excision and extensive chelation treatment with calcium ethylenediaminetetraacetic acid and calcium diethylenetriaminepentaacetic acid. Approximately 2.2 kBq of $^{239}$Pu was measured in the wound site 44 y after the accident. Major soft tissues and selected bones were collected at autopsy and radiochemically analyzed for $^{238}$Pu, $^{239}$Pu, and $^{241}$Am. Postmortem systemic retention of $^{238}$Pu, $^{239}$Pu, and $^{241}$Am was estimated to be 32.0±1.4 Bq, 2,172±70 Bq, and 394±15 Bq, respectively. Approximately 3% of $^{239}$Pu whole-body activity was still retained in the lungs 51 y after the accident indicating exposure to insoluble plutonium material. To estimate the intake and calculate radiation dose, urine measurements not affected by chelation treatment, in vivo chest counts, and postmortem radiochemical analysis data were simultaneously fitted using Integrated Modules for Bioassay Analysis Professional Plus software. The currently recommended International Commission on Radiological Protection Publication 130 human respiratory tract model and National Council on Radiation Protection and Measurements Report 156 wound model were used with default parameters. The intake, adjusted for $^{239}$Pu removed by chelation treatment, was estimated at approximately 79.5 kBq with 68% resulting from inhalation and 32% from the wound. Inhaled plutonium was predominantly insoluble type S material (74%) with insoluble plutonium fragments deposited in the wound. Only 1.3% reduction in radiation dose was achieved by chelation treatment. The committed effective dose was calculated to be 1.49 Sv. Using urine data available for this case, the effect of chelation therapy was evaluated. Urinary excretion enhancement factors were calculated as 83±52 and 38±17 for initial and delayed calcium ethylenediaminetetraacetic acid treatments, respectively, and as 18±5 for delayed calcium diethylenetriaminepentaacetic acid. The enhancement factor decreases proportionally to an inverse cubic root of time after intake. For delayed calcium ethylenediaminetetraacetic acid treatment, with five consecutive daily administrations, the enhancement factor increased from day 1 to 4, followed by approximately a 50% drop on day 5. The half-time of plutonium ethylenediaminetetraacetic acid complex removal in urine was evaluated to be 1.4 d.

*Health Physics* 117 (2): 156–167; 2019.

USTUR-0435-16

## USTUR Case 0846: Modeling americium biokinetics after intensive decorporation therapy

B. Breustedt[1], M. Avtandilashvili[2], S. L. McComish[2], S.Y. Tolmachev[2]

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Decorporation therapy with salts of diethylenetriamine-pentaacetic acid binds actinides, thereby limiting uptake to organs and enhancing the rate at which actinides are excreted in urine. International Commission on Radiological Protection reference biokinetic models cannot be used to fit this enhanced exertion simultaneously with the baseline actinide excretion rate that is observed prior to the start of therapy and/or after the effects of therapy have ceased. In this study, the Coordinated Network on Radiation Dosimetry approach, which was initially developed for modeling decorporation of plutonium, was applied to model decorporation of americium using data from a former radiation worker who agreed to donate his body to the US Transuranium and Uranium Registries for research. This individual was exposed to airborne Am, resulting in a total-body activity of 66.6 kBq. He was treated with calcium-diethylenetriamine-pentaacetic acid for 7 y. The time and duration of intakes are unknown as no incident reports are available. Modeling of different assumptions showed that an acute intake of 5-μm activity median aerodynamic diameter type M aerosols provides the most reasonable description of the available pretherapeutic data; however, the observed Am activity in the lungs at the time of death was higher than the one predicted for type M material. The Coordinated Network on Radiation Dosimetry approach for decorporation modeling was used to model the in vivo chelation process directly. It was found that the Coordinated Network on Radiation Dosimetry approach, which only considered chelation in blood and extracellular fluids, underestimated the urinary excretion of Am during diethylenetriamine-pentaacetic acid treatment; therefore, the approach was extended to include chelation in the liver. Both urinary excretion and whole-body retention could be described when it was assumed that 25% of chelation occurred in the liver, 75% occurred in the blood and ST0 compartment, and the chelation rate constant was $1 \times 10$ $\text{pmol}^{-1}$ $\text{d}^{-1}$. It was observed that enhancement of urinary excretion of Am after injection of diethylenetriamine-pentaacetic acid exponentially decreased to the baseline level with an average half-time of 2.2±0.7 d.

*Health Physics* 117 (2): 168–178; 2019.

