12th International Conference on Health Effects of Incorporated Radionuclides
Fontenay-aux-Roses, France
October 8 - 11, 2018

USTUR: Expanding horizons for actinide biokinetics and dosimetry

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"Learning from Plutonium and Uranium Workers"

U.S. Transuranium and Uranium Registries

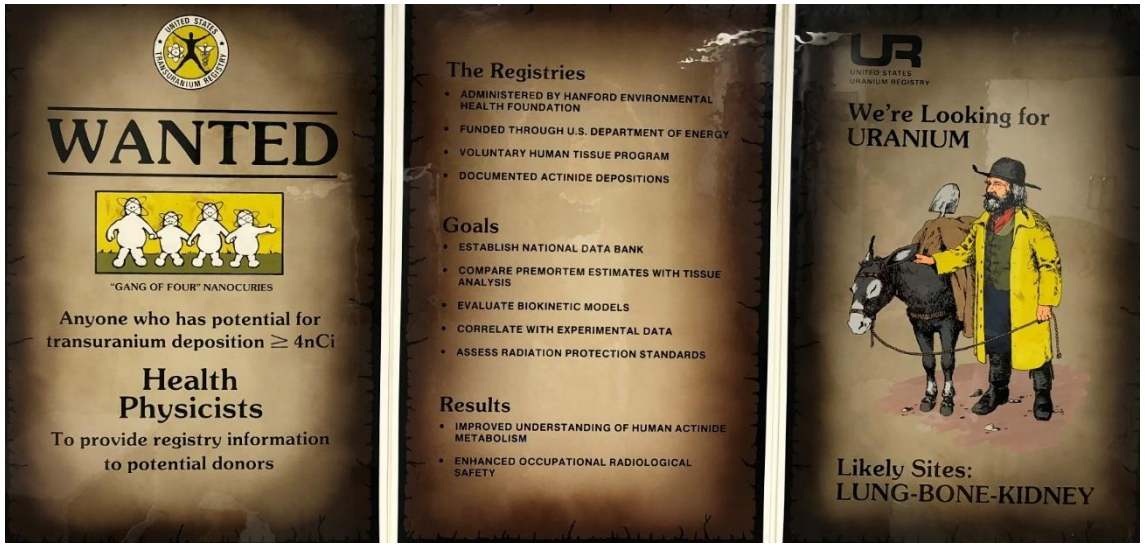
- Funded by the U.S. Department of Energy since 1968
- Follows up occupationally-exposed individuals (volunteer Registrants) by studying the biokinetics (deposition, translocation, retention, and excretion) and tissue dosimetry of U and transuranium elements, such as Pu, Am, Cm, and Np

USTUR Registrants

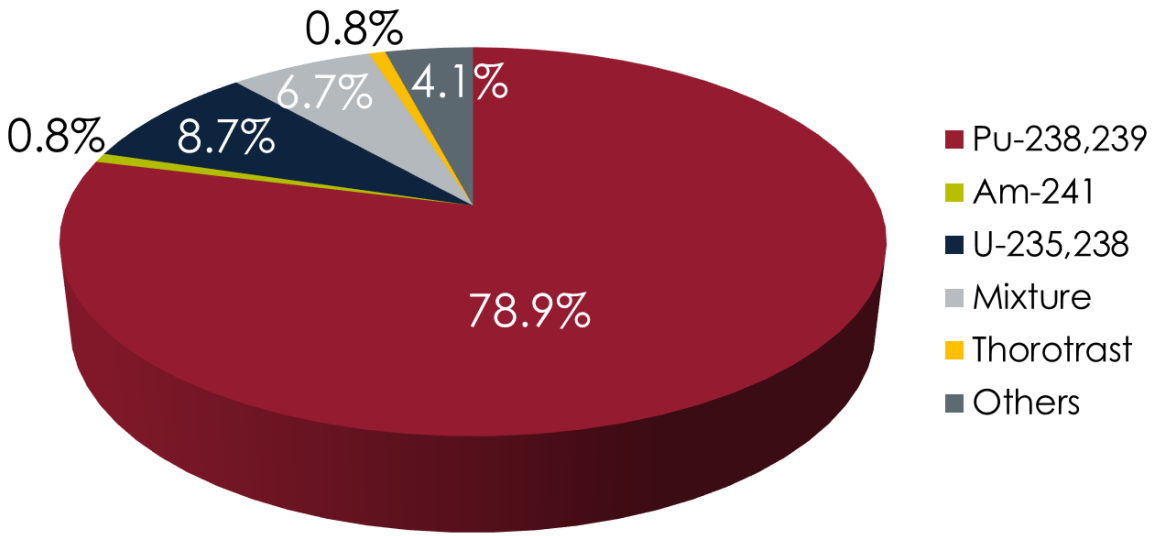
- Voluntary tissue donors (posthumous):

