USTUR-0654-23

United States Transuranium and Uranium Registries

Annual Report

April 1, 2022 – March 31, 2023

College of
Pharmacy and Pharmaceutical Sciences
WASHINGTON STATE UNIVERSITY

USTUR-06354-23

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April 1, 2022 – March 31, 2023

Compiled and Edited

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

August 4, 2023

Acknowledgment: This material is based upon work supported by the U.S. Department of Energy, Office of Domestic and International Health Studies (AU-13) under Award Number DE-HS0000073.

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United States Transuranium and Uranium Registries
College of Pharmacy and Pharmaceutical Sciences
Washington State University 1845 Terminal Drive, Suite
201, Richland, WA 99354

800-375-9317 Toll Free
509-946-6870 Direct
509-946-7972 FAX
www.ustur.wsu.edu

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Faculty and Staff

Faculty

Sergey Y. Tolmachev	Director, Research Professor
Maia Avtandilashvili	Assistant Research Professor
George Tabatadze	Assistant Research Professor
Martin Šefl	Postdoctoral Research Associate
Xirui Liu	Associate in Research
Stacey L. McComish	Associate in Research
Alexander Tabatadze	Associate in Research

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
Florencio T. Martinez	Medical Technologist

Consultants

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

Advisory Committee

Committee Chair

Thomas L. Rucker	Radiochemistry

Committee Members

Janet Benson	Toxicology
Luiz Bertelli	Health Physics
Katherine Ertell	Ethics (*incoming*)
Timothy J. Ledbetter	Ethics
Heather J. Hoffman	Epidemiology & Biostatistics
David Pawel	Epidemiology & Biostatistics (*incoming*)
Arthur W. Stange	Occupational Health

Contact Information

Address

U.S. Transuranium and Uranium Registries
College of Pharmacy and Pharmaceutical Sciences
Washington State University
1845 Terminal Drive, Suite 201
Richland, WA 99354–4959

Phone: 509–946–6870
Toll-Free: 800–375–9317
Fax: 509–946–7972
www.ustur.wsu.edu

E-mail

Sergey Y. Tolmachev	stolmachev@wsu.edu
Maia Avtandilashvili	m.avtandilashvili@wsu.edu
Margo D. Bedell	margo.bedell@wsu.edu
Xirui Liu	xirui.liu@wsu.edu
Stacey L. McComish	s.mccomish@wsu.edu
Martin Šefl	martin.sefl@wsu.edu
George Tabatadze	george.tabatadze@wsu.edu
Alexander Tabatadze	alexander.tabatadze@wsu.edu
Elizabeth M. Thomas	elizabeth.thomas@wsu.edu

Executive Summary

Sergey Y. Tolmachev, *Professor and 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, 2022 – March 31, 2023. This is the first fiscal year (FY) of the USTUR's 5-year grant proposal (FY2023–FY2027: April 1, 2022 – March 31, 2027).

National Council on Radiation Protection and Measurements

Dr. Avtandilashvili has been elected as a Council Member (2023–2029) for the National Council on Radiation Protection and Measurements.

U.S. Environmental Protection Agency

Dr. Avtandilashvili and Dr. Strom were appointed as Special Government Employees with the U.S. Environmental Protection Agency (EPA) to serve as members of the Radionuclide Cancer Risk Coefficients Panel of the EPA's Science Advisory Board. The panel will review Federal Guidance Report No. 16.

DOE Officials Visit

Kevin Dressman, Director of DOE Office of Health and Safety (EHSS-10), and Garrett Smith, Director of DOE Office of Nuclear Safety (EHSS-30), visited the USTUR. Dr. Tolmachev provided an overview of the USTUR history, research, and operation. Topics such as radiochemical tissue analysis and cost of laboratory facility operation, uniqueness of the USTUR/NHRTR tissue sample collections, and utilization of the available materials for research other than the core USTUR research were discussed.

HPS Workshop: USTUR Special Session

Marking its 55th anniversary, the USTUR organized the special session at the Health Physics Society's (HPS) Second Annual Hybrid Winter Workshop on Internal Dosimetry. This is a second USTUR special session conducted at the HPS national meetings. Nine podium presentations were given.

Anthony C. James /USTUR Scholarship

2023 Anthony C. James/USTUR scholarships of $1,000 were awarded by WSU Foundation to two WSU Tri Cities undergraduate students from College of Nursing and School of Engineering and Applied Sciences. These are the fifth and sixth awardees since the inception of the scholarship in 2019.

Scientific Advisory Committee

The annual 2022 meeting of the USTUR's Scientific Advisory Committee was held April 28–29, 2022 by videoconference. The Committee reviewed USTUR's progress since the previous meeting (April 8–9, 2021) and provided seven recommendations for 2023.

DOE Grant Renewal

The FY2024 grant renewal proposal to manage and operate the USTUR and the associated NHRTR, during April 1, 2023 – March 31, 2024 was submitted to the Department of Energy (DOE) Office of Health and Safety, Office of Domestic and International Health Studies (EHSS-13). The approved FY2024 budget amounted to $1,310,544.

Extra Funding Received

The Registries received $765,527 of additional funding from DOE/EHSS-10. This is a 4-year (February 1, 2023 –

March 31, 2027) 'amendment' grant to improve radiochemistry laboratory infrastructure and to increase tissue analysis throughput as well as to hire a research faculty to strengthen internal research.

New Hires

Xirui Liu was hired as an Associate in Research (teleworking) at 0.5 full-time equivalent (FTE). Ms. Liu has both a master's degree in health informatics from Weill Cornell Medicine (2022) and a master's in public health in international health and development from Tulane University (2021). She also earned her Bachelor of Medicine, Bachelor of Surgery degree from Huazhong University of Science and Technology, China in 2017. Ms. Liu has worked with the USTUR as a student collaborator since 2019.

Organization and Personnel

In FY2023, 7.8 full-time equivalent (FTE) positions, including one full-time postdoctoral research associate, and a total of 0.3 FTE for temporary professional workers, were supported by the available funding. The organizational structure of the USTUR Research Center during FY2023 is provided in Appendix A.

Registrant Donations

Two tissue body donations were received in FY2023: (i) whole-body Case 0802 and (ii) partial-body Case 0398. As of March 31, 2023, the USTUR had received 48 whole- and 318 partial-body tissue donations.

Scholar Activities

FY2023 was a very productive year for the Registries. Dr. Tolmachev published a review paper "Radiochemistry and nuclear chemistry workforce in the United States" at the Journal of Applied Clinical Medical Physics. Three scientific papers and one editorial letter were co-authored by the USTUR faculty. Five invited talks, nine podium presentations, and three poster presentation were given by USTUR faculty. In addition, one invited talk and ten podium presentations were co-authored.

Radiochemistry Operation

Radiochemistry laboratory operation was reduced due to infrastructure upgrades. One hundred sixteen tissue samples were analyzed for plutonium and americium isotopes using α-spectrometry. Radiochemical analyses of two partial-body cases were completed. As of March 31, 2023, the USTUR retains a backlog of 2,210 tissue samples from 20 whole- and eight partial-body cases.

Health Physics Database

A total of 8,203 exposure and bioassay records from 23 partial-body cases was standardized. As of March 31, 2023, the database holds 168,428 data records from 334 USTUR cases.

Institutional Review Board

The annual Institutional Review Board (IRB) review was completed and approved by the Central DOE IRB, and is valid until August 21, 2023 (WASU-68-50181).

Registrant Communication

The annual USTUR Newsletter (USTUR-0635-22) was sent to the Registrants and/or their next-of-kin (Appendix B).

Reporting Requirements Met

Four FY2023 quarterly progress reports for the USTUR federally funded grant (DE-HS0000073) were distributed to the sponsoring agency and university. The FY2022 annual report (USTUR-0632-22) was published and electronically distributed among scientific collaborators, and published on the USTUR website.

Financial and Administrative Report

Margo D. Bedell, *Program Specialist II*

On March 31, 2023, the USTUR completed the first grant year of the USTUR's 5-year grant proposal (April 1, 2022 – March 31, 2027). The FY2023 funding was:

Federal Grant

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

Award number: DE-HS0000073.

Title: Manage and Operate the United States Transuranium and Uranium Registries.

Amount awarded: $1,200,000.

Period: April 1, 2022 – March 31, 2023.

Operating budget

A positive balance of $513 was reported at the end of FY2022, resulting in FY2023 operating budget of $1,200,513. Total expenses for FY2023 were $1,199,924 (Figure 1).

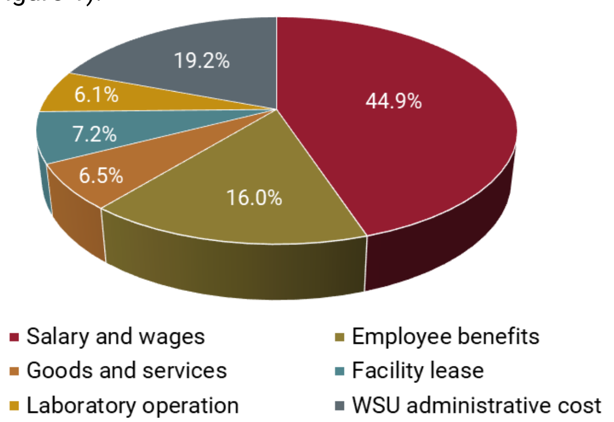


Fig. 1. FY2023 operating budget breakdown.

FY2024 Funding

Grant renewal

On January 3, 2023, the FY2024 grant renewal proposal to manage and operate the USTUR and the associated NHRTR, during April 1, 2023 – March 31, 2024 was submitted to the DOE/EHSS-13. The approved FY2024 budget was $1,310,544.

Grant amendment

On December 14, 2022, the Registries requested $765,527 of additional funding from DOE/EHSS-13. This is DE-HS0000073 grant amendment to improve radiochemistry laboratory infrastructure and to hire a research faculty to strengthen internal research. Funding was allocated as follows: $350,162 in the Year 1 (Y1), $204,693 (Y2), $169,510 (Y3), and $41,162 (Y4). A total of $350,162 was allocated in FY2023 (Y1). Of that, $335,000 was carried over to FY2024.

Reporting

The FY2022 annual report (USTUR-0632-22) for the DE-HS0000073 grant was published online: https://ustur.wsu.edu/publications/annual-reports/ and electronically distributed within the scientific community. Four quarterly reports were electronically submitted to the funding agency and the university.

Registrant Statistics

Stacey L. McComish, *Associate in Research*

As of March 31, 2023, the Registries had 880 Registrants in all categories (Table 1). Of that number, 22 were living and 375 were deceased. The 22 living Registrants included four individuals who were registered for eventual whole-body donation, 14 for partial-body donation, and four for 'Special Studies,' i.e., a bioassay study with no permission for autopsy. There were also 483 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, 2023

Total living and deceased Registrants	397
Living Registrants	22
Potential partial-body donors	14
Potential whole-body donors	4
Special studies	4
Deceased Registrants	375
Partial-body donations	318
Whole-body donations	48
Special studies	8
Inactive Registrants	483
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. Instead, any new Registrants will be asked to sign the informed consent and other forms at the point of initial consent, and no renewal of this consent will be required. Existing Registrants are required to sign the one-time consent paperwork when their existing five-year renewal paperwork expires. One Registrant who had previously signed a five-year agreement was sent one-time renewal paperwork shortly before his autopsy authorization was set to expire. He chose to withdraw from the program, and his status was changed to inactive. All living Registrants have now signed one-time renewal paperwork, and no further renewals will be needed in the future.

Annual Newsletter

The USTUR distributes a newsletter to Registrants and their next-of-kin on a yearly basis. The 2023 letter was mailed in December (Appendix B). It discussed a visit by DOE directors, and how increased funding was used by the Registries to replace corroded fume hoods, and to hire a post-doctoral researcher and a part-time faculty member. The newsletter also contained articles about the USTUR's role in deepening our understanding of how plutonium is retained in the lungs and about two faculty members who have been selected to serve on an Environmental Protection Agency (EPA) advisory board.

Registrant Deaths

During FY2023, the USTUR received two donations from individuals who had worked with actinides for decades. The first was a whole-body donor was involved in several contamination and minor wound incidents. Worksite personnel estimated that his systemic deposition of plutonium was 1 nCi. The second was a partial-body donor who had no recorded plutonium intakes, and a single lung count that detected ^{241}Am and natural uranium. He was involved in several beta/gamma contamination incidents, and several lung counts detected fission products; however, the worksite estimated that there was no deposition of radioactive material above 5% of the contemporary limits.

One additional partial-body Registrant passed away this quarter; however, there was insufficient time to test for HIV/Hepatitis and perform the autopsy before scheduled cremation. He had been involved in an inhalation of soluble plutonium, and was changed to a special studies case for possible biokinetic modeling.

Registrant Status

The average age of living whole- and partial-body Registrants was 87.6±7.8 years and 82.8±14.0 years, respectively. The average age at death for the USTUR's deceased whole- and partial-body Registrants was 78.6±11.4 and 69.0±13.5 years, respectively.