USTUR-0432-16

## Digital autoradiography of $^{241}Am$ spatial distribution within trabecular bone regions

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*[3]College of Optical Sciences, University of Arizona, Tucson, AZ*

Digital autoradiography with the ionizing radiation quantum imaging detector is used at the US Transuranium and Uranium Registries for visualizing the microdistribution of alpha particles from $^{241}Am$ and quantifying the activity. The radionuclide spatial distribution was investigated within cortical and trabecular regions of bone samples from US Transuranium and Uranium Registries Case 0846. Multiple specimens from the humerus proximal end, humerus proximal shaft, and clavicle acromial end were embedded in plastic, and 100-μm-thick sections were taken and imaged using the ionizing radiation quantum imaging detector. The detector images were superimposed on the anatomical structure images to visualize $^{241}Am$ distribution in cortical bone, trabecular bone, and trabecular spongiosa. Activity concentration ratios were used to characterize $^{241}Am$ distribution within different bone regions. The trabecular-to-cortical bone and trabecular-spongiosa-to-cortical bone activity concentration ratios were quantified in both humerus and clavicle. The ionizing radiation quantum imaging detector results were in agreement with those obtained from radiochemical analysis of the remaining bone specimens. The results were compared with International Commission on Radiological Protection default biokinetic model predictions. Digital autoradiography was proven to be an effective method for microscale heterogeneous distribution studies where traditional counting methods are impractical.

*Health Physics* 117 (2): 179–186; 2019.

USTUR-0433-16

## A Monte Carlo t-test to evaluate mesothelioma and radiation in the U.S. Transuranium and Uranium Registries

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A cluster of nine mesothelioma cases was observed among 341 registrants' deaths in the US Transuranium and Uranium Registries. Descriptive analysis showed that mesothelioma cases had the highest average cumulative external radiation dose compared with lung cancer, other cancer, and noncancer deaths. Further analysis indicated that the mesothelioma cluster was very different demographically from lung cancer, other cancer, and noncancer deaths. Therefore, an internally matched case-control approach was applied to evaluate the differences in an average cumulative external radiation dose between mesothelioma deaths and other causes of death. A Monte Carlo t test was used to examine the statistical significance of the differences. The results

showed that there were no significant statistical differences in an average cumulative external radiation dose between mesothelioma and lung cancer, other cancers, or noncancers for the internally matched cases and controls.

*Health Physics* 117 (2): 187–192; 2019.

USTUR-0437-16

### Measurements and Monte Carlo simulations of $^{241}$Am activities in three skull phantoms: EURADOS–USTUR collaboration

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An international intercomparison was organized by Working Group 7, Internal Dosimetry, of the European Radiation Dosimetry Group in collaboration with Working Group 6, Computational Dosimetry, for measurement and Monte Carlo simulation of $^{241}$Am in three skull phantoms. The main objectives of this combined exercise were (1) comparison of the results of counting efficiency in fixed positions over each head phantom using different germanium detector systems, (2) calculation of the activity of $^{241}$Am in the skulls, (3) comparison of Monte Carlo simulations with measurements (spectrum and counting efficiency), and (4) comparison of phantom performance. This initiative collected knowledge on equipment, detector arrangements, calibration procedures, and phantoms used around the world for in vivo monitoring of $^{241}$Am in exposed persons, as well as on the Monte Carlo skills and tools of participants. Three skull phantoms (BfS, USTUR, and CSR phantoms) were transported from Europe (10 laboratories) to North America (United States and Canada). The BfS skull was fabricated with real human bone artificially labeled with $^{241}$Am. The USTUR skull phantom was made from the US Transuranium and Uranium Registries whole-body donor (Case 0102) who was contaminated due to an occupational intake of $^{241}$Am; one-half of the skull corresponds to real contaminated bone, the other half is real human bone from a noncontaminated person. Finally, the CSR phantom was fabricated as a simple hemisphere of equivalent bone and tissue material. The three phantoms differ in weight, size, and shape, which made them suitable for an efficiency study. Based on their own skull calibration, the participants calculated the activity in the three European Radiation Dosimetry Group head phantoms. The Monte Carlo intercomparison was organized in parallel with the measurement exercise using the voxel representations of the three physical phantoms; there were 16 participants. Three tasks were identified with increasing difficulty: (1) Monte Carlo simulation of the simple CSR hemisphere and the