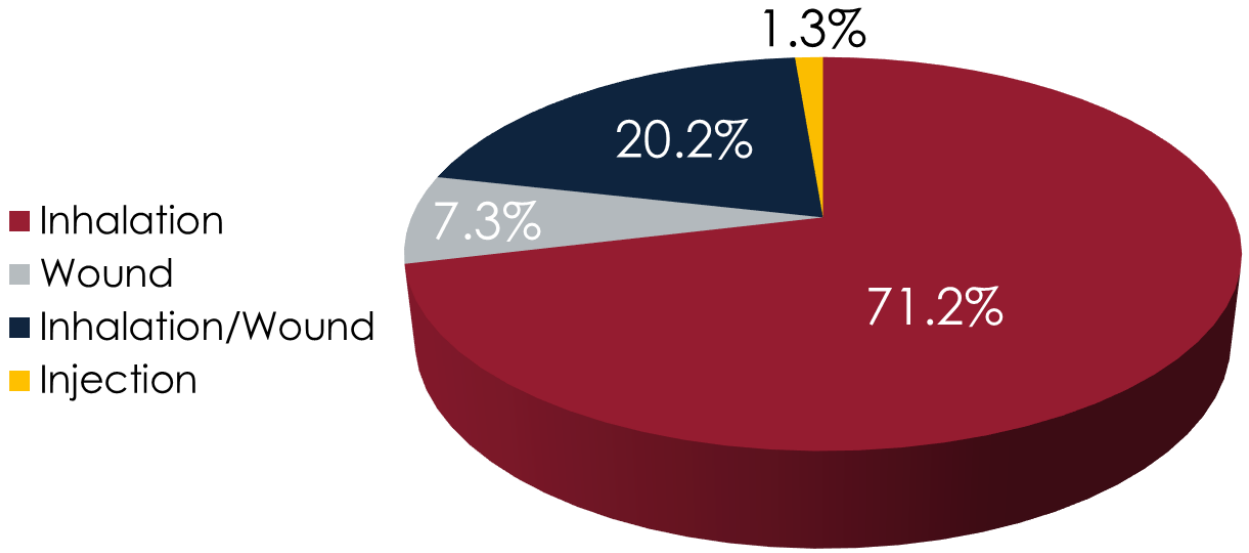
whole- (46) and/or partial-body (310) donations

- Former nuclear workers from DOE sites
- Documented radiation exposure and work history
- Acceptance criteria:
  i. actinide internal deposition of ≥74 Bq (2 nCi)
  ii. external dose to whole body ≥0.1 Sv (10 rem)