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

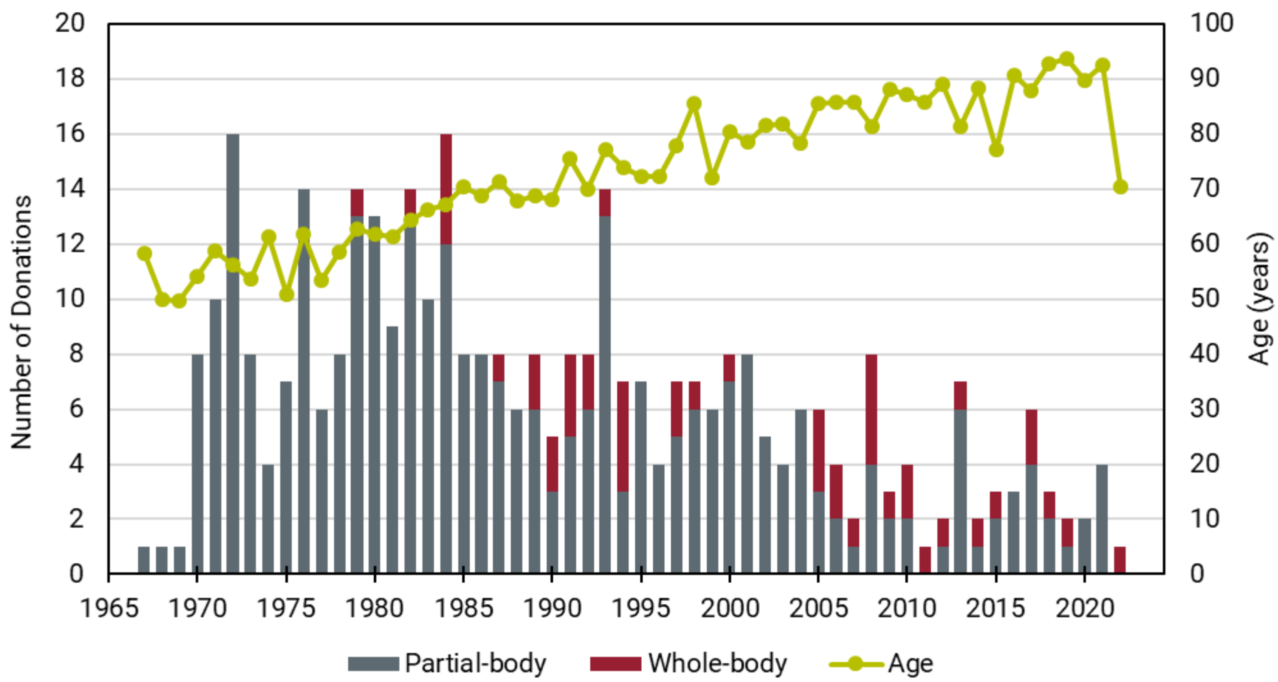


Fig. 2. Number of whole- and partial-body donations by calendar year and average age.

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 48 whole-body and 318 partial-body tissue donors, as well as 18 living potential donors and 13 special study cases (four living and nine deceased).

As of March 31, 2023, standardization of health physics records and bioassay data was completed for 18 living potential donors (four whole-body and 14 partial-body), and 312 deceased donors (48 whole-body and 264 partial-body). In total, 167,540 health physics records from deceased and living Registrants have been entered into the database. In addition, data entry was completed for four special study cases with a total of 889 records. Figure 3 shows FY2023 progress toward population of the database.

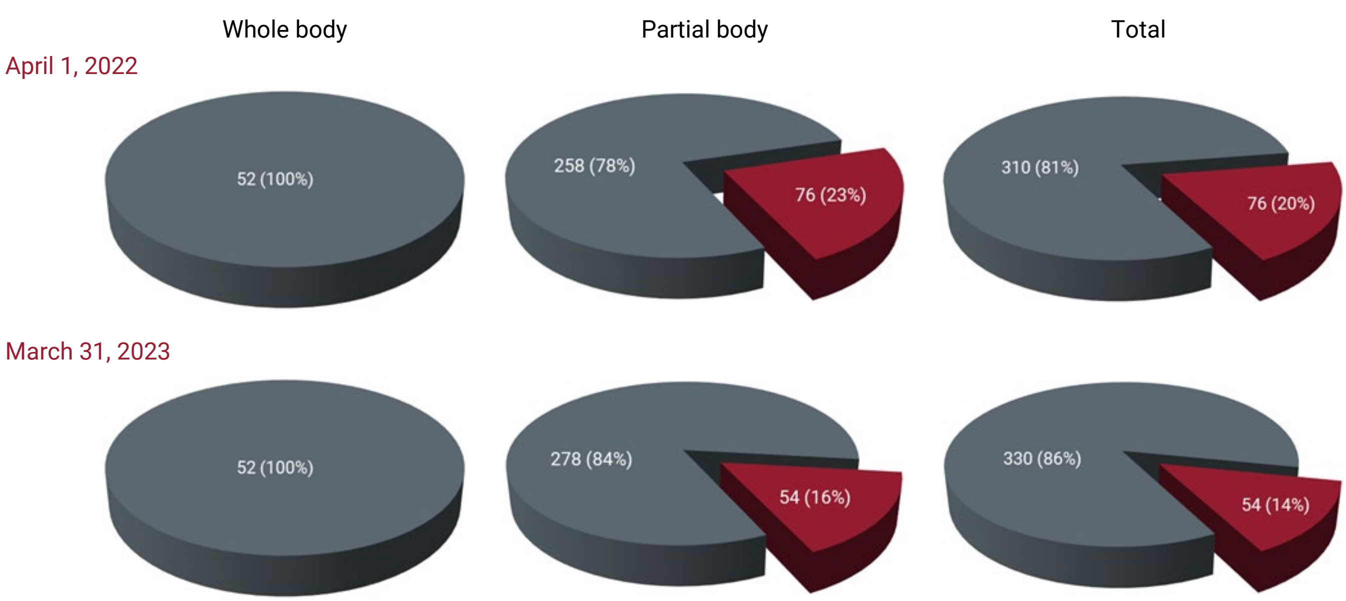


Fig. 3. FY2023 health physics database progress: ■ complete cases; ■ incomplete cases.

Figure 4 shows the FY2008 – FY2023 progress and the overall status of the health physics database as of March 31, 2023.

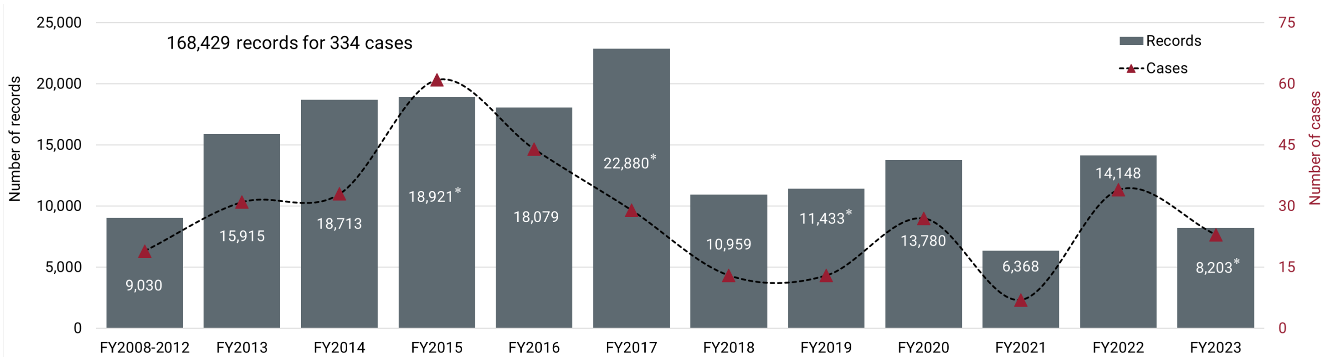


Fig. 4. FY2023 status of the USTUR health physics database. Includes four special study cases completed in FY2015, FY2017, FY2019, and FY2023 (*)

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).

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, and are deferred until we are able to hire appropriate student laboratory personnel to complete them.

THEMIS Inventory

As of March 31, 2023, 25,665 parent samples and 12,711 subsamples had been inventoried using the THEMIS database (Table 2).

Table 2. Inventoried samples as of March 31, 2023

Tissue type	Samples		
	Parent	Sub-	Total
USTUR donations			
Soft tissue samples	5,319	500	5,819
Bone samples	4,823	84	4,907
Histology slides	1,694	2,196	3,890
Acid solutions	7,046	1,193	8,239
Planchets	0	8,035	8,035
Paraffin blocks	134	48	182
ANL tissues & slides	1,440	434	1,874
LASL solutions	4,447	92	4,539
Blank and QC acids	451	56	507
Miscellaneous	311	73	384
Total	25,665	12,711	38,376

Long-term Trends

Figure 5 shows the cumulative number of inventoried samples at the end of each calendar year from 2010 to 2022. It can be seen that initial efforts focused on inventorying USTUR tissues and acids. From 2016 to 2019, laboratory personnel focused on LASL acids and USTUR planchets inventories. Since the beginning of the COVID-19 pandemic in 2020, only inventory activities associated with routine radiochemical operations have been maintained. This is reflected in the gradual increase in the number of USTUR acids and planchets.

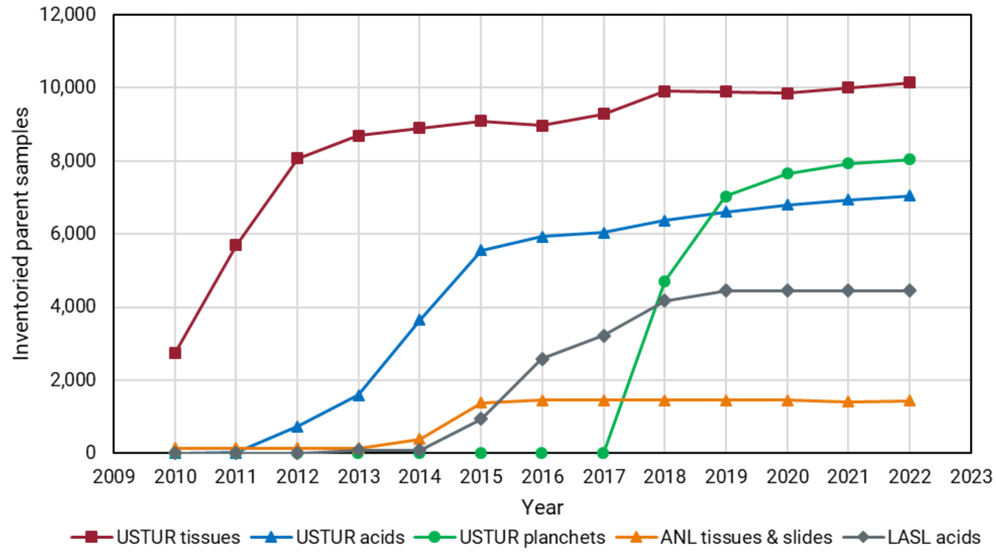


Fig. 5. Cumulative number of inventoried NHRTR samples at the end of each calendar year.

Radiochemistry Operations

George Tabatadze, *Research Assistant Professor*

This section describes specific activities and achievements of the Radiochemistry Group during FY2023.

Personnel

As of March 31, 2023, operation of the radiochemistry laboratory was supervised by Dr. Tolmachev (Principal Radiochemist) with two full-time personnel – Dr. George Tabatadze (Research Assistant Professor) and Ms. Elizabeth Thomas (Laboratory Technician II).

Facility and Equipment

In the beginning of FY2023, the laboratory facility's operational tasks were limited due to the installation of the exhaust system for newly installed fume hoods. Three polypropylene fume hoods were delivered and installed at the USTUR radiochemistry laboratory in Q4 FY2022. The new fume hoods became operational in Q3 FY2023.

In FY2023, a ductless fume hood for the electrodeposition unit was purchased and installed in the radiochemistry laboratory.

Additionally, two plastic fume hoods and plastic fume exhaust system (ducting and blowers) were purchased for the radiochemistry laboratory with anticipated delivery and installation in FY2024.

Data Quality Assurance Plan

During FY2023, the USTUR completed a Data Quality Objectives document that harmonizes the Quality Assurance Program plan of the Registries with the concepts, processes, and guidelines outlined in the Multi-Agency Radiological Laboratory Analytical Protocols and ANSI ANS N41.5-2012 documents. This brings a nationally consistent approach to producing radioanalytical laboratory data that meet USTUR's data requirements, including aspects of the USTUR radiochemistry operation that are innovative or unique to the Registries.

Radiochemistry laboratory new polypropylene ducted fume hoods (top), new PVC ducting and exhaust system (middle), and new ductless fume hood (bottom)

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 FY2023, analyses of 116 tissue samples for ^{238}Pu, $^{239+240}Pu$, and ^{241}Am, including 40 bone and 76 soft tissue samples from four partial-body donation, cases 0334 (died 2004), 0452 (2020), 0475 (2021) and 0640 (1992), were completed. Additionally, 185 tissue samples, including 24 bone and 161 soft tissue samples from five partial-body and four whole-body donations, were submitted for analysis. Figure 6 shows FY2018 – FY2023 tissue analysis progress.

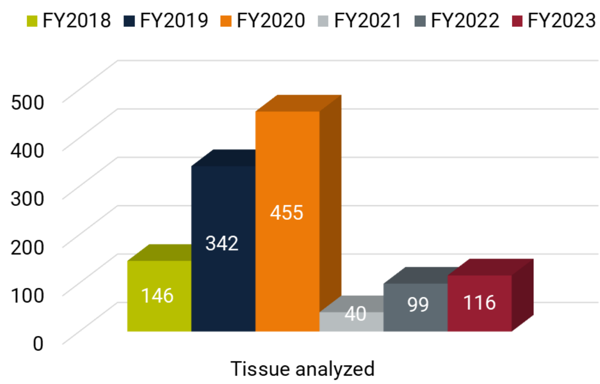


Fig. 6. USTUR tissue analysis progress in FY2018 – FY2023.

Radiochemistry Case Analysis

As of March 31, 2023, the USTUR had received 48 whole- and 318 partial-body donations, including one whole-body and one partial-body donations accepted during FY2023.

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 provide 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 FY2023, radiochemical analyses of two 'incomplete' partial-body donations (cases 0454 and 0475) were complete. Radiochemistry status of these cases was changed to 'complete'. Radiochemical analysis of two previously 'intact' partial-body donations, cases 0288 and 0718, began in FY2023. Radiochemistry status of these cases was changed to 'incomplete'. Figure 7 shows FY2018 – FY2023 case analysis progress.

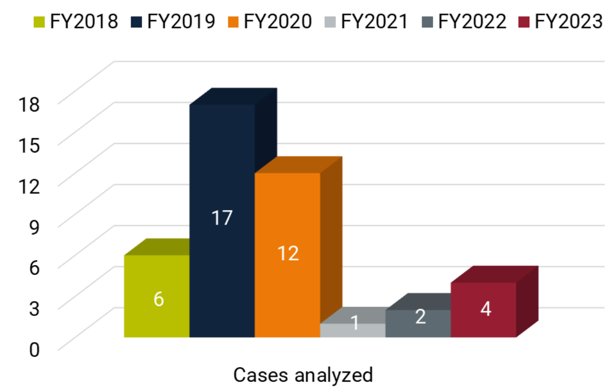


Fig. 7. USTUR case analysis progress in FY2018 – FY2023.