Helmholz Zentrum München high-purity germanium detector for calculating the counting efficiency for the 59.54 keV photons of $^{241}$Am, in established measurement geometry; (2) Monte Carlo simulation of particular measurement geometries using the BfS and USTUR voxel phantoms and the Helmholz Zentrum München high-purity germanium detector; and (3) application of Monte Carlo methodology to calculate the calibration factor of each participant for the detector system and counting geometry (single or multidetector arrangement) to be used for monitoring a person in each in vivo facility, using complex skull phantoms. The results of both exercises resulted in the conclusion that none of the three available head phantoms is appropriate as a reference phantom for the calibration of germanium detection systems for measuring $^{241}$Am in exposed adult persons. The main reasons for this are: (1) lack of homogeneous activity distribution in the bone material, or (2) inadequate shape/size for simulating an adult skull. Good agreement was found between Monte Carlo results and measurements, which supports Monte Carlo calibration of body counters as an alternative method when appropriate physical phantoms are not available and the detector and source are well known.

*Health Physics* 117 (2): 193–201; 2019.

USTUR-0429-16

## Estimation of total skeletal content of plutonium and $^{241}$Am from analysis of a single bone

S.Y. Tolmachev, M. Avtandilashvili, R. L Kathren

*U.S. Transuranium and Uranium Registries, College of Pharmacy, Washington State University, Richland, WA*

The skeleton is one of the major retention sites for internally deposited actinides. Thus, an accurate estimation of the total skeleton content of these elements is important for biokinetic modeling and internal radiation dose assessment. Data from 18 whole-body donations to the US Transuranium and Uranium Registries with known plutonium intakes were used to develop a simple and reliable method for estimation of plutonium and $^{241}$Am activity in the total skeleton from single-bone analysis. A coefficient of deposition $K_{dep}$, defined as the ratio of actinide content in the patella to that in the skeleton, was calculated for $^{239}$Pu, $^{238}$Pu, and $^{241}$Am. No statistical difference was found in $K_{dep}$, values among these radionuclides. Variability in $K_{dep}$, values was investigated with relation to skeleton pathology (osteoporosis). The average $K_{dep}$, of 0.0051±0.0009 for the osteoporotic group was statistically different from $K_{dep}$, of 0.0032±0.0010 for nonosteoporotic individuals. The use of $K_{dep}$, allows for rapid estimation of the total skeletal content of plutonium and $^{241}$Am with up to 35% uncertainty. To improve accuracy and precision of total skeleton activity estimates, regression analysis with power function was applied to the data. Strong correlation ($r^2 > 0.9$) was found between $^{239}$Pu, $^{238}$Pu, and $^{241}$Am activities measured in the patella bone and total skeleton activity. The results of this study are specifically important for the optimization of bone sample collection for US Transuranium and Uranium Registries partial-body donations cases.

*Health Physics* 117 (2): 202–210; 2019.

USTUR-0506-18A

### The United States Transuranium and Uranium Registries: Fifty-year history of actinide biokinetic research

M. Avtandilashvili, S. L. McComish, S. Y. Tolmachev

*U.S. Transuranium and Uranium Registries, Washington State University, Richland, WA, USA*

Designed as a program to improve radiation protection of nuclear workers, the U.S. Transuranium and Uranium Registries (USTUR) studies the biokinetics and internal dosimetry of actinides (uranium, plutonium, and americium) in occupationally exposed Registrants who volunteer portions of their bodies, or their whole bodies, for scientific use posthumously. The USTUR is an invaluable national and international resource for testing biokinetic models and improving the application of bioassay data to estimate tissue doses. Established as the National Plutonium Registry (NPR) in 1968 by the U.S. Atomic Energy Commission (AEC), today, the USTUR is one of the longest-operating research programs funded by the U.S. Department of Energy (DOE). Since 1992, the Registries is a grant-funded program operated by College of Pharmacy and Pharmaceutical Sciences at Washington State University.

*BIO Web of Conferences* 2019, 14: 05001.

USTUR-0507-18A

### Biokinetics of soluble plutonium after wound injury treated with Ca-DTPA

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The mission of the United States Transuranium and Uranium Registries (USTUR) is to study the uptake, translocation, retention and excretion (biokinetics), and tissue dosimetry of uranium, plutonium, americium, and other actinides in occupationally exposed volunteer Registrants (tissue donors). These individuals were mainly exposed to various types of plutonium material with inhalation and wound as primary routes of intake. The USTUR holds records on exposure history and bioassay measurements, as well as post-mortem tissue radiochemical analysis results for 19 individuals who had documented intakes of $^{239}$Pu due to contaminated wounds. For 8 individuals, internal deposition resulted from a single wound injury, and three of them were treated with decorporation therapy. In this study, USTUR Case 0303 was used to study biokinetics of soluble Pu after wound intake.