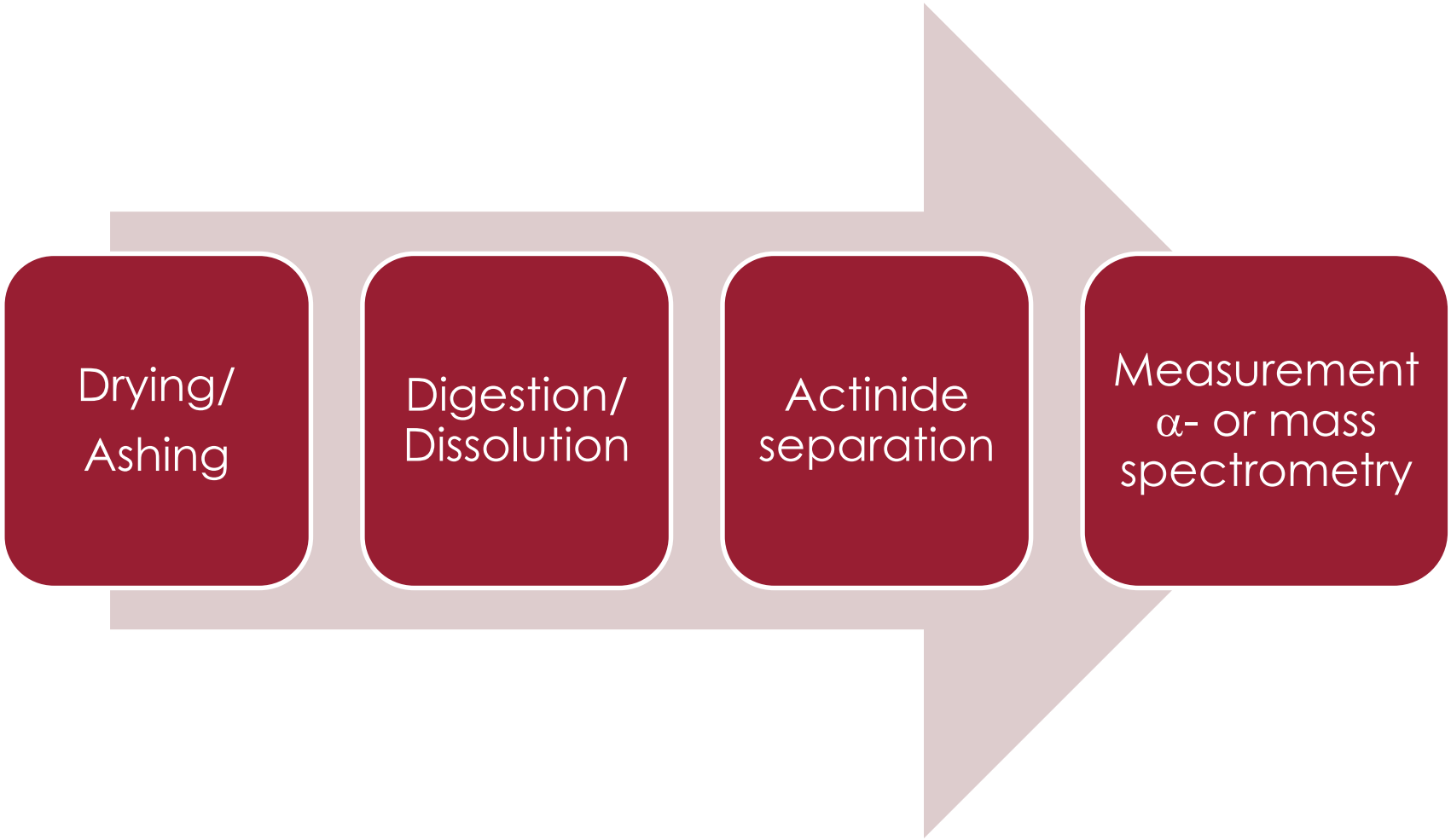


Primary Intakes



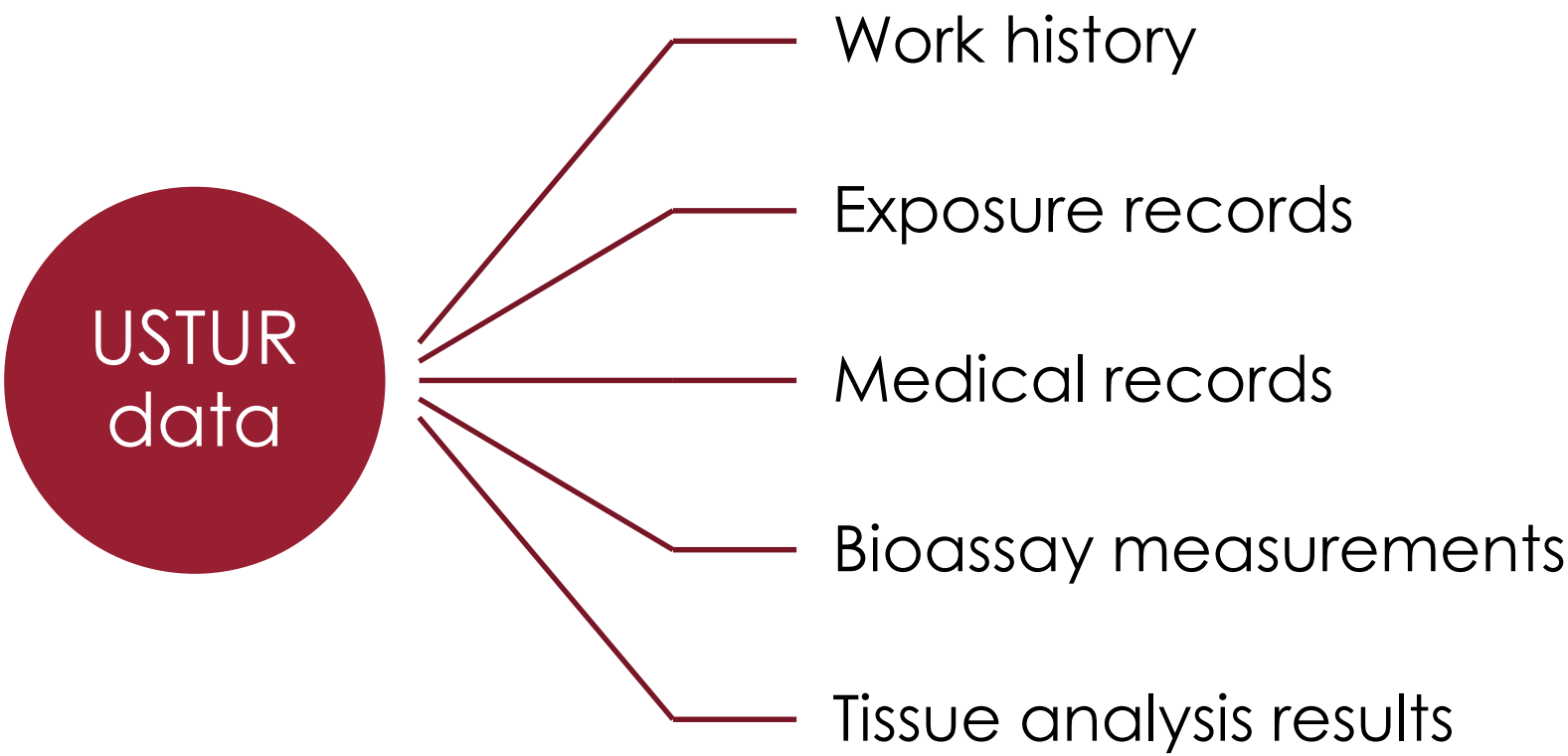


Radiochemical Analysis of Tissue Samples



- 300 – 400 tissue analysis for Pu/Am and U per year

Unique Data Resource



Primary Research: *Biokinetic Modeling and Internal Dosimetry of Actinides*

- Testing, improving and parameterizing biokinetic models for radiological protection
  - ✓ Human Respiratory Tract Model (ICRP 130)
  - ✓ Wound Model (NCRP 156)
  - ✓ Systemic models for U, Pu, Am (ICRP OIR3 & OIR4)
- Evaluating uncertainties in internal radiation dose assessment
- Modeling actinide decorporation

Avtandilashvili *et al*. The United States Transuranium and Uranium Registries: Fifty-year history of actinide biokinetic research (invited)

Avtandilashvili *et al*. Biokinetics of soluble plutonium after wound injury treated with Ca-DTPA

Leggett *et al.* Case studies in brain dosimetry for internal emitters: Is more detail needed for epidemiology?