The status change of case analyses from FY2022 to FY2023 is shown in Figure 8.

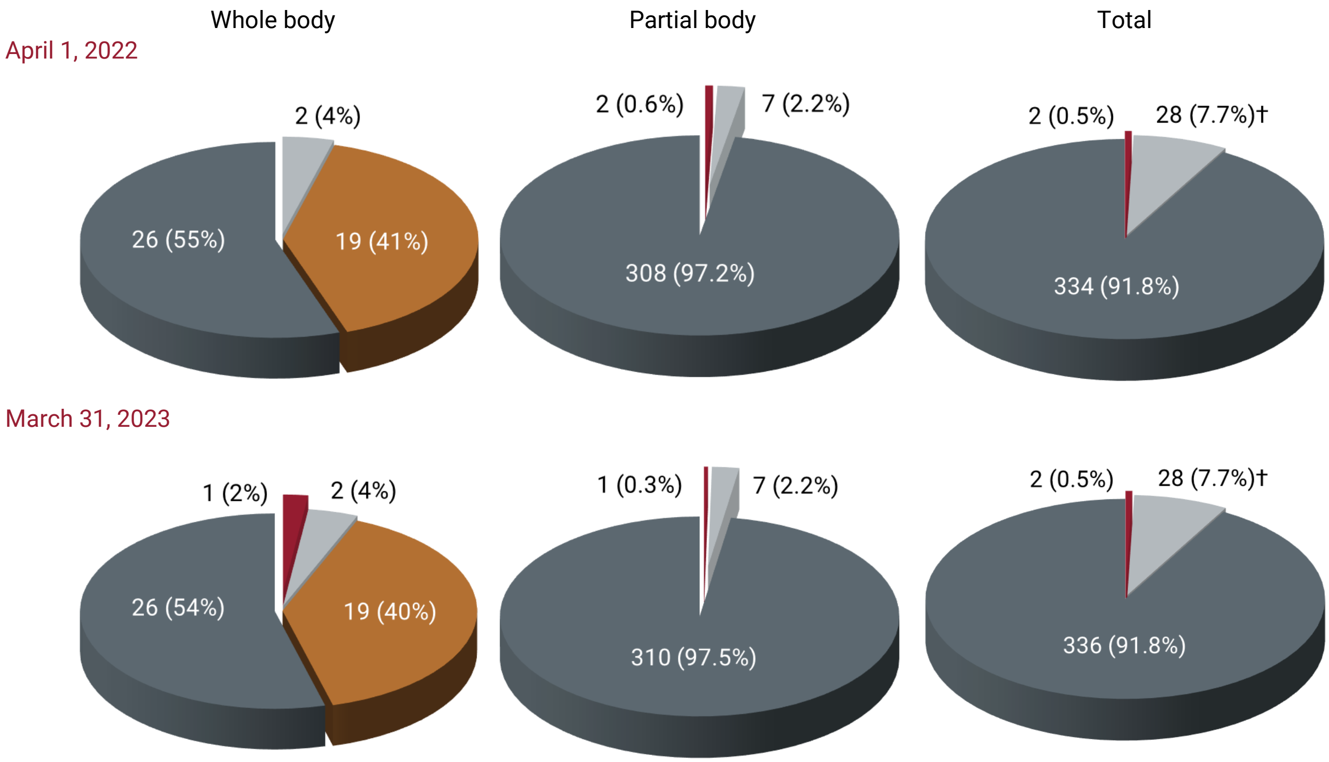


Fig. 8. Radiochemistry case analysis status: ■ Intact; ■ Incomplete; ■ Surveyed; ■ Complete.
† Includes 'Surveyed' whole-body cases.

Tissue Sample Backlog

The USTUR/NHRTR retains a tissue backlog of 2,210 samples from 28 whole- and partial-body cases. They remain 'Incomplete' as of March 31, 2023. This includes 1,945 tissue samples from 20 whole-body cases, and 265 tissues from eight partial-body cases. Of 2,210 backlog samples, 1,830 (83%) need to be analyzed for plutonium, 139 (6%) for americium, and 241 (11%) for uranium (Figure 9).

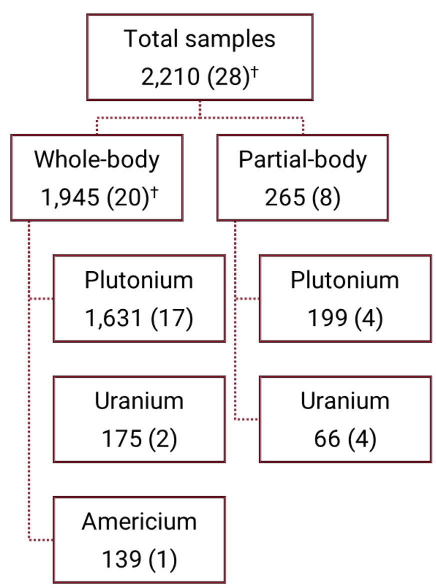


Fig. 9. USTUR tissue sample backlog at the end of FY2023. † Excludes two Thorotrast cases.

2022 Advisory Committee Meeting Summary

Thomas L. Rucker, *Chair*

The 2022 annual meeting of the USTUR's Scientific Advisory Committee (SAC) was held via the video conference on April 28–29. The meeting was divided into two sessions. The first focused on the operational aspects of the Registries and featured three technical presentations. The second provided time for SAC members to discuss the USTUR's activities during the past year, and to make recommendations for the coming year. The meeting agenda is available as Appendix C.

Meeting Summary

The meeting opened with introductions by the USTUR director, Sergei Tolmachev, and opening remarks by the committee chair, Thomas Rucker. This was followed by an update by Kevin Dressman, Director of DOE Office of Health and Safety (EHSS-10). WSU Tri-Cities chancellor, Sandra Haynes, provided an update on the Tri-Cities campus, and WSU College of Pharmacy and Pharmaceutical Sciences (CPPS) dean, Mark Leid, summarized research at CPPS and shared his vision on the USTUR within the college. The USTUR's faculty and staff gave several presentations on the operational aspects of the Registries, including financial developments, progress toward addressing recommendations from the 2021 SAC meeting, radiochemistry laboratory operations, database harmonization, institutional review board (IRB) changes, and the USTUR's research and operational plan for FY2023. In addition, three technical presentations were given on: plutonium lung dosimetry (D. Poudel, LANL), biokinetics of enriched uranium (M. Avtandilashvili, USTUR), and application on latent bone modeling for uncertainty reduction (M. Šefl, USTUR).

The second day was administrative in nature and was open only to SAC members, USTUR staff, and the DOE program manager. The day began with a Q&A session, where the SAC and USTUR staff discussed their observations about topics presented during Day 1. This was followed by a "closed-door" executive session, where only SAC members remained in the meeting. After lunch, USTUR staff and the DOE program manager rejoined the meeting, and the SAC shared several comments regarding progress during the past year as well as recommendations for the coming year. The SAC members strongly supported the idea of requesting out-of-cycle salary increases for the USTUR staff.

Comments on 2022 Recommendations

1. We recognize the need for investments in capital equipment and infrastructure. We recommend funding for these be requested in the next 5-year submission and/or from donors.

   We appreciate the investment in new hoods in the laboratory. See recommendations below.

2. We recommend that the 20-year-old Radiochemistry Quality Assurance (QA) Plan be updated.

   We appreciate the effort made for the QA Plan Update. See recommendation for addition below.

3. We recommend that a USTUR overall Quality Assurance Plan be developed that includes software quality assurance and data backup practices.

   Included in above.

4. We recommend that minimum detectable activities (MDAs) and minimum quantification activities (MQAs) be specified as measurement quality objectives (MQOs) for sensitivity, accuracy, and precision at specific levels of activity. We recommend that the MDA be set at the 2 nCi or 5% of the Annual Limit of Intake (ALI). We recommend that the MQA be set at 10 times the MDA. Also, consider using batch blank results for calculation total random uncertainties.

   We appreciate the effort made toward specifying MQOs. See additional recommendation below.

5. We continue to recommend improvements in the number of publications in the area of Radiochemistry. These may include the work with developing data quality objectives (DQOs) and MQOs.

   We appreciate the significance of Dan and George's paper on the Measurand in meeting this objective. See related recommendations below.

6. We continue to recommend increased participation of undergraduate and graduate students and postdoctoral fellows in USTUR research projects to enhance mutually beneficial activities with WSU.

   We appreciate the effort made toward increased participation of undergraduate and graduate students and postdoctoral fellows in USTUR research projects. See additional recommendation below.

7. We again recommend tracking progress towards benchmarks established in the 5 and 10-year plans and updating the plans annually.

   We appreciate the significant progress towards benchmarks established in the 5- and 10-year plans and updating the plans annually. We encourage continuance of this progress.

Observations

1. We think that significant work is being done in publications and the use of the data to advance scientific knowledge in distribution and metabolism of radionuclides in the body after intake. We believe the USTUR should be promoted based on these efforts. Perhaps these studies can be used to further knowledge of metabolism of non-radioactive elements, such as calcium distribution in bones, as well.

2. We are pleased to see the continued collaboration with the Million Person Study, European Radiation Dosimetry Group (EURADOS), NCRP, Joint Coordinating Committee for Radiation Effects Research (JCCRER), LANL and other efforts. These collaborations elevate the importance and demonstrate the utility of the USTUR.

3. We are glad to see progress on the urine analysis program by collecting samples for analysis and plans for follow-up.

4. We also recognize significant progress in improving the database harmonization.

5. We recognize the difficulties in lab production due to COVID and the difficulty with the hoods. We are glad to see the infrastructure upgrades and efforts to resume.

6. We support the idea of requesting out-of-cycle salary increases for staff.

2023 Recommendations

1. We recommended that a budget be considered for saving for further infrastructure upgrades that are needed over time. We suggest that funding for the budget sought and added may be accumulated in a savings fund over time. We also recommend that a timeline schedule be developed for such upgrades.
2. We recommend including data entry quality control of Health Physics records in addition to the radiochemistry in the Quality Assurance Plan.
3. We continue to recommend further publications in the area of Radiochemistry analytical measurements. These may include the work with developing DQOs and MQOs.
4. We recommend that clarity be added to the MDAs and MQAs by adding the applicable levels for the uncertainty goals for the MQA and the ties to the 2 nCi uptake monitoring objective for the MDA.
5. We continue to recommend working on increased opportunities for involvement of graduate students and postdoctoral fellows in USTUR research projects by working with the Dean of the College of Pharmacy in his development of graduate programs. In addition, we recommend continue working to develop undergraduate opportunities as well.
6. We recommend consideration of acquiring funding for adding staff and infrastructure. Considering the uniqueness of the expertise of staff members, training of backup and replacement staff needs to be considered for long-term continuity.
7. We recommend the addition of KPA (kinetic phosphorescence analysis) capabilities for uranium analysis.

SAC Membership

Thomas Rucker completed his second term as a health physics representative, and was renewed for another three-year term. All six SAC members attended the meeting:

- Thomas Rucker, Chair, Radiochemistry, *Leidos*
- Janet Benson, Toxicology, *Lovelace Biomedical Research Institute*
- Luiz Bertelli, Health Physics, *Los Alamos National Laboratory*
- Heather Hoffman, Epidemiology and Biostatistics, *George Washington University*
- Arthur “Bill” Stange, Occupational Health, *Oak Ridge Associated Universities (retired)*
- Timothy Ledbetter, Ethics, *Chaplaincy Health Care*

Bias in Plutonium Systemic and Lung Activity Predictions

Martin Šefl, *Postdoctoral Research Associate*

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

Radiation epidemiology typically relies on dose predictions based on urine bioassay measurements and other worksite monitoring data. At the USTUR, bioassay data and post-mortem tissue radiochemical analyses are used for actinide biokinetic modeling and estimation of organ doses.

For this study, a group of nine former nuclear workers (died 1973–2016) from Rocky Flats Plant was selected from the USTUR health physics database. The study group included four whole- and five partial-body tissue donors who were exposed to 'high-fired' PuO_2 aerosols in the 1965 glove-box fire accident[1]. The measured ^{239}Pu activities were between 9.4 and 123 Bq in the liver, between 9.2 and 215 Bq in the skeleton, and between 92.9 and 7,540 Bq in the lungs. For lungs and liver+skeleton, the bias was calculated as a relative difference between measured and predicted organ activities. The predicted values were based on urine and chest counts. The combined activity in the liver and skeleton was used to eliminate the inter-subject liver and skeleton variability.

Table 3 and Figure 10 show the results of bias calculations.

Table 3. Mean and absolute mean bias in 239Pu activity predictions for liver+skeleton and lungs

Organ	Bias (%)	
	Mean	Absolute mean
Liver+skeleton	54±72	63±67
Lungs	−19±62	55±34

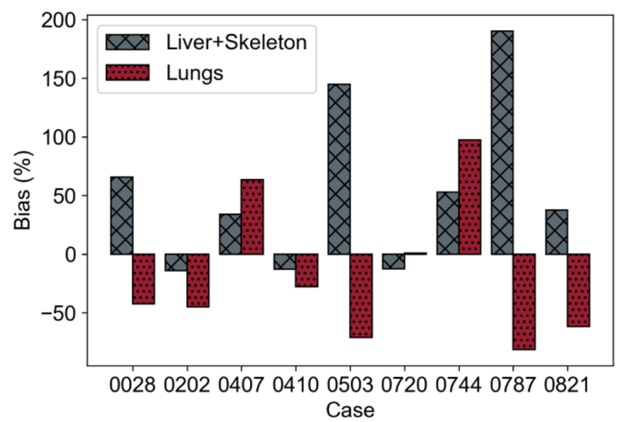


Fig. 10. Bias in systemic and lung activity predictions for study cases.

On average, current biokinetic models overestimated the liver+skeleton activity by 54% and underestimated the lung activity by 19%.

References

1. Mann JR, Kirchner RA. Evaluation of lung burden following acute inhalation exposure to highly insoluble PuO_2. Health Physics 13: 877–882; 1967.