*BIO Web of Conferences* 2019, 14: 02008.

USTUR-0508-18A

## Expanding horizons for actinide biokinetics and dosimetry

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Since 1968, the U.S. Transuranium and Uranium Registries (USTUR) has followed up with occupationally-exposed individuals (volunteer Registrants) by studying the biokinetics (deposition, translocation, retention, and excretion) and tissue dosimetry of actinide elements. The USTUR holds data on work history, radiation exposure and bioassay measurements, as well as medical records from more than 400 former nuclear workers. These individuals had documented intakes of actinides at the levels higher than 74 Bq. Inhalation and wound are two major routes of intake and $^{239}Pu$ is a primary radionuclide.

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USTUR-0509-18A

## Case studies in brain dosimetry for internal emitters: Is more detail needed for epidemiology?

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Element-specific biokinetic models are used to reconstruct doses to systemic tissues from internal emitters. These models typically depict explicitly only those tissues that tend to dominate the systemic behaviour of the element over time. The remaining tissues are aggregated into a pool called *Other* tissue in which activity is assumed to be uniformly distributed. Explicitly identified tissues usually consist of some subset of the tissues liver, kidneys, bone, bone marrow, gonads, thyroid, spleen, and skin. The brain is included explicitly in systemic biokinetic models for a few elements but typically is addressed as an implicit mass fraction of *Other* tissue. This paper summarizes an assessment of potential improvements in brain dosimetry for internal emitters from explicit modelling of brain kinetics in place of treating the brain as an implicit mass fraction of *Other* tissue. Comparisons are made of dose coefficients for selected radionuclides based on alternate versions of the systemic biokinetic model for each radionuclide, differing only in the handling of brain tissue.

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## Limitations of cause of death data among autopsied population in the United States Transuranium and Uranium Registries

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The United States Transuranium and Uranium Registries (USTUR) is a human tissue program that studies the biokinetics and internal dosimetry of actinides – such as uranium, plutonium, and americium – in former nuclear workers who were occupationally exposed to these elements. Tissue donors were predominantly Caucasian males, who volunteered portions of their bodies, or their whole bodies, for scientific use posthumously. The causes of death among 356 USTUR Registrants were determined, and a preliminary analysis of discrepancies between death certificates and autopsy findings was conducted. Although the USTUR population is not a representative sample of U.S. nuclear workers due to self-selection, it provides valuable information, such as the accuracy of death certificates among this autopsied population.

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USTUR-0520-19A

## Case studies in brain dosimetry for internally deposited radionuclides

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Element-specific biokinetic models are used to reconstruct radiation doses to systemic tissues from internally deposited radionuclides. These models typically represent explicitly only those tissues that tend to dominate the systemic behavior of the element over time. The remaining tissues are aggregated into a pool called *Other* tissue in which activity is assumed to be uniformly distributed. Explicitly identified tissues usually consist of some subset of the tissues: liver, kidneys, bone, bone marrow, gonads, thyroid, spleen, and skin. The brain is included explicitly in systemic biokinetic models for a few elements; however, it is typically addressed as an implicit mass fraction of *Other* tissue. There is increasing interest in potential adverse effects of internal emitters, particularly alpha emitters, on the brain as limited analogues for galactic cosmic ray exposures during space travel. The Million Person Study is estimating brain doses from exposure to radionuclides and evaluating dementia, Alzheimer's disease, Parkinson's disease, and motor neuron disease as possible adverse outcomes of combined high- and low-LET exposures to brain tissue. This paper summarizes an assessment of potential improvements in brain dosimetry for internal emitters from explicit modelling of brain biokinetics in place of treating the brain as an implicit mass fraction of *Other* tissue. Comparisons are made of dose coefficients for

selected radionuclides based on alternate versions of the systemic biokinetic model for each radionuclide, differing only in the handling of brain tissue.

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USTUR-0521-19A

## Cylindrical representations of recycling biokinetic models

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In 2018, the USTUR developed a cylindrical representation of the Leggett et al. (2005) recycling model describing the biokinetics of systemic plutonium. That visualization is updated to incorporate the International Commission on Radiological Protection (ICRP) human alimentary tract model (HATM) in place of the "GI Tract" compartment, which required assuming that uptake from the small intestine goes into the Blood 2 compartment rather than the Blood 1 compartment. New cylindrical visualizations are presented for recycling models for uranium and americium based on the ICRP publication series on occupational intakes of radionuclides (OIR). The OIR publications or drafts currently show these models with "GI Tract" compartments; in this work, the HATM has been used in place of the GI tract in the uranium and americium models. Extensions of the models to include an explicit compartment for brain have also been developed, since the effects of high-linear energy transfer radiation on the brain are of interest to those studying the effects of space radiation on astronauts. The insights provided by these novel representations are discussed.