Research Opportunities

- Actinide biokinetics and tissue dosimetry
- Decorporation modeling
- Long-term retention and distribution in human body
- …and more

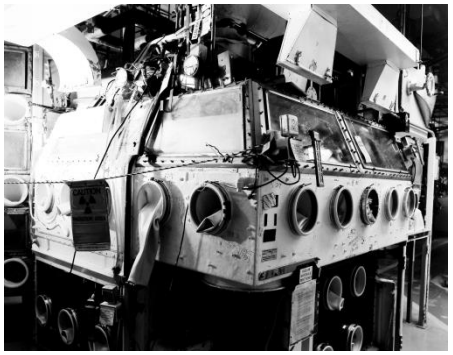
Inhalation of Refractory ^{239}Pu

'High-fired' PuO_2 aerosols

- Generated at 1800°C
- Particle size: 1 μm AMAD

22 USTUR Registrants involved

- 5 whole-body donations
- 16 partial-body donations
- 1 living Registrant



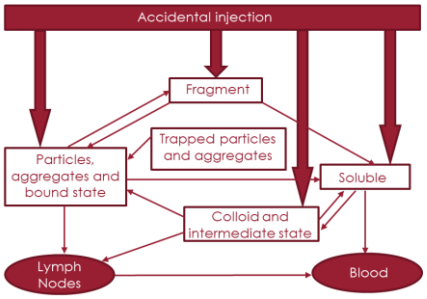
https://www.lm.doe.gov

Follow-up bioassay

- Urine, chest counts, and feces
- From 1 to 60+ positive urine measurements

^{239}Pu Contaminated Wound

- 14 USTUR Registrants with wound as primary intake
  - ✓ 4 whole-body donations
  - ✓ 8 partial-body donations
  - ✓ 2 living Registrants
- No chelation treatment
- Follow-up bioassay: wound counts, urine
  - ✓ From 1 to 94 positive urine measurements



Fifty-two Year Follow-up of Wound Intake

- Living partial-body donor: Case 0820
- Puncture wound to the right hand: ~1 cm depth
- Initial ^{239}Pu deposition: 11 kBq
- Treatment: wound excision
- Activity after excision: 1.6 kBq

Follow up (2016)

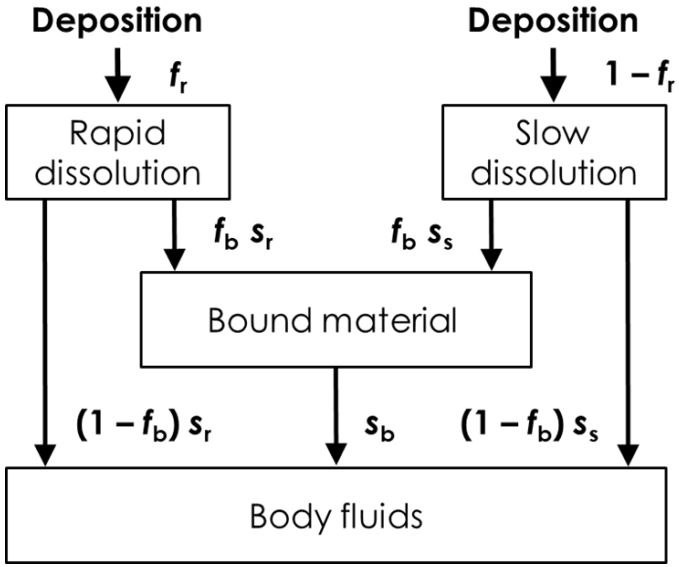
- Nodule excised 51-y later
- Activity removed: 632 Bq
- Activity retained: 1.9 ± 0.2 kBq