USTUR for Dose Reconstruction at Rocky Flats Plant

Richard W Leggett, *Research Scientist, Oak Ridge National Laboratory*
Caleigh Samuels, *Staff Member, Oak Ridge National Laboratory*

As a part of collaboration with U.S. DOE Million Person Study (MPS), the USTUR provided measured ^{239}Pu concentrations and estimated activities in the lungs, thoracic lymph nodes (LNTH), skeleton, and liver from 25 Rocky Flats workers, along with incident history and bioassay monitoring data. These data were used for development of site-specific biokinetic models for dose reconstruction at Rocky Flats Plant[1].

The workers' ^{239}Pu intakes were estimated using standard biokinetic models for plutonium described in ICRP Publication 141[2] or case-specific modifications of those models. To estimate tissue doses and effective doses from the intakes, dosimetric models applied in the ICRP's Occupational Intake of Radionuclides (OIR) series were used. Intake routes were assumed to be inhalation or wound. Several of the workers had multiple exposures over their careers. The times of intakes were based on a combination of incident records provided by the USTUR and changes in ^{239}Pu urinary excretion patterns over time. Route of intake (wound or inhalation), absorption type for inhalation intakes, and magnitude of intake were assigned to reproduce post-mortem organ activities (autopsy data). With one exception, no effort was made to fit the urinary excretion data. Rather, the urinary excretion rates predicted by the models designed to fit the autopsy data were compared with measured urinary ^{239}Pu to assess, for each case, whether ^{239}Pu urinary data alone would have been an adequate tool for tissue dose reconstruction. For Case 20, the ICRP default rates of transfer of plutonium from blood to the urinary bladder contents were adjusted as a "proof of principle", i.e., to demonstrate that the ^{239}Pu urinary excretion pattern could be described by a case-specific adjustment of the ICRP systemic model for plutonium.

The following biokinetic models were applied:

- Case-specific modifications of the model for systemic plutonium defined in Table 18.6 of ICRP Publication 141
- The Human Respiratory Tract Model (HRTM)[3] with the ICRP absorption parameter values for Pu nitrate (Table 22.11 of Publication 141)
- The HRTM with the ICRP absorption parameter values for ^{239}Pu dioxide (Table 22.11 of Publication 141), with case-specific modifications designed to fit the rate of accumulation of activity in the LNTH, and in a few cases, an extremely low rate of absorption of activity from the lungs to the blood.
- The ICRP Human Alimentary Tract Model (HATM)[4] with no modifications.

Wound cases were treated as a rapid injection into blood, except in one case in which a slowly absorbed component of retention was indicated. It is expected that most plutonium wound cases would have slow absorption components, but slow absorption generally was not evident in the urinary data for the studied wound cases.

Individual organ doses and the total effective dose for each worker were estimated. The total effective dose for a worker is defined here as the sum of the 50-year committed effective doses for individual types and times of intake. Interpretation of the "type of intake" for these cases is illustrated using the three intake types for Case 2:

1. Type N case 2 time 0
2. Mod Type O2 case 2 time 0
3. Wound case 2 time 6.

This worker was assumed to have inhaled Type N material as well as a modified (Mod) version of the plutonium dioxide model (Type O2) at time 0. Time 0 refers to the time of first intake by a worker. This worker was assumed to be exposed via a wound at time 6, which means 6 years from the time of the first exposure.

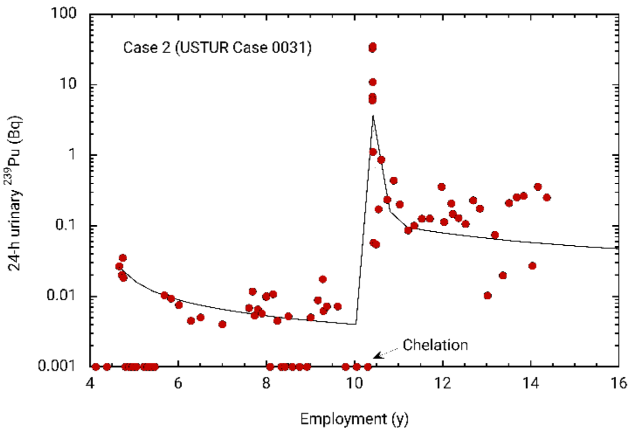


Fig. 11. Observed (circles) and modeled (curve) 24-hour ^{239}Pu urinary excretion for Case 2.

Figure 11 shows the urinary excretion rates predicted by the models for Case 2 compared with measured ^{239}Pu urinary excretion.

Estimated intakes ranged from 1.715 kBq to 221.1 kBq with a geometric mean (GM) of 8.81 kBq. The corresponding effective doses ranged from 0.073 Sv to 10.2 Sv with GM = 0.45 Sv.

References

1. Samuels C, Leggett R. Dose reconstruction for plutonium-239 intakes at the Rocky Flats Plant. International Journal of Radiation Biology: 1–14; 2023. doi:10.1080/09553002.2023.2241896
2. ICRP. Occupational intakes of radionuclides: Part 4. ICRP Publication 141. Ann. ICRP 48(2/3); 2019.
3. ICRP. Occupational Intakes of Radionuclides: Part 1. ICRP Publication 130. Ann. ICRP 44(2); 2015.
4. ICRP. Human Alimentary Tract Model for Radiological Protection. ICRP Publication 100. Ann. ICRP 36 (1–2); 2006.

Modeling Chelation for a Female Nuclear Worker

Sara Dumit, *Scientist, Los Alamos National Laboratory*

This individual is a USTUR special study Registrant who worked with plutonium during her employment at nuclear defense facility. She was involved in an airborne contamination incident due to a fire involving scrap material which contained plutonium/americium mixture. The incident resulted in acute inhalation intake even though the worker was wearing a respirator at the time. She was thoroughly decontaminated immediately after the exposure and received three chelation treatments with 1 g of Ca-DTPA: intramuscular injection on day 0, and two intravenous injections on days 5 and 14 post-intake. ^{239}Pu deposition in the lungs was estimated to be 18.5–24.0 Bq based on an in-vivo chest count of ^{241}Am on day 7.[1] She was followed-up for 14 years for bioassay measurements. A total of 38 ^{239}Pu, ten ^{238}Pu, and 24 ^{241}Am urinalysis results, as well as 13 ^{239}Pu, ^{238}Pu, and ^{241}Am fecal analysis results are available. Urine and fecal samples contained measurable amounts of ^{239}Pu and ^{241}Am for a month following the incident; however, subsequent routine urine measurements were below the detection limits. The worksite personnel estimated the intake as approximately 73.3 Bq (1.98 nCi) of ^{239}Pu, 18.9 Bq (0.51 nCi) of ^{241}Am, and 2.22 kBq (60 nCi) of ^{241}Pu.

The uniqueness of this dataset is due to: (i) early and long-term data from a female with plutonium intake; (ii) bioassay data following chelation therapy for a female; (iii) fecal measurement results.

For chelation modeling, the software package IDode was used. IDode is able to solve second-order kinetics, perform statistical analysis, and calculate parameter uncertainties using Markov Chain Monte Carlo (MCMC) method[2]. Figure 12 shows the model fit to urine and fecal data. Preliminary results of the modeling estimate the intake of 21.6 Bq, using aerosol's activity median aerodynamic diameter of 0.1 µm.

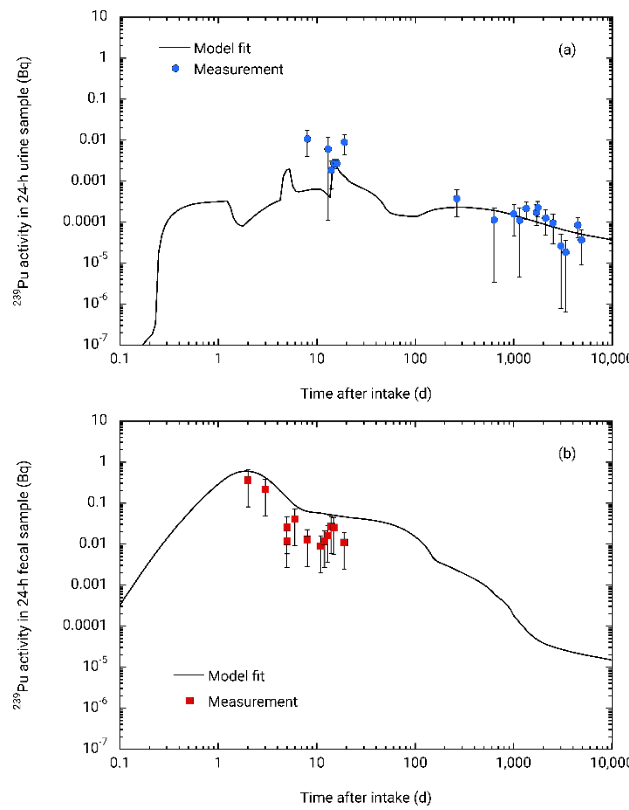


Fig. 12. Model fit to bioassay data: urine (a) and fecal (b).

References

1. Russell JJ, Sikov MR, Kathren RL. Plutonium content of human placental tissues after occupational exposure. Radiation Protection Dosimetry 104:231–236; 2003.
2. Miller G, Bertelli L, Klare K, Weber W, Doyle-Eisele M, Guilmette R. Software for empirical building of biokinetic models for normal and decorporation-affected data. Health Physics 103:484–494; 2012.

Misclassification of Underlying Cause of Death

Xirui Liu, *Associate in Research*
Stacey L. McComish, *Associate in Research*

The USTUR has (i) drafted a paper on the over- and under-misclassification of disease on death certificates, and (ii) initiated a secondary study to use the misclassification rates associated with the first task to simulate how over- and under-classification errors on death certificates change the significance of relative risk estimates.

To quantify misclassification rates among USTUR Registrants, USTUR faculty compared the underlying causes of death identified on death certificates to those on autopsy reports. These were used to calculate match rates, over-classification rates (aka false positive rates), and under-classification rates (aka false negative rates). Cases were divided into three groups to investigate how the use of autopsy findings to complete the death certificates influenced misclassification rates: autopsy findings used, autopsy findings not used, and unknown. Cases were also divided into the five most common disease categories: circulatory, neoplasms, respiratory, nervous system, and external causes. The match rate for the entire dataset was 75%; the disease category with the highest match rate was neoplasms and the category with the lowest rate was respiratory. Death certificates where autopsy findings were used to complete the cause of death section consistently had higher match rates, and lower misclassification rates, than death certificates that were not based on autopsy findings. USTUR Registrants represent an all-autopsied population that avoids biases associated with scenarios that often lead to autopsies, such as suspicious or unclear causes of death. Registrants are also representative of a major target population for radiation epidemiological studies, because the majority of them are former nuclear workers from Department of Energy facilities.

For the second project, Xirui Liu used external doses and cancer incidence from USTUR Registrants to run preliminary simulations of how over- and under-classification errors on the death certificates may impact the findings of epidemiological studies. Autopsy findings were used to calculate the true odds ratio and associated *p*-value for USTUR Registrants. Then, non-cancer cases were randomly selected and changed to cancer cases to simulate the effect of over-classification errors on findings based on death certificates. This simulation was run 200,000 times to generate a distribution of odds ratios and *p*-values. Similarly, the effects of under-classification errors, as well as the effects of combined under- and over-classification errors, were simulated.

Professional Activities and Services

During FY2023, the USTUR staff was actively involved in professional and academic activities nationally and internationally.

Professional Services

NCRP Council

Dr. Avtandilashvili has been elected to serve as a Council Member for the National Council on Radiation Protection and Measurements (NCRP). This is a six-year appointment (2023–2029).

Dr. Tolmachev served as a Council Member of the NCRP.

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

NCRP Scientific Committee 6-12

Dr. Tolmachev and Dr. Avtandilashvili served 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 (2018–2022).

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

NCRP Scientific Committee 6-13

Dr. Avtandilashvili served on the NCRP scientific committee (SC 6-13) on Methods and Models for Estimating Organ Doses from Intakes of Radium (2021–2023).

https://ncrponline.org/program-areas/sc-6-13-methods-and-models-for-estimating-organ-doses-from-intakes-of-radium/

EPA Science Advisory Board's Review Panel

Dr. Avtandilashvili and Dr. Strom were selected for the Special Government Employee (SGE) appointment with the U.S. Environmental Protection Agency (EPA) to serve as members of the Radionuclide Cancer Risk Coefficients (RCRC) Review Panel of the EPA's Science Advisory Board. The panel will review the EPA's draft Cancer Risk Coefficients for Environmental Exposure to Radionuclides (Federal Guidance Report No. 16). This document is an update to Federal Guidance Report No. 13 and provides new radionuclide-specific cancer risk coefficients for incidence and mortality associated with internal radionuclide exposure from ingestion and inhalation, and external exposure to radionuclides distributed in air, water, and soil.

https://sab.epa.gov/ords/sab/f?p=114:14:14616146437943:::14:P14_COMMITTEEON:Radionuclide%20Cancer%20Risk%20Coefficients%20Review%20Panel

U.S. DOE Russian Health Studies

Dr. Tolmachev served as an *ex-officio* member of the Scientific Review Group of the U.S. DOE Russian Health Studies Program. He is a reviewer for Project 2.8 "Mayak Worker Tissue Repository".

https://www.energy.gov/ehss/russian-health-studies-program

Herbert M. Parker Foundation

Dr. Tolmachev and Dr. Tabatadze have served as members of the Board of Trustees of the Herbert M. Parker Foundation (2016– present and 2019– present, respectively).

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

Hanford Advisory Board

Dr. Strom, a USTUR/CPPS adjunct faculty member, served as an alternate member of the Hanford Advisory Board (HAB) in a position representing the Benton-Franklin Public Health District. He also serves on the HAB's Public Involvement and Communication and Health Safety and Environment Protection committees.

https://www.hanford.gov/page.cfm/hab/

HPS International Collaboration Committee

Dr. Tabatadze was re-appointed to serve as a member (2022–2025) of the Scientific Support Committee of the Health Physics Society.

http://hps.org/aboutthesociety/organization/committees/committee18.html

Columbia Chapter of Health Physics Society

Dr. Martin Šefl served as a secretary (2021–2023) of the Columbia Chapter of Health Physics Society (CCHPS).