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USTUR-0522-19A

## Macrodistribution of plutonium among dosimetric compartments of the human respiratory tract

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The International Commission on Radiological Protection (ICRP) Publication 66 human respiratory tract model (HRTM) and its revised version published in ICRP Publication 130 divide the thoracic region of the lungs into three compartments: bronchial (BB), bronchiolar (bb), and alveolar-interstitial (AI). Human lungs consist of five anatomical lobes. Each lobe contains tissues from all three dosimetric compartments. Most of extensive data, published in peer-reviewed literature on retention and distribution of inhaled plutonium in different anatomical regions and segments of the human lungs, were obtained from autopsy studies of the Mayak Production Association workers. However, there are very limited data on plutonium distribution among the compartments of the ICRP HRTM. From a dosimetry standpoint, information on plutonium retention in BB, bb and AI compartments is critical. In this study, the lungs from four US Transuranium and Uranium

Registries' (USTUR) tissue donors were dissected based on the ICRP human respiratory tract model and radiochemically analyzed. Plutonium activity was measured separately in BB, bb and AI. Three of these donors had documented inhalation intake of soluble plutonium nitrate, while the fourth individual inhaled very insoluble, refractory $PuO_2$ particles. Two of these individuals were smokers. Results indicated that plutonium was uniformly distributed among the dosimetric compartments. Plutonium distribution was independent of smoking status and plutonium material solubility type.

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USTUR-0525-19A

## Plutonium in human brain: Is more biokinetic detail needed for dosimetry?

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Introduction: Biokinetic model for systemic plutonium is used to estimate internal radiation doses to organs and tissues. The brain is not included explicitly in the model but is aggregated into a pool called *Other* tissue in which activity is assumed to be uniformly distributed. Explicitly identified tissues are liver, bone, bone marrow, kidneys, and gonads. Due to increasing interest in potential adverse effects of radiation on the brain, efforts are underway within the Million Person Study to improve brain dosimetry for both internal and external radiation sources. The purpose of this study was to assess potential improvements in brain dosimetry for incorporated plutonium from explicit modelling of brain kinetics.

Methods: The most relevant data available for modelling brain kinetics of plutonium are autopsy data for individuals occupationally exposed to this element. The U.S. Transuranium and Uranium Registries (USTUR) has studied the biokinetics and tissue dosimetry of actinides in nuclear workers. Plutonium ($^{239}$Pu) activities in brains were measured for 70 individuals. In 31 cases, Brain/(Liver+Skeleton) activity ratios were estimated to modify plutonium systemic model by explicitly adding brain compartment. Plutonium brain dosimetry was evaluated for two alternate versions of the systemic biokinetic model: (a) with the brain as an implicit mass fraction of *Other* tissue and (b) with explicit modelling of brain kinetics. Dose coefficients for $^{239}$Pu based on both versions of the biokinetic model were calculated and compared.

Results: $^{239}$Pu activity concentrations in brain tissue of occupationally exposed individual ranged from 0.0003 to 4.4 Bq kg$^{-1}$ with a median of 0.027 Bq kg$^{-1.}$ A median value for these individuals, the brain contains ~0.2% as much $^{239}$Pu as liver and skeleton combined. A single compartment representing brain was added to the plutonium biokinetic model, and parameter values were set to yield a long-term total activity ratio Brain/(Liver + Skeleton) of 0.002. Dose coefficient for brain for acute $^{239}$Pu input to blood was 0.022 mSv Bq$^{-1}$ based on biokinetic model with brain included in *Other* tissue and 0.026 mSv Bq$^{-}$1 based on modified version with an

explicit brain compartment. The dose coefficient based on the modified model with an explicit brain compartment is 0.96 times the value based on the model with implicit brain.

Conclusions: The results of the study to this point suggest that explicit biokinetic modelling of a brain pool for plutonium is not likely to result in significant difference in estimated dose to the brain.