Plutonium Bound Fraction

- USTUR Case 0269: f_b = 0.0037

Puncher M *et al*. The Mayak Worker Dosimetry System (MWDS-2013): A re-analysis of USTUR Case 0269 to determine whether plutonium binds to the lungs. *Radiat Prot Dosim* 176: 50-61; 2017

- ICRP OIR Part 4 (upcoming): f_b = 0.002



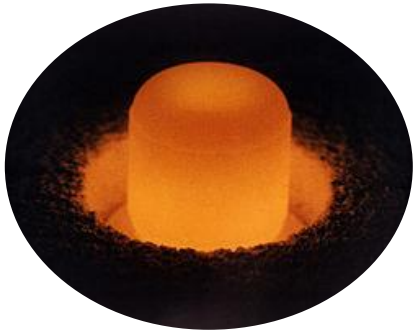
- More USTUR cases available

Inhalation of Soluble ^{239}Pu

- U(you)P(ee)PU Club: 26 workers exposed at Los Alamos during 1943 – 1945
- 14 of them are USTUR Registrants
  - ✓ 7 whole-body donations
  - ✓ 5 partial-body donations
  - ✓ 2 special study cases
- Follow-up data: chest counts, urine
  - ✓ From 3 to 100+ positive urine measurements

http://permalink.lanl.gov

Intakes of ^{238}Pu



https://en.wikipedia.org

- 10 USTUR Registrants
  - ✓ 2 whole-body donations
  - ✓ 4 partial-body donations
  - ✓ 4 living Registrants
- Follow-up bioassay: lung counts, urine
  - ✓ From 10 to 300+ positive urine measurements

Plutonium Decorporation

- Treatment: Ca-EDTA, Ca/Zn-DTPA
- 15 USTUR Registrants
  - ✓ 6 whole-body donations
  - ✓ 7 partial-body donations
  - ✓ 2 living Registrants
- USTUR decorporation model

James *et al*. USTUR whole body Case 0269: Demonstrating effectiveness of i.v. Ca-DTPA for Pu. *Radiation Protection Dosimetry* 127(1-4): 449-455; 2007

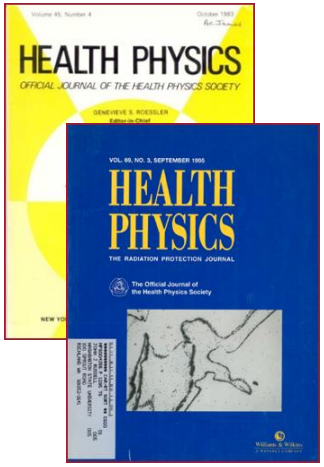
- Compartmental decorporation model

Dumit *et al*. Development of a new system of models for plutonium decorporation therapy. *Radiation Research* Submitted; 2018

Americium Decorporation

USTUR Case 0246: *'Atomic Man'*

- Highest recorded ^{241}Am intake: > 40 MBq
- Ca/Zn-DTPA therapy: 4 years
- Treatment efficacy factor: 80



USTUR Case 0846

- Initial systemic deposition: 66.7 kBq
- Ca-DTPA therapy: 7 years
- Post-mortem activity in skeleton: 26 kBq

Breustedt B *et al*. USTUR Case 0846: Modeling americium biokinetics after intensive decorporation therapy. *Health Phys* 2018; Published ahead of print