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

WSU Radiation Safety Committee

Dr. Tabatadze has served as a member (2019–2025) of the WSU Radiation Safety Committee (RSC). The RSC establishes and ensures compliance with radiation protection policies, reviews applications for, and approves the 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 has served as a Technical Advisor (2016–2024) at the Kyushu Environmental Evaluation Association (Fukuoka, Japan). http://www.keea.or.jp/

Japanese Journal of Health Physics

Dr. Tolmachev served as a member (2011–2023) of the Editorial Board for the *Japanese Journal of Health Physics* (JJHP).

Austin Biometrics and Biostatistics

Dr. Maia Avtandilashvili has served as a member (2016–present) of the Editorial Board for the journal of *Austin Biometrics and Biostatistics*.

Physical Science and Biophysics Journal

Dr. George Tabatadze has been appointed to serve as a member (2022–present) of the Editorial Board for the journal of *Physical Science and Biophysics Journal*.

Scientific Meetings

USTUR faculty attended and participated in the following scientific meetings:

- Virtual meeting of the Radiation Protection Computer Code Analysis and Maintenance Program (RAMP) User Group, April 4–5, 2022
- Herbert M. Parker Public Lecture "It Takes Energy to Calculate Dose", April 7, 2022
- Virtual 12th Workshop of the Million Person Study, April 7–8, 2022
- Health Physics Society Webinar "Personnel Dosimetry: Practical Examples of Setting up a Personnel Dosimetry Program", May 2, 2022
- Virtual meeting of EURADOS Working Group 7 and WHO REMPAN on Wound Contamination Project, June 30, 2022
- Virtual meetings of the NCRP scientific committee 6–13 meetings, July 8, July 13, September 13, 2022, and January 5, 2023
- 67th Annual Meeting of Health Physics Society, Spokane, WA, July 17–21, 2022
- 65th Annual Radiobioassay and Radiochemical Measurements Conference (RRMC), Atlanta, GA, October 31 – November 4, 2022
- 68th Radiation Research Society Annual Meeting, Waikoloa Village, HI, October 16–19, 2022
- Herbert M. Parker Public Lecture "The ICRP System of Radiological Protection: What Comes Next?", November 2, 2022

- 6th International Symposium on the System of Radiological Protection (ICRP 2021^{+1}), Vancouver, Canada, November 7–10, 2022
- Virtual plenary meeting of EURADOS Working Group 7 (WG7), December 13, 2022
- Virtual 13th Workshop of the Million Person Study, February 2–3, 2023
- 2nd Annual Winter Workshop of Health Physics Society on Internal Dosimetry, Corvallis, OR, February 6–9, 2023
- 59th NCRP Annual Meeting "Integration of physics, biology and epidemiology in radiation risk assessment", Bethesda, MD, March 27–28, 2023

Professional Affiliations

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

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

Publications and Presentations

The following manuscripts and presentations were published or presented during the period of April 2022 to March 2023.

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 D of this report.

Published

USTUR-0596-21

Tolmachev SY, Auxier JD, 2nd, Nilsson M, Powell BA, Rucker TL, Sudowe R. Radiochemistry and nuclear chemistry workforce in the United States. Journal of Applied Clinical Medical Physics 23(S1): e13789; 2022.

USTUR-0601-21

Arbova DL, Tolmachev SY, Brockman JD. Quadrupole and sector field ICP-MS analysis of ^{226}Ra in brain from a radium dial painter. Journal of Analytical Atomic Spectrometry 37(6): 1369-1376; 2022.

USTUR-0614-22

Arbova DL, Tolmachev SY, Brockman JD. ICP-MS analysis of actinides in brain tissue of an occupationally exposed individual. Journal of Radioanalytical and Nuclear Chemistry 331: 5147–5151; 2022.

USTUR-0610-22

Leggett RW, Tolmachev SY, Avtandilashvili M, Eckerman KF, Grogan HA, Sgouros G, Woloschak GE, Samuels C, Boice JD, Jr. Methods of improving brain dose estimates for internally deposited radionuclides. Journal of Radiological Protection 42(3): 3001; 2022.

USTUR-0652-23

Newhauser WD, Williams JP, Noska MA, Borrás C, Holahan EV, Dewji SA, Johnson TE, Hiatt JW, Poston JW, Hertel N, Gress DA, Mills MD, Jordan DW, Sutlief SG, Martin MC, Jackson E, Bluth EI, Frush DP, Oates ME, LaBerge J, Pan HY, Rosenthal SA, Townsend LW, Brady L, Lindegard J, Hall HL, McAndrew-Benavides E, Abelquist E, Anscher MS, Vazquez M, Kronenberg A, Willey JS, Lawrence T, Woloschak GE, Marples B, Wong R, Story M, Howell RW, Hei TK, Tolmachev SY, Auxier JD, Rucker TL, Nilsson M, Sudowe R, Powell BA, Jensen MP. The professional radiation workforce in the United States. Journal of Applied Clinical Medical Physics 23(Suppl 1): e13848; 2023.

USTUR-0538-20A

Tolmachev SY. U.S. Transuranium and Uranium Registries: 2010 – 2022 research accomplishments and collaborative efforts. Health Physics 123(1): 79; 2022.

USTUR-0539-20A

Šefl M, Zhou JY, Avtandilashvili M, Tolmachev SY. Uncertainties in radiation dose assessment for internally deposited plutonium in support of radiation epidemiology. Health Physics 123(1): 80; 2022.

USTUR-0537-20A

Avtandilashvili M, Larivière D, Momoshima N, Wegge D, Brockman JD, Tolmachev SY. Beryllium in the tissues of former nuclear workers. Health Physics 123(1): 80; 2022.

USTUR-0603-22A

McComish SL, Liu X, Martinez FT, Zhou JY, Tolmachev SY. Misclassification of causes of death among USTUR

Registrants: Death Certificates vs. Autopsy Reports. Health Physics 123(1): 67; 2022.

USTUR-0604-22A

Goans RE, Toohey RE, Iddins CJ, Mumma M, McComish SL, Tolmachev SY. The neutrophil to lymphocyte ratio shows evidence for chronic inflammation in a Radium Dial Painter cohort. Health Physics 123(1): 55; 2022.

USTUR-0605-22A

Strom DJ, Avtandilashvili M, Felsot A, McComish SL, Šefl M, Tabatadze G, Tolmachev SY. Proposed revision of the ICRP 141 Pu systemic model to incorporate the HAT model and the hepatic portal vein. Health Physics 123(1): 67; 2022.

USTUR-0607-22A

Wegge D, Tolmachev SY, Brockman JD. Measurement of ^{239}Pu in autopsy brain tissue from an occupationally exposed worker using ICP-MS. Book of Abstracts International Conference on Methods and Applications of Radioanalytical Chemistry (MARC XII): 113; 2022.

USTUR-0608-22A

Wegge D, Tolmachev SY, Brockman JD. Method for measuring Pu, Am, and U in hair and nails of occupationally exposed workers through extraction chromatography and MC-ICP-MS. Book of Abstracts International Conference on Methods and Applications of Radioanalytical Chemistry (MARC XII): 114; 2022.

USTUR-0632-22

Tolmachev SY, McComish SL, Avtandilashvili M. United States Transuranium and Uranium Registries Annual Report: April 1, 2021 – March 31, 2022. United States Transuranium and Uranium Registries; USTUR-0632-22, Richland, WA, 2022.

Presented

Invited

USTUR-0599-21A

Poudel D, Avtandilashvili M, Bertelli L, Klumpp J, Tolmachev SY. Analysis of regional retention of plutonium in the respiratory tract of four acutely-exposed workers using scar-tissue compartments. International Conference on Individual Monitoring of Ionising Radiation (IM2022), Kraków, Poland, April 25–29, 2022.

USTUR-0538-20A

Tolmachev SY. U.S. Transuranium and Uranium Registries: 2010–2022 research accomplishments and collaborative efforts. 67th Annual Meeting of Health Physics Society, Spokane, WA, July 17–21, 2022.

USTUR-0539-20A

Šefl M, Zhou JY, Avtandilashvili M, McComish SL, Strom DJ, Tabatadze G, Tolmachev SY. Uncertainties in radiation dose assessment for internally deposited plutonium in support of radiation epidemiology. 67th Annual Meeting of Health Physics Society, Spokane, WA, July 17–21, 2022.

USTUR-0537-20A

Avtandilashvili M, Lariviere D, Momoshima N, Arbova DL, Brockman JD, Tolmachev SY. Beryllium in the tissues of former nuclear workers. 67th Annual Meeting of Health Physics Society, Spokane, WA, July 17–21, 2022.

USTUR-0623-22P

Šefl M. U.S. Application of principal component regression at the U.S. Transuranium and Uranium Registries. Whitman College Mathematical Sciences Foundry Talks, Walla Walla, WA, September 19, 2022.

USTUR-0612-22A

Tolmachev SY. Actinides in humans: 50-year experience at the U.S. Transuranium and Uranium Registries. 68th Annual Meeting of Radiation Research Society, Waikoloa Village, HI, October 16–19, 2022.

Podium

USTUR-0607-22A

Wegge D, Tolmachev SY, Brockman JD. Measurement of ^{239}Pu in autopsy brain tissue from an occupationally exposed worker using ICP-MS. International Conference on Methods and Applications of Radioanalytical Chemistry (MARC XII), Kona, HI, April 3–8, 2022.

USTUR-0608-22A

Wegge D, Tolmachev SY, Brockman JD. Method for measuring Pu, Am, and U in hair and nails of occupationally exposed workers through extraction chromatography and MC-ICP-MS. International Conference on Methods and Applications of Radioanalytical Chemistry (MARC XII), Kona, HI, April 3–8, 2022.

USTUR-0550-20A

Avtandilashvili M, Tolmachev SY. Biokinetics of highly enriched uranium in a female nuclear worker. 6th European Congress on Radiation Protection (IRPA2022), Budapest, Hungary, May 30 – June 3, 2022.

USTUR-0594-21A

Šefl M, Avtandilashvili M, Zhou JY, Tolmachev SY. Estimation of plutonium concentration in skeleton from occupationally exposed individuals. 6th European Congress on Radiation Protection (IRPA2022), Budapest, Hungary, May 30 – June 3, 2022.

USTUR-0611-22A

Poudel D, Avtandilashvili M, Bertelli L, Klumpp J, Tolmachev SY. Modified human respiratory tract model to describe the retention of plutonium in scar tissues. 6th European Congress on Radiation Protection (IRPA2022), Budapest, Hungary, May 30 – June 3, 2022.

USTUR-0603-22A

McComish SL, Liu X, Martinez FT, Zhou JY, Tolmachev SY. Misclassification of causes of death among USTUR Registrants: death certificates vs. autopsy reports. 67th Annual Meeting of Health Physics Society, Spokane, WA, July 17–21, 2022.

USTUR-0604-22A

Goans RE, Toohey RE, Iddins CJ, Mumma M, McComish SL, Tolmachev SY. The neutrophil to lymphocyte ratio shows evidence for chronic inflammation in a Radium Dial Painter Cohort. 67th Annual Meeting of Health Physics Society, Spokane, WA, July 17–21, 2022.

USTUR-0605-22A

Strom DJ, Avtandilashvili M, Felsot A, McComish SL, Šefl M, Tabatadze G, Tolmachev SY. Proposed revision of the ICRP 141 Pu systemic model to incorporate the HAT model and the hepatic portal vein. 67th Annual Meeting of Health Physics Society, Spokane, WA, July 17–21, 2022.

USTUR-0621-22A

Tabatadze G, Strom DJ, Rucker TL. Measurement and uncertainty challenges in bringing USTUR's decades-old radiochemistry program into the 21st century – Part 1. 65th Annual Radiobioassay and Radiochemical Measurements Conference (RRMC), Atlanta, GA, October 31 – November 4, 2022.

USTUR-0622-22A

Tabatadze G, Strom DJ, Rucker TL. Measurement and uncertainty challenges in bringing USTUR's decades-old radiochemistry program into the 21st century – Part 2. 65th Annual Radiobioassay and Radiochemical

Measurements Conference (RRMC), Atlanta, GA, October 31 – November 4, 2022.

USTUR-0624-22A

Tolmachev SY. 55 years of the United States Transuranium and Uranium Registries: history, contributions and impact on radiation protection. 2nd Annual Winter Workshop of Health Physics Society on Internal Dosimetry, Corvallis, OR, February 6–9, 2023.

USTUR-0629-22A

Martinez NE. Unique resources available through collaboration with the USTUR. 2nd Annual Winter Workshop of Health Physics Society on Internal Dosimetry, Corvallis, OR, February 6–9, 2023.

USTUR-0627-22A

Dumit S, Avtandilashvili M, McComish SL, Tolmachev SY. Applicability of a unique USTUR dataset: female nuclear worker treated with chelation therapy after plutonium exposure via inhalation. 2nd Annual Winter Workshop of Health Physics Society on Internal Dosimetry, Corvallis, OR, February 6–9, 2022.

USTUR-0630-22A

Šefl M, Avtandilashvili M, Zhou J, Tolmachev SY. Uncertainty in plutonium internal dose estimates for Rocky Flats workers. 2nd Annual Winter Workshop of Health Physics Society on Internal Dosimetry, Corvallis, OR, February 6–9, 2022.

USTUR-0631-22A

Riddell AE, Smith TJ, Gregoratto D, Hyatt T. Taurus Advanced - internal dosimetry software for research. 2nd Annual Winter Workshop of Health Physics Society on Internal Dosimetry, Corvallis, OR, February 6–9, 2022.

USTUR-0625-22A

Arbova DL, Tolmachev SY, Brockman JD. ICP-MS measurement of plutonium, uranium, and ^{241}Am in the hair and nail samples of former nuclear workers. 2nd Annual Winter Workshop of Health Physics Society on Internal Dosimetry, Corvallis, OR, February 6–9, 2022.

USTUR-0633-22A

Goans RE, Toohey RE, Iddins CJ, Mumma M, McComish SL, Tolmachev SY. Hematology profile of a Radium Dial Painter cohort. 2nd Annual Winter Workshop of Health Physics Society on Internal Dosimetry, Corvallis, OR, February 6–9, 2022.