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USTUR-0526-19A

## Uranium content, distribution, and biokinetics in human body

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Since 1968, the U.S. Transuranium and Uranium Registries (USTUR) has followed up occupationally-exposed individuals (volunteer tissue donors) by studying biokinetics and dosimetry of actinide elements. The USTUR currently holds data and tissue samples from six whole- and 27 partial-body donors with occupational uranium intakes. In this study, uranium tissue concentrations, body distribution, and biokinetics were compared between a group of individuals with occupational exposure to uranium and a group with chronic environmental-only intakes. Of two occupationally-exposed individuals, one had chronic inhalation intake of uranium oxide with natural composition, and another had acute inhalation of slightly enriched uranium hexafluoride. For all five individuals, the skeleton was a major deposition site where 51±20% of systemic uranium was retained at the time of death. Average concentration in the skeleton was 4.0±0.5 mg $kg^{-1}$ for all individuals except the uranium hexafluoride case, where concentration in the skeleton was two times higher. Uranium was well-distributed among soft tissues with concentrations mostly clustered about 1 μg $kg^{-1}$, except the uranium hexafluoride case, where median concentration was three times lower. For the uranium hexafluoride case, $^{235}U/^{238}U$ atom ratio analysis 65 years post-intake indicated that 95% of uranium in the lungs originated from accidental inhalation. This fraction was estimated to be 40% for the brain, 26% for the liver, 21% for the skeleton, and 7% for the kidneys.

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USTUR-0527-19A

## A method to measure U, Pu, and Am in human keratinous samples using extraction chromatography and ICP-MS

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Human biomonitoring at nuclear facilities is a potential tool for treaty compliance monitoring. A non-invasive bioassay sensitive to special nuclear materials could be useful for identifying personnel involved in clandestine activities. A recent, small pilot study has demonstrated that hair and nail samples collected from occupationally exposed contain actinides. A limitation of the pilot study is that occupational exposure was self-reported and information was not available on how or when workers were exposed to actinides. To further develop the use of keratinous material as a biomonitor for exposure to internally deposited actinides, hair and nail samples from the United States Transuranium and Uranium Registries (USTUR) will be analyzed for Pu, Am, and U. The advantage of this cohort is that worker exposure histories are well documented and actinide concentrations in hair and nail can be related to concentrations in other organs. The hair and nail samples from the USTUR have previously been acid-digested and stored in 6–8 M HCl. This work will compare two methods developed to measure Pu, Am, and U isotope ratios in keratinous samples stored in 6–8 M HCl. In the first method, samples are evaporated to dryness and brought back up in 3 M $HNO_3$. The separation is accomplished using TEVA, UTEVA, and DGA resin cartridges. In the second method, the samples are evaporated to dryness and brought back up in 6 M HCl. The separation is accomplished using a single DGA resin. The separated samples are analyzed for $^{235}U/^{238}U$ and $^{236}U/^{238}U$ using a multi-collector inductively coupled plasma mass spectrometry (MC-ICP-MS) with a desolvating nebulizer (DSN). The DSN-MC-ICP-MS also used to analyze $^{239}Pu$, $^{240}Pu$, and $^{241}Am$ by isotope dilution techniques. Each method will be evaluated by sample limit of detection, chemical tracer recovery, and analysis of duplicate samples.

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## Plutonium in human brain: Is more biokinetic detail needed for dosimetry?

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The possible health effects of cosmic rays in space (i.e., high energy heavy ions) are unknown. Animal experiments suggest that these exotic high-energy ions with high atomic numbers might result in cognition

effects and perhaps early dementia. National Aeronautics and Space Administration is particularly interested in such exposures to galactic cosmic rays and their possible consequences for long-term missions, such as to Mars. The Million Person Study attempts to address these issues related to cognition and dementia by studying nuclear workers with intakes of alpha-emitting radionuclides. Although limited in numbers, these workers are the only human analogue for exposure to space radiation. Postmortem radiochemical analyses of human tissues collected at autopsies have shown that intakes of plutonium, radium, americium, uranium, and polonium deposit in the brain. Studies at the US Transuranium and Uranium Registries have demonstrated that approximately 0.2% of systemic plutonium is deposited in the brain. Internally deposited radionuclides continually expose the brain to helium nuclei (alpha particles). The radiation dose to brain tissue is assumed to be uniform and can be estimated from bioassay data and tissue analyses using biokinetic and dosimetric models. To improve brain dose estimates for internally deposited radionuclides, explicit modelling of brain biokinetics is being investigated. Actinide distribution within the brain is being examined at Argonne National Laboratory by synchrotron-based x-ray fluorescent microscopy using the Advanced Photon Source.

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