Uranium Occupational Intake

33 USTUR Registrants

- ✓ U-natural: 17
- ✓ U-enriched: 5
- ✓ U-depleted: 3
- ✓ Unknown: 8

https://en.wikipedia.org

Follow-up bioassay: urine, lung counts

- ✓ From none to 300 positive urine measurements

Uranium Distribution in Human Body

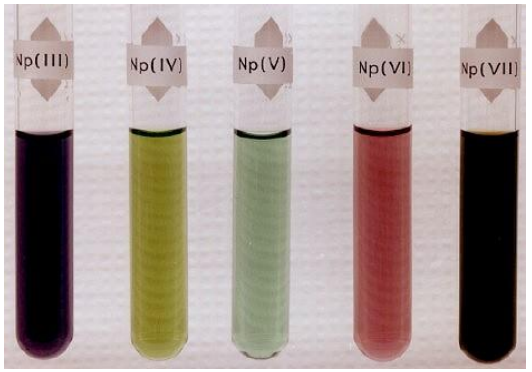
- Uranium in man
  - ✓ Five plutonium workers
  - ✓ No occupational exposure to U
  - ✓ Chronic exposure to natural U

Kathren RL, Tolmachev SY. Natural uranium tissue content of three Caucasian males. *Health Phys* 109: 187-197; 2015.

- Uranium in woman
  - ✓ Two whole-body donors
  - ✓ No radiation workers
  - ✓ Therapeutic injection of Thorotrast (^{232}Th)
  - ✓ Chronic exposure to natural U

Neptunium-237

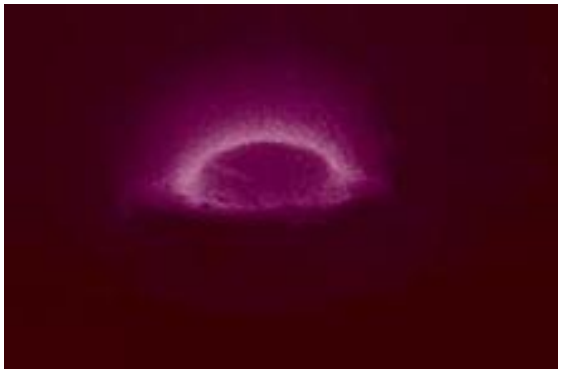
- One living partial-body donor
- Single acute inhalation of ^{237}Np ($T_{1/2}$ = 2.14 × 10^6 y)
- Estimated intake: 15 Bq
- Three positive ^{237}Np urine measurements
- Major intake: inhalation of $^{238}PuO_2$



https://en.wikipedia.org

Curium-244

- One living partial-body donor
- Single acute inhalation of ^{244}Cm ($T_{1/2}$ = 18.1 y)
- Estimated systemic deposition: 1.3 kBq
- Potential intake of enriched U



https://en.wikipedia.org

Collaborative Research Network

- Actinide biokinetic modeling and dosimetry
- Chelation therapy modeling
- Radiation biomarkers
- Nuclear forensics
- Actinide nanoparticles
- Beryllium and zirconium

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NCRP National Council on Radiation Protection and Measurements

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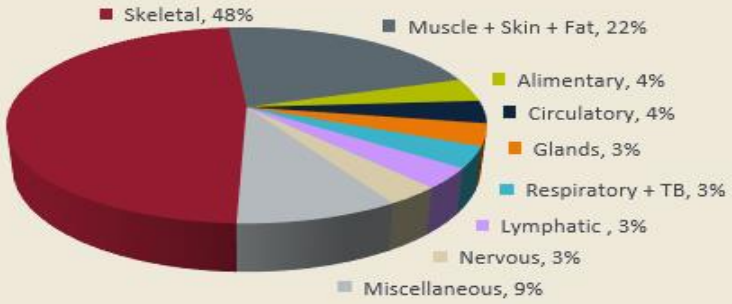
U.S. TRANSURANIUM AND URANIUM REGISTRIES
Learning from Plutonium and Uranium Workers

What materials are available?



So many opportunities –

– So little time!

Acknowledgment

USTUR Special Session at 61st Annual Meeting of the Health Physics Society, July 19, 2016, Spokane, WA

Questions?

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