USTUR-0628-22A

Liu X, McComish SL, Martinez FT, Zhou JY, Tolmachev SY. Is the autopsy report a “gold standard”? 2nd Annual Winter Workshop of Health Physics Society on Internal Dosimetry, Corvallis, OR, February 6–9, 2022.

USTUR-0626-22A

Boice Jr JD, Dauer LT. USTUR - a golden nugget among DOE resources. 2nd Annual Winter Workshop of Health Physics Society on Internal Dosimetry, Corvallis, OR, February 6–9, 2022.

Poster

USTUR-0617-22A

Šefl M, Avtandilashvili M, Zhou JY, Tolmachev SY. EasySkel: Estimation of plutonium concentration in the skeleton. 68th Annual Meeting of Radiation Research Society, Waikoloa Village, HI, October 16–19, 2022.

USTUR-0590-21A

Zhou JY, Tabatadze G, Šefl M, Avtandilashvili M, Tolmachev SY. Comparison of latent bone modeling and simple average method for estimating plutonium activity concentration in human skeleton. 68th Annual

Meeting of Radiation Research Society, Waikoloa Village, HI, October 16–19, 2022.

USTUR-0619-22A

Avtandilashvili M, Poudel D, Klumpp J, Bertelli L, Tolmachev SY. Human respiratory tract model to describe long-term retention of plutonium using scar tissue compartments. 6th International Symposium on the System of Radiological Protection (ICRP 2021+1), Vancouver, Canada, November 7–10, 2022.

Bibliographic Metrics

Stacey L. McComish, *Associate in Research*

Since its inception in 1968, the USTUR has published 292 papers in conference proceedings and peer-reviewed journals, 31 books/book sections, 130 abstracts in journals, and 29 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 42 different journals, with the highest impact factor of 12.7 (American Journal of Public Health). Four journals account for 73% of these papers: Health Physics (2.2), Radiation Protection Dosimetry (1.0), the Journal of Radioanalytical and Nuclear Chemistry (1.6), and Radiation Research (3.4).

The USTUR used the Publons bibliographic service to generate an online publications profile until August 2022, when Publons moved its profiles to the Web of Science (WOS). As such, the WOS is now used to track USTUR journal articles and citation metrics. The WOS has citation data for 243 USTUR publications. These articles were cited 4,455 times, and the USTUR has an *h*-index of 33. 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 12 displays the number of USTUR journal articles published per year, and the number of times articles were cited each year. To explore the USTUR's publications on the WOS, visit:

https://www.webofscience.com/wos/author/record/I-1056-2013

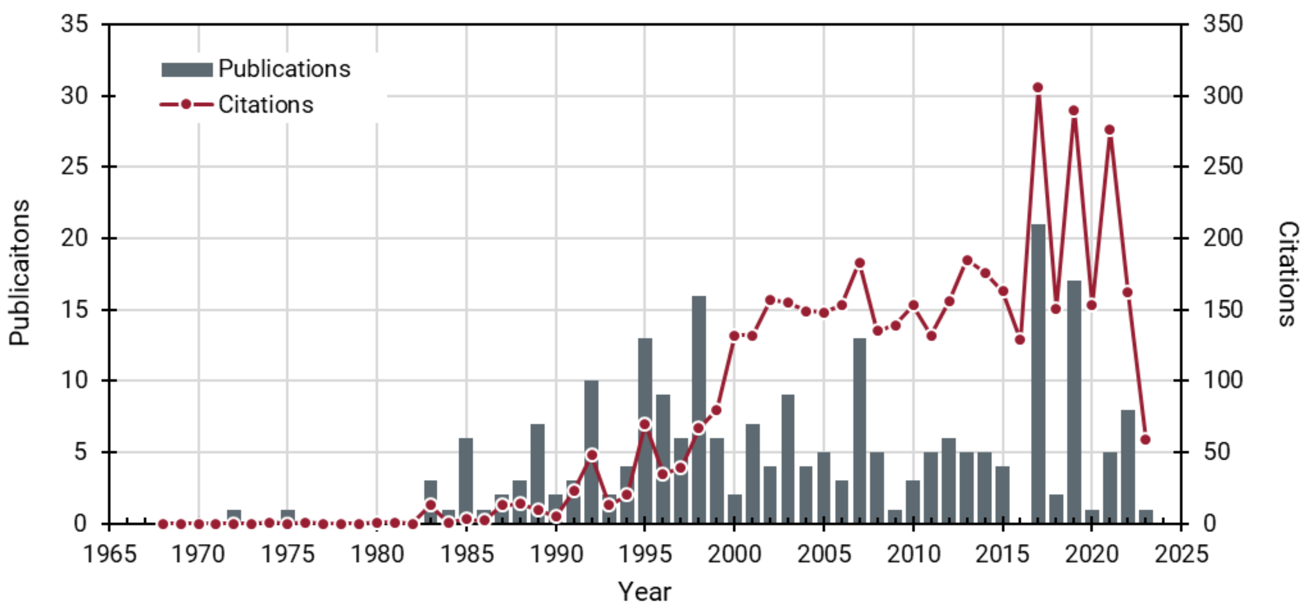
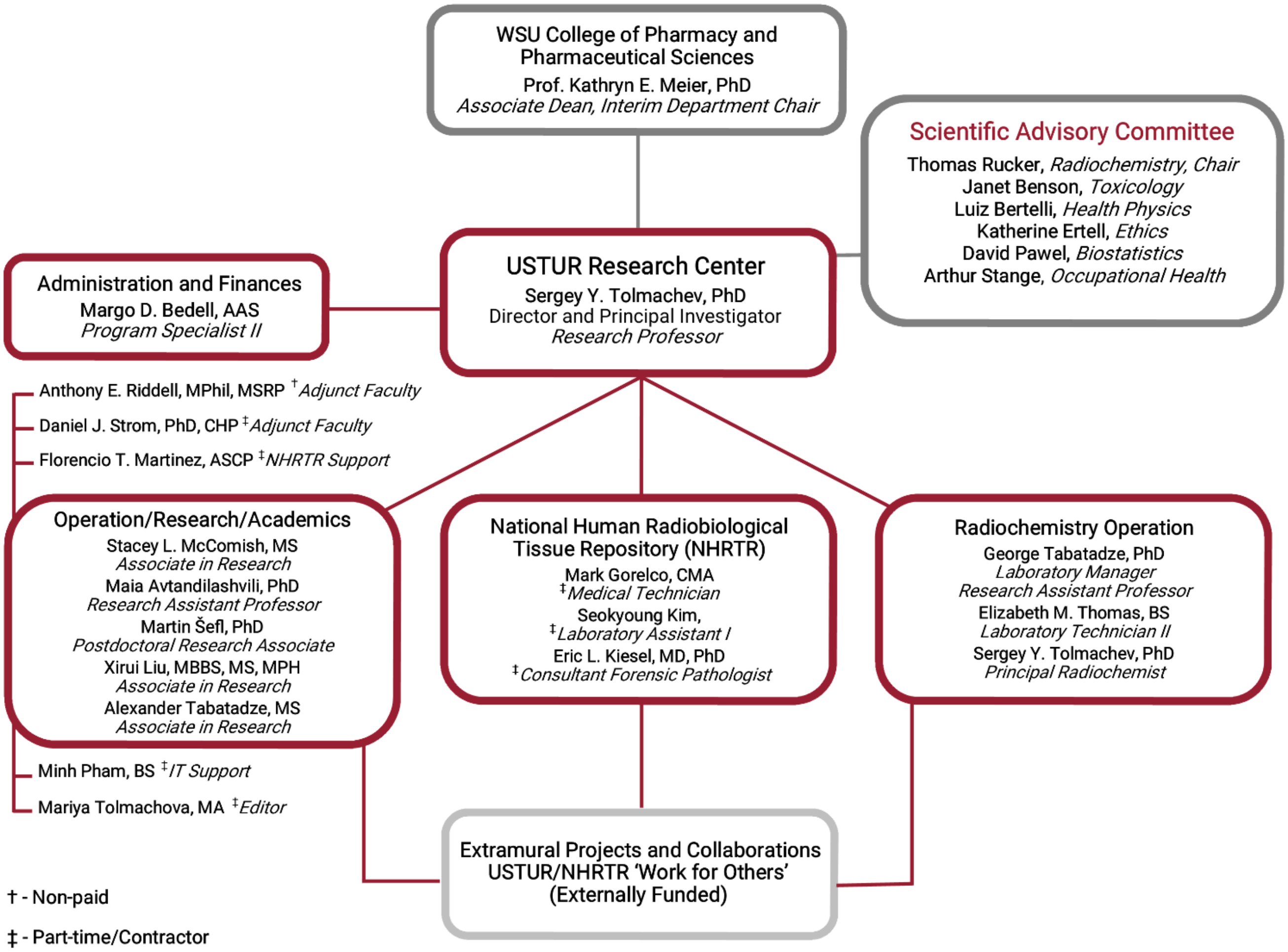


Fig 12. The number of USTUR journal publications per year, and the number of times articles were cited in each year.

Appendix A

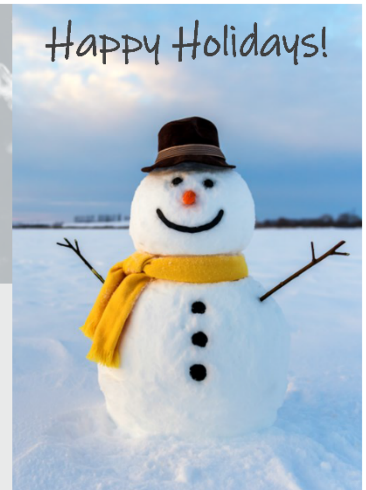


USTUR Research Center organization structure during FY2023.

Appendix B

USTUR Newsletter

December 2022 | Issue 28
USTUR-0635-22



Direct from the Director

Dear Registrants and Families.

This is a time of the year when I am traditionally telling you about the USTUR's activities and achievements during the ongoing year.

Our 5-year grant to manage and operate the Registries during April 1, 2022 - March 31, 2027 period was approved by the Department of Energy (DOE) and the budget was increased. This allows us to keep up with inflation and bring some stability to the Registries in the coming years.

Two USTUR members were recognized by the Environmental Protection Agency in their specialties within the science and practice of radiation protection, and appointed to serve on a science advisory board to conduct a peer review of a draft report “Cancer Risk Coefficients for Environmental Exposure to Radionuclides”.

In 2022, the Registries continued to publish its research findings in scientific literature. Specifically, I would like to highlight the National Council on Radiation Protection and Measurements (NCRP) Commentary 31 “Development of Kinetic and Anatomical Models for Brain Dosimetry for Internally Deposited Radionuclides”. This is the 6th NCRP publication where the USTUR data were directly used.

On February 7, 2023, during the 2023 Health Physics Society (HPS) Workshop on Internal Dosimetry, the USTUR will have a special session dedicated to the 55th anniversary of the Registries Ten talks will be given during the meeting. Since the HPS 2016 meeting, this will be the 2nd special session dedicated to the history and research of the USTUR.

More details about the Registries' progress and discoveries are included elsewhere in this Newsletter. Our gratitude goes out to you and we wish you happy holiday season!

~Sergei Tolmachev

In this Issue...

Small program with a big impact

Last June, DOE directors, Kevin Dressman (EHSS-10) and Garrett Smith (EHSS-30), visited the USTUR and toured our laboratory facility. Dr. Tolmachev discussed USTUR's history, past and present research, and the uniqueness of the USTUR program. They were, as all visitors are, impressed with the resources that are available at the USTUR, and the research that is being conducted.

Our DOE funding has increased over the past 6 years. This has helped the USTUR to keep up with the rising costs of laboratory supplies and to replace old, corroded fume hoods with acid-resistant fume hoods at the laboratory. It also allowed us to hire a post-doctoral researcher, Martin Šefl, in 2019, and a part-time faculty member, Xirui Liu, this year. Clearly, having the funding to maintain a safe and functional laboratory is vital to the work that is done here. Equally important is funding for research staff, since the true value of Registrant donations is unlocked as we analyze the data. And the data that is generated from our Registrants' generous donations is truly unique on a worldwide scale. The closest analogue to the USTUR is a study of workers from the Mayak Production Association in Russia. The Mayak program has information on over 25,000 workers, which is considerably more than the 398 workers in the USTUR program. However, they do not have nearly the level of detail about exposure scenarios that the USTUR has, or the volume of results from lung counts, urinary excretion, and other measurements. This information is what allows the USTUR to accurately calculate dose to an individual worker, and to test and refine the mathematical (biokinetic) models that are used to calculate those doses.

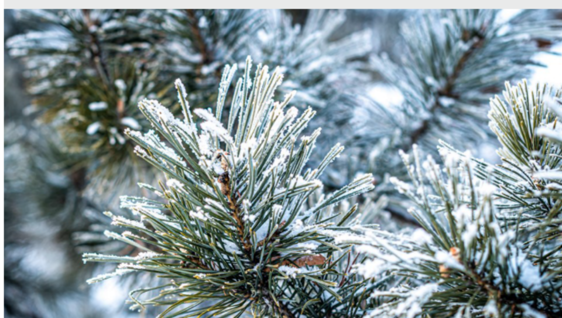
New Fume Hoods

Laboratory operations were paused for several months so that three new fume hoods could be installed. The original stainless-steel fume hoods and their exhaust system had substantially corroded since they were installed in 2009. The system had been repaired several times; however, the most recent inspection revealed that the extent of the corrosion was beyond repair. Carryover of funds not spent due to pandemic travel restrictions was used to purchase and install new polycarbonate fume hoods, plastic exhaust ducting, and exhaust blower fans. The new fume hoods became operational in October, and sample analysis was resumed.

Plutonium in the lungs: a deeper understanding

In 2007, the USTUR published a paper showing that a small fraction of inhaled soluble plutonium had remained in the lungs of a USTUR Registrant for nearly 40 years. Soluble plutonium dissolves rapidly once deposited in the lungs, which allows it to be quickly absorbed to the bloodstream and removed from the lungs. Therefore, this finding came as a surprise to many. At the time, any plutonium that was retained in the lungs was expected to be chemically bound to lung tissue. Thus, it came as a second surprise when autoradiography of lung tissues from the same Registrant revealed that plutonium was congregated as "stars," which were encapsulated within scar tissue. This finding was indicative of physically, not chemically, bound plutonium. At first, the distinction between chemically and physically bound plutonium may sound unimportant; however, it has big implications for the dose that is delivered to the lungs. Since plutonium emits alpha particles, which can travel only a very short distance in human tissue, all of the dose from physically bound plutonium would be delivered to the scar tissue instead of the more radiation-sensitive epithelial cells of the lungs.

Recently, the USTUR has collaborated with Deepesh Poudel from Los Alamos National Laboratory to further explore the possibility that scar tissue plays a role in the long-term retention of plutonium. Dr. Poudel used mathematical models to describe the absorption and transport of plutonium within the bodies of four USTUR Registrants. His findings were also inconsistent with chemical binding, suggesting that plutonium may indeed be physically bound in scar tissue. A proposed revision to the most recent International Commission on Radiological Protection (ICRP) respiratory tract model has been published in scientific literature as a series of four papers, and has been presented at several meetings, most recently at ICRP's 6th International Symposium on the System of Radiological Protection.



Interested in learning more about USTUR activities?

For more information about the work that is conducted at the USTUR, give us a call to request a copy of our annual report, or browse through our website. When visiting the website, the newsfeed (ustur.wsu.edu/news) is a good place to start! It not only includes information about the research conducted at the USTUR, but also about faculty involvement with organizations outside the Registries. It is through collaboration with outside institutions, and service on various committees and advisory boards, that our research (which is based on the generosity of our Registrants) is communicated to the broader radiation protection community.

Welcome aboard!

We want to welcome the newest member of the USTUR research faculty, Xirui Liu. Ms. Liu has worked with the USTUR as a student collaborator since 2019, where her research focused on using autopsy reports to determine how often the underlying causes of death found on death certificates are incorrect. Ms. Liu earned a Bachelor of Medicine, Bachelor of Surgery degree from Huazhong University of Science and Technology, China in 2017. She also has both a master's degree in public health in international health and development from Tulane University (2021), and a master's degree in health informatics from Weill Cornell Medicine (2022). Her first project will build on the findings of her original work to explore how under- and over-classification of diseases on death certificates changes estimates of cancer risk in epidemiological studies. Do errors on death certificates lead to an overestimation of the risk? Or do they lead to underestimation of risk? These are important questions for identifying potential biases in epidemiological studies, and understanding the true impact of radiation on human health.

Thank you for the urine samples!

We want to say a BIG thank you to everyone who sent a urine sample to us! We appreciate your willingness to participate in this effort and look forward to seeing the results of the analyses.

Environmental Protection Agency advisory board

Maia Avtandilashvili and Daniel Strom

Two USTUR faculty members, Maia Avtandilashvili and Daniel Strom, have been selected to serve on the science advisory board that will conduct a peer review of a draft Environmental Protection Agency report. "Cancer Risk Coefficients for Environmental Exposure to Radionuclides" (Federal Guidance Report No. 16) will provide estimates of risk coefficients that can be used for assessment of potential cancer risks from exposure to radionuclides in air, water, and soil.

U.S. Transuranium and Uranium Registries

1845 Terminal Drive
Richland, WA 99354

Phone: 509-392-3749
Toll free: 800-375-9317

ustur.wsu.edu

Appendix C

UNITED STATES TRANSURANIUM AND URANIUM REGISTRIES

College of Pharmacy and Pharmaceutical Sciences
Washington State University

2022 Scientific Advisory Committee Meeting

Zoom Teleconference (Pacific Daylight Time), April 28–29, 2022

Day 1

Thursday, April 28, 2022

07:30 – 08:00	Zoom in	All
08:00 – 08:10	Welcome & Introduction	S. Tolmachev, *USTUR Director*
08:10 – 08:15	Opening Remarks	T. Rucker, *SAC Chair*
08:15 – 08:30	Updates from DOE	K. Dressman, *DOE HQ EHSS-10 Director*
08:30 – 08:45	WSU Tri-Cities Updates	S. Haynes, *WSU TC Chancellor*
08:45 – 09:00	WSU/CPPS News	M. Leid, *CPPS Dean*
09:00 – 09:10	Administrative & Financial Developments	M. Bedell, *Program Specialist II*
09:10 – 09:50	2021 SAC Recommendations & Overview	S. Tolmachev, *USTUR Director*
09:50 – 10:00	*Coffee Break*	
10:00 – 10:15	Radiochemistry Progress Report	G. Tabatadze, *Assistant Professor*
10:15 – 10:30	Registrant Statistics and IRB	S. McComish, *Associate in Research*
10:30 – 10:45	Database Harmonization	S. McComish, *Associate in Research*
10:45 – 11:00	Plutonium Lung Dosimetry	D. Poudel, *LANL Scientist*
11:00 – 11:10	*Coffee Break*	
11:10 – 11:25	Uncertainty Project	M. Šefl, *Research Associate*
11:25 – 11:40	Enriched Uranium Study	M. Avtandilashvili, *Assistant Professor*
11:40 – 12:00	Research & Operations: Plan for FY2023	S. Tolmachev, *USTUR Director*
12:00 – 12:30	Discussion and Q & A	USTUR, DOE, SAC, Guests

Day 2

Friday, April 29, 2022 – SAC, DOE and USTUR Management

08:30 – 08:40	SAC Membership	S. Tolmachev, *USTUR Director*
08:40 – 09:00	SAC Q & A	T. Rucker, *SAC Chair*
9:00 – 12:00	SAC Executive Session	T. Rucker, *SAC Chair*
12:00 – 13:00	*Lunch*	
13:00 – 14:00	SAC Debriefing	T. Rucker, *SAC Chair*

Appendix D

USTUR-0596-21

Radiochemistry and nuclear chemistry workforce in the United States

S. Y. Tolmachev[1], J. D. Auxier, II[2], M. Nilsson[3], B. A. Powell[4], T. L. Rucker[5], R. Sudowe[6]

[1]*U.S. Transuranium and Uranium Registries, Washington State University, Richland, WA*
[2]*Los Alamos National Laboratory, Los Alamos, NM*
[3]*Department of Chemical and Biomolecular Engineering, University of California, Irvine, CA*
[4]*Department of Environmental Engineering and Earth Sciences and Department of Chemistry, Clemson University, Anderson, SC*
[5]*Leidos, Oak Ridge, TN*
[6]*Department of Environmental and Radiological Health Sciences, Colorado State University, Fort Collins, CO*

The disciplines of radiochemistry and nuclear chemistry have direct applications in the fields of national security, nuclear medicine, nuclear power production, and environmental management. Although, often, nuclear and radiochemistry are grouped together and many experts work in both areas, the definition for each field is slightly different. For example, radiochemistry may be defined as the application of the phenomena of radioactive decay and techniques common to nuclear physics so as to solve problems in the field of chemistry. In contrast, nuclear chemistry may be defined as the application of procedures and techniques common to chemistry to study the structure of the atomic nucleus. This chapter provides a brief update of the current state of, and critical U.S. needs for, nuclear chemistry and radiochemistry expertise as the Assuring a Future U.S.-Based Nuclear and Radiochemistry Expertise report was published by National Academy of Sciences (NAS) in 2012.

Journal of Applied Clinical Medical Physics 23(S1): e13789; 2022.

USTUR-0601-21

Quadrupole and sector field ICP-MS analysis of ^{226}Ra in brain from a radium dial painter

D. L. Arbova[1], S. Y. Tolmachev[2], J. D. Brockman[1,3]

[1]*Department of Chemistry, University of Missouri, Columbia, MO*
[2]*U.S. Transuranium and Uranium Registries, College of Pharmacy and Pharmaceutical Sciences, Washington State University, Richland, WA*
[3]*Research Reactor, University of Missouri, Columbia, MO*

Two ICP-MS methods were developed to measure the radiotoxic isotope ^{226}Ra in brain tissues from a radium dial painter worker. The first method was a direct analysis of acid digested samples using quadrupole ICP-MS. The instrumental LOD of ^{226}Ra was 0.1 ng kg^{-1}. Polyatomic interferences at *m/z* 226 were investigated and Pb was identified from a polyatomic interferent in an in-house sample prepared from bovine brain, with a 226/208 formation ratio of 4×10^{-8}. The quadrupole ICP-MS method was also used to measure levels of beryllium, strontium, and

uranium. A second method was developed that included cation-exchange chromatography to separate ^{226}Ra followed by analysis with sector field MC-ICP-MS. The instrumental LOD for the cation exchange method with MC-ICP-MS detection was 0.5 pg kg^{-1} (19 mBq kg^{-1}). The measured concentrations of ^{226}Ra in different brain regions ranged from 0.09–0.72 ng kg^{-1} (3.3–27 Bq kg^{-1}) and radium was non-uniformly distributed in the brain.

Journal of Analytical Atomic Spectrometry 37(6): 1369-1376; 2022.

USTUR-0614-22

ICP-MS analysis of actinides in brain tissue of an occupationally exposed individual

D. L. Arbova[1], S. Y. Tolmachev[2], J. D. Brockman[1,3]

[1]*Department of Chemistry, University of Missouri, Columbia, MO*
[2]*U.S. Transuranium and Uranium Registries, College of Pharmacy and Pharmaceutical Sciences, Washington State University, Richland, WA*
[3]*Research Reactor, University of Missouri, Columbia, MO*

An ICP-MS method was developed to measure the actinides in autopsy brain tissue of an occupationally exposed individual. ^{239}Pu, ^{240}Pu, ^{241}Am, and ^{238}U concentrations as well as $^{240}Pu/^{239}Pu$, $^{235}U/^{238}U$ atom ratios were measured by quadrupole ICP-MS following extraction chromatography. The ^{239}Pu concentrations measured in the cerebral lobe of the right side of the brain was 0.66 ± 0.08 ng/kg. The $^{239}Pu/^{240}Pu$ ratio was 0.071 ± 0.025. The ^{241}Am level was below the LOD. The ^{238}U concentration was 106.6 ± 0.29 ng/kg and the $^{235}U/^{238}U$ ratio was 0.00703 ± 0.00087.

Journal of Radioanalytical and Nuclear Chemistry 331: 5147–5151; 2022.

USTUR-0610-22

Methods of improving brain dose estimates for internally deposited radionuclides

R. W. Leggett[1], S. Y. Tolmachev[2], M. Avtandilashvili[2], K. F. Eckerman[1], H. A. Grogan[3], G. Sgouros[4], G. E. Woloschak[5], C. Samuels[1], J. D. Boice Jr.[6,7]

[1]*Oak Ridge National Laboratory, Oak Ridge, TN*
[2]*U.S. Transuranium and Uranium Registries, Washington State University, Richland, WA*
[3]*Cascade Scientific, Bend, OR*
[4]*The Johns Hopkins University School of Medicine, Baltimore, MD*
[5]*Northwestern University Chicago, Chicago, IL*
[6]*National Council on Radiation Protection and Measurements, Bethesda, MD*
[7]*Vanderbilt University, Nashville, TN*

The US National Council on Radiation Protection and Measurements (NCRP) convened Scientific Committee 6–12 (SC 6–12) to examine methods for improving dose estimates for brain tissue for internally deposited radionuclides, with emphasis on alpha emitters. This Memorandum summarises the main findings of SC 6–12 described in the recently published NCRP Commentary No. 31, 'Development of Kinetic and Anatomical Models for Brain Dosimetry for Internally Deposited Radionuclides'. The Commentary examines the extent to which dose estimates for the brain

could be improved through increased realism in the biokinetic and dosimetric models currently used in radiation protection and epidemiology. A limitation of most of the current element-specific systemic biokinetic models is the absence of brain as an explicitly identified source region with its unique rate(s) of exchange of the element with blood. The brain is usually included in a large source region called Other that contains all tissues not considered major repositories for the element. In effect, all tissues in Other are assigned a common set of exchange rates with blood. A limitation of current dosimetric models for internal emitters is that activity in the brain is treated as a well-mixed pool, although more sophisticated models allowing consideration of different activity concentrations in different regions of the brain have been proposed. Case studies for 18 internal emitters indicate that brain dose estimates using current dosimetric models may change substantially (by a factor of 5 or more), or may change only modestly, by addition of a sub-model of the brain in the biokinetic model, with transfer rates based on results of published biokinetic studies and autopsy data for the element of interest. As a starting place for improving brain dose estimates, development of biokinetic models with explicit sub-models of the brain (when sufficient biokinetic data are available) is underway for radionuclides frequently encountered in radiation epidemiology. A longer-term goal is development of coordinated biokinetic and dosimetric models that address the distribution of major radioelements among radiosensitive brain tissues.

Journal of Radiological Protection 42(3): 3001; 2022.

USTUR-0538-20A

U.S. Transuranium and Uranium Registries: 2010 – 2022 research accomplishments and collaborative efforts

S. Y. Tolmachev

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

The United States Transuranium and Uranium Registries (USTUR), and the associated National Human Radiobiology Tissue Repository (NHRTR), is a federal-grant program funded by U.S. Department of Energy and operated by College of Pharmacy and Pharmaceutical Sciences at Washington State University in Richland, Washington, USA. The Registries was established in 1968 to study the biokinetics and internal dosimetry of actinides (uranium, plutonium, and americium) in occupationally-exposed Registrants who volunteered portions of their bodies, or their whole bodies, for scientific use posthumously. The USTUR is the only program worldwide that can comprehensively study biokinetics and dosimetry of internally deposited actinides. The USTUR serves as a source for both scientific research and public information regarding the biokinetics and tissue dosimetry of the actinide elements in humans. Since 1992, eight PhD and eight MS students have used USTUR data to complete the research requirements of their studies. Currently, USTUR research focuses on: (i) estimation of uncertainties in radiation dose assessment for internally deposited actinides, (ii) biokinetic modeling of individual cases, (iii) development of actinide chelation models, (iv) study of post-mortem distribution of actinides in the human body, and (v) study of occupational exposure to non-radioactive materials associated with the nuclear industry. The USTUR core operational functions are: (i) accepting and processing Registrant donations, (ii) completing radiochemical analysis of donated tissue samples, and (iii) completing the development and population of the USTUR databases. Currently, the Registries holds records and data for 364 deceased and 22 living Registrants. The USTUR/NHRTR data and materials are available to qualified scientists for their research upon request. The USTUR maintains well-established collaborations with national and international scientists and institutions, and develops new collaborative relationships. Since its establishment, the USTUR has published over 350 peer-reviewed manuscripts, and has contributed to six National Council on Radiation Protection and Measurements reports and nine International Commission on Radiological Protection publications.

(Abstract) *Health Physics* 123(1): 79; 2022.

USTUR-0539-20A

Uncertainties in radiation dose assessment for internally deposited plutonium in support of radiation epidemiology

M. Šefl[1], J. Y. Zhou[2], M. Avtandilashvili[1], S. Y. Tolmachev[1]

[1]*U.S. Transuranium and Uranium Registries, Washington State University, Richland, WA*
[2]*U.S. Department of Energy, Washington, DC*

Since its establishment in 1968, the United States Transuranium and Uranium Registries (USTUR) has received 317 partial- and 47 whole-body donations for scientific research from former nuclear workers who had accidental intakes of actinide radionuclides. These individuals typically have well-documented work history, exposure, bioassay monitoring, and medical records. Among 349 cases with completed radiochemical analysis, 59 cases with recorded ^{239}Pu intake(s) were selected for evaluation of uncertainties in the radiation dose assessment for radiation epidemiology. These individuals were not extensively treated with chelation therapy and had at least five ^{239}Pu urine measurements exceeding the contemporary detection limit, as well as ^{239}Pu concentrations in the skeleton and liver greater than 0.1 Bq kg^{-1} and 1 Bq kg^{-1}, respectively. The objectives were to compare: (i) predicted ^{239}Pu activities in the skeleton and liver, based upon urine bioassays, with measured post-mortem activities in the skeleton and liver; (ii) dose estimates calculated from urine data alone with those based on both urine data and post-mortem radiochemical analyses. Taurus internal dosimetry software was used to model individual cases using default ICRP biokinetic model assumptions. Biases for the predicted and measured post-mortem organ activities and calculated radiation doses were studied as a pilot study of 11 former Manhattan Project workers. Current biokinetic model predictions for the liver+skeleton retention appear to be on average within 5% of the measured organ activities. On the other hand, the use of early urine bioassay data collected during the exposure period in the 1940s overestimated the liver+skeleton activity on average by a factor of 2.5. This demonstrates the importance of a long-term collection of bioassays as a part of follow-up. Analysis of the remaining cases are in progress.

(Abstract) *Health Physics* 123(1): 80; 2022.

USTUR-0537-20A

Beryllium in the tissues of former nuclear workers

M. Avtandilashvili[1], D. Larivière[2], N. Momoshima[3], D. Wegge[4], J. D. Brockman[4], S. Y. Tolmachev[1]

[1]U.S. Transuranium and Uranium Registries, Washington State University, Richland, WA
[2]Laval University, Laval, Canada
[3]Kyushu Environmental Evaluation Association, Kyushu, Japan
[4]University of Missouri, Columbia, MO

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. The US Transuranium and Uranium Registries (USTUR), established in 1968 to study the biokinetics and internal dosimetry of actinides by following up former nuclear workers with documented intakes of these elements, who volunteered their bodies for scientific use posthumously, holds detailed work history, radiation exposure, and industrial hygiene records including self-reported information on beryllium exposure. Out of 364 deceased USTUR Registrants, 92 self-reported working with beryllium, but only 73 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 13 USTUR cases with beryllium exposure duration ranging from 3 to 39 years. A total of 149 tissues was analyzed including 105 tissues from a whole-body donor who was potentially exposed to beryllium for 6 years. The highest concentrations were measured in thoracic lymph nodes with the range of 6 – 334 μg kg^{-1} (median: 59.1 μg kg^{-1}). For other tissues, beryllium median concentration followed the order: liver (6.84 μg kg^{-1}) > kidney (0.55 μg kg^{-1}) > lung (0.30 μg kg^{-1}) > skeleton (0.16 μg kg^{-1}). For analyzed whole-body case, the total beryllium content was estimated to be 54.8 μg, including 5.8 μg retained in the respiratory tract 22 years post-exposure. It was found that systemic beryllium primarily accumulated in the skeleton (27.3 μg), followed by the liver (11.3 μg) and other soft tissues (10.4 μg). Beryllium concentration in the liver (10.2 μg kg^{-1}) was three times higher than the average concentration in the skeleton (3.0 μg kg^{-1}) and 42 times higher than that in other soft tissues (0.24 μg kg^{-1}).

(Abstract) *Health Physics* 123(1): 80; 2022.

USTUR-0603-22A

Misclassification of causes of death among USTUR Registrants: Death Certificates vs. Autopsy Reports

S. L. McComish[1], X. Liu[2], F. T. Martinez[1], J. Y. Zhou[3], S. Y. Tolmachev[1]

[1]U.S. Transuranium and Uranium Registries, Washington State University, Richland, WA
[2]Weill Cornell Medicine, New York, NY
[3]U.S. Department of Energy, Washington, DC

The USTUR performs autopsies on each of its Registrants as a part of its mission to follow up occupationally-exposed individuals. This provides a unique opportunity to explore death certificate misclassification errors among this small population of former nuclear workers. Underlying causes of death (UCOD) from death certificates and autopsy reports were coded using the 10th revision of the International Classification of Diseases (ICD-10). These codes were then used to quantify misclassification rates among 240 individuals for whom both death certificates and autopsy reports were available. ICD-10 categorizes diseases using 22 chapters. Death certificates incorrectly identified the UCOD ICD-10 disease chapter in 28.3% of cases. The misclassification rates for the most common disease chapters were: 13.8% neoplasms, 15.0% circulatory, 64.0% respiratory, 23.5% external causes, and 40.0% nervous system. Death certificates often include fields that indicate if the autopsy report was used to determine the cause of death. The misclassification rate was 18.4% for death certificates that used the autopsy report to determine the UCOD, 38.0% for those that did not, and 23.1% for those where use was unknown. The difference between the misclassification rate for death certificates that used the autopsy report to determine the UCOD and those that did not was statistically significant.

(Abstract) *Health Physics* 123(1): 67; 2022.

USTUR-0604-22A

The neutrophil to lymphocyte ratio shows evidence for chronic inflammation in a Radium Dial Painter cohort

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

[1]MJW Corporation Inc., Buffalo, NY
[2] Radiation Emergency Assistance Center/Training Site (REAC/TS), Oak Ridge, TN
[3]International Epidemiology Institute, Rockville, MD
[4]U.S. Transuranium and Uranium Registries, Washington State University, Richland, WA

The neutrophil to lymphocyte ratio (NLR) is widely regarded in clinical medicine as a nonspecific marker of inflammation. In a collaborative effort with the US Transuranium and Uranium Registries (USTUR) and with the NCRP Million Person Study, it has been possible to evaluate NLR from medical records of a cohort of 166 former radium dial painters previously evaluated at Argonne National Laboratory. The radium dial painters (RDP) are a well-described group of predominantly young women who incidentally ingested ^{226}Ra and ^{228}Ra as they painted luminescent watch dials in the first part of the twentieth century. Members of the cohort had ingestion of radium at an early age (mean age 20.6 ± 5.4 y). Exposure duration ranged from 1–1,820 weeks with red marrow dose 1.5 mGy

– 10.52 Gy. Two subsets (n=7 each; marrow dose > 50 cGy) were derived from this cohort: one set consists of those RDP without a history of radium-induced sarcoma (average red marrow dose 164 cGy) and another set of RDP with a history of treated sarcoma (average marrow dose 371 cGy). In addition, a set of normal unirradiated controls (n=125) was obtained. NLR is found to be the same in the RDP subset without sarcoma as in controls (2.06 ± 0.062 vs. 2.07 ± 0.12; mean ± SEM; p=0.43 NS, Mann-Whitney Rank Sum Test). However, NLR in the treated sarcoma group is markedly higher (3.17 ± 0.25), significant at p<0.001 using Mann-Whitney. This observation suggests a possible state of chronic inflammation in those patients previously treated for radium-induced osteosarcoma.

(Abstract) *Health Physics* 123(1): 55; 2022.

USTUR-0605-22A

Proposed revision of the ICRP 141 Pu systemic model to incorporate the HAT model and the hepatic portal vein

D. J. Strom[1], M. Avtandilashvili[1], A. S. Felsot[2], S. L. McComish[1], G. Tabatadze[1], S. Y. Tolmachev[1]

[1]*U.S. Transuranium and Uranium Registries, Washington State University, Richland, WA*
[3]*School of Environment, Washington State University, Richland, WA*

The human liver typically receives about 25% of systemic blood circulation. The liver is unusual in that it has two separate input streams of blood: the hepatic artery supplies oxygenated blood and about 20% of blood flowing into the liver; and the hepatic portal vein brings nutrient-rich oxygen-depleted blood from the alimentary tract and associated secretory organs, and accounts for about 80% of the blood flowing into the liver. After the liver processes nutrients and other material from the digestive system, the streams combine and exit the liver via the hepatic vein. While the ICRP 100 human alimentary tract (HAT) model explicitly includes the HPV, the ICRP 141 models for actinides and for plutonium do not, and in fact show uptake from the small intestine directly to blood. The fact that all blood from the HAT first passes through the liver before mixing with systemic circulation is critical for understanding the metabolism and toxicity of chemicals, as well as understanding the processing of all materials entering from the gut. The liver selectively removes plutonium from blood and retains a significant fraction of a body's systemic Pu. This paper proposes a modification to the ICRP 141 Pu systemic model to harmonize the entire ICRP 100 HAT model with the systemic model, explicitly modeling the first stop in the liver for all blood containing Pu. Since it is doubtful whether existing data can be used to determine all the new model parameters, some simplification may be required, but the product of such efforts must retain the fundamental fact that any uptake of Pu from the HAT first visits the liver. It is unknown if this anatomically and physiologically improved model would provide a better understanding of Pu biokinetics, and we pose several questions regarding how inclusion of the HPV may impact the kinetics of Pu in the liver.

(Abstract) *Health Physics* 123(1): 67; 2022.

USTUR-0607-22A

Measurement of ^{239}Pu in autopsy brain tissue from an occupationally exposed worker using ICP-MS

D. Wegge[1], S. Y. Tolmachev[2], J. D. Brockman[1,3]

[1]Department of Chemistry, University of Missouri, Columbia, MO
[2]U.S. Transuranium and Uranium Registries, College of Pharmacy and Pharmaceutical Sciences, Washington State University, Richland, WA
[3]Research Reactor, University of Missouri, Columbia, MO

^{239}Pu is a radiotoxic alpha emitter. The International Commission on Radiological Protection evaluated lifetime risk assessment of ^{239}Pu exposure and lung, liver, and bone cancer mortality. There is interest in evaluating neurological outcomes associated with ^{239}Pu exposure and in revision of the biokinetic models to include a brain compartment. This study presents the first work to measure Pu in brain tissue using ICP-MS. Two ICP-MS methods were developed to measure the radiotoxic isotope ^{239}Pu in autopsy brain tissue of an occupationally exposed worker. The first method was a direct analysis of digested samples by quadrupole ICP-MS with quantification by using standard additions. Polyatomic interferences at m/z = 239 were investigated. Hg, Pb, and U were identified to form polyatomic interferences in a sample prepared from bovine brain, with a 239/202 formation ratio of 8×10^{-6} from ^{202}Hg, a 239/208 formation ratio of 3×10^{-6} from ^{208}Pb, and a 239/238 formation ratio of 1×10^{-5} from ^{238}U. A second analysis method was developed using extraction chromatography to separate Pu, Am, and U from the matrix followed by isotope dilution analysis of ^{239}Pu. The instrumental LOD of ^{239}Pu was 0.01 ng/kg. The results from the extraction chromatography method showed a ^{239}Pu brain concentration of 0.69 ± 0.05 ng/kg. This result supports the use of isotope dilution ICP-MS to measure ^{239}Pu in autopsy brain samples.

(Abstract) *Book of Abstracts International Conference on Methods and Applications of Radioanalytical Chemistry (MARC XII)*: 113; 2022

USTUR-0608-22A

Method for measuring Pu, Am, and U in hair and nails of occupationally exposed workers through extraction chromatography and MC-ICP-MS

D. Wegge[1], S. Y. Tolmachev[2], J. D. Brockman[1,3]

[1]Department of Chemistry, University of Missouri, Columbia, MO
[2]U.S. Transuranium and Uranium Registries, College of Pharmacy and Pharmaceutical Sciences, Washington State University, Richland, WA
[3]Research Reactor, University of Missouri, Columbia, MO

Human biomonitoring of actinides is a potential tool that could aid in treaty compliance monitoring, forensic investigations of nuclear smuggling, and for determination of internal dose following a nuclear accident or use of a radioactive dispersal device or nuclear weapon. Currently, the ICRP biokinetic models for actinides do not include hair and nails as a compartment. This work describes an analytical method to measure of $^{235}U/^{238}U$, $^{236}U/^{238}U$, and

^{239}Pu/^{240}Pu, as well as ^{235}U, ^{238}U, ^{239}Pu, ^{241}Am concentrations at ultra-trace levels by ICP-MS. Extraction chromatography resins TEVA, DGA, and UTEVA were used to separate Pu, Am, and U from the digested sample. The concentration of Pu and Am was measured using isotope dilution analysis with a multi-collector ICP-MS. The instrumental LOD was 1×10^{-5} ng/kg for ^{239}Pu and 3×10^{-5} ng/kg for ^{241}Am. The measured concentrations of ^{239}Pu in 18 hair and nail samples from 9 occupationally exposed individuals ranged from 1.8×10^{-1} – 1.6×10^{1} ng/kg. The ^{240}Pu/^{239}Pu isotopic ratios ranged from 0.029 to 0.075, indicating an exposure to weapons-grade Pu. The concentration of U was measured using a quadrupole ICP-MS and had an instrumental LOD of 1×10^{-3} ug/kg. The U levels ranged from 3.4×10^{-5} – 6.0×10^{-1} ug/kg. This work demonstrates that ^{239}Pu is excreted through hair and nail for years after the reported exposure and could be useful as a long-term biomonitor.

(Abstract) *Book of Abstracts International Conference on Methods and Applications of Radioanalytical Chemistry (MARC XII)*: 114; 2022