Radiochemistry Webinars
Environmental/Bioassay Radiochemistry Series

Bioassay

In Cooperation with our University Partners

NWP
NEW BRUNSWICK LABORATORY
CDC
OSU
ILLINOIS INSTITUTE OF TECHNOLOGY
New Mexico State University Carlsbad
THE UNIVERSITY OF IOWA
UNLV
University of California
Dr. Jones is the Chief of the Inorganic and Radiation Analytical Toxicology Branch at the Centers for Disease Control and Prevention (CDC). His responsibilities include planning, implementation, oversight, and completion of programs related to public health that involves non-radioactive and radioactive elements or their isotopes. These programs involve research and development of a wide variety of analytical methods to enable the CDC to assay and monitor the exposure of populations to toxic or radioactive element exposures. The programs also involve a large amount of analytical services to various programs in which the laboratory collaborates with other national and international government agencies, state health departments and universities. These programs look at a broad spectrum of essential, trace and toxic metals using, Inductively Coupled Plasma Mass Spectrometry with Dynamic Reaction Cell Technology, HPLC or GC coupled to Inductively Coupled Plasma Mass Spectrometry with Dynamic Reaction Cell Technology, Electrochemical, Gamma Spectroscopy, Alpha Spectroscopy and Liquid Scintillation methods. Dr. Jones is also overseeing the development of a variety of radionuclide bioassay methods for emergency and terrorism preparedness and response. These methods will allow CDC to assist the states in responding to a major radiological or nuclear incident and allow for the assessment of contamination and exposure in people and to enable the efficient use of medical countermeasures. Dr. Jones' responsibilities also include the implementation and laboratory aspects of multiple local, state, regional, national and international health studies or investigations, responses to multiple Epidemiological Aids and "emergency responses." The Branch is also involved with many long-term (multi-year) local, national or international public health studies. Dr. Jones has 106 publications in the field of analytical chemistry, biophysical chemistry, clinical chemistry and Biomonitoring. He has presented more than 60 national or international invited talks or workshops related to the laboratory aspects of inorganic Biomonitoring as well as chemical and radiological terrorism preparedness and response. Dr. Jones is a Co-Chair of multiple workgroups in the DHS Integrated Consortium of Laboratory Networks (ICLN) and is a member of several CDC, DHS, HHS, FEMA and CLSI national workgroups or committees.

Email: RLJones@cdc.gov
Bioassay for Emergency Response

Robert L. Jones, PhD
Chief, Inorganic and Radiation Analytical Toxicology Branch
Disclosure

Mention of company or product names does not constitute endorsement by the National Center for Environmental Health (NCEH), Centers for Disease Control (CDC), or the Public Health Service.
Potential Radiological or Nuclear Incidents

- Nuclear
  - Damaged nuclear facility
  - Improvised nuclear device
  - Nuclear weapon

- Radiological
  - Radiological dispersion device (RDD); e.g., “Dirty bomb”
Population Monitoring

Following an environmental release of radioactive material, large numbers of people may require external and/or internal monitoring and, if indicated, decontamination.
The Boston Marathon

April 15th, 2013
Explosive device detonated
The Boston Marathon

April 15th, 2013

• ~26,000 Runners from 55 States and Territories
• ~500,000 Spectators
The Boston Marathon

What if?
The Boston Marathon

What if

It had been an RDD

("Dirty Bomb")?
Bioassay Objective

After a Radiological Incident, Public Health Officials Will Need to Answer the following:

- **What** are people exposed to or contaminated with?
- **Who** was exposed or contaminated?
- **How much** exposure or contamination did each person have?

The decision to medically treat people will depend on our ability to **rapidly** and accurately **identify** and **quantify** internal contamination.
Dispersal Pattern

- Fireball Interaction Area (< 100 μm, about 5% of material in fireball)
- Large Particles (~100 - 500 μm)
- Ballistic Fragments (> 1 cm)
- Downwind Fallout (small particles)

Radiation measurements at this nominal location are dominated by the hot spot from the Fireball Interaction Area.
Was it a Widespread Dispersal?
(M. Brown, LANL)
CDC Guidance on Population Monitoring and Safety

- **Target audience:**
  - State and local public health and emergency preparedness personnel
- **Focus:**
  - Terrorism incidents involving mass casualties
- **Scope:**
  - Assumes local infrastructure is intact
  - Principles apply to all radiation incidents
- **Currently being revised**

Examples of Contamination Triage Testing

External Testing:
Alpha/Beta/Gamma Emitters
Pre-Decon

External
(Alpha/Beta/Gamma) Testing

Internal
(Gamma) Testing:
Post-Decon

External/Internal
(Gamma) Testing
MANAGEMENT OF PERSONS CONTAMINATED WITH RADIONUCLIDES: HANDBOOK
## Clinical Decision Guide (Adult)

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Route</th>
<th>Class/chem</th>
<th>AMAD</th>
<th>ALI (Bq)</th>
<th>CDG (Bq)</th>
<th>(Bq/d)</th>
<th>(Bq/ml)</th>
<th>(Bq/L)</th>
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<tbody>
<tr>
<td>Co-60</td>
<td>Inhalation</td>
<td>M</td>
<td>1 um</td>
<td>7.40E+06</td>
<td>1.23E+05</td>
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<tr>
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<td>n/a</td>
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<td>4.96E+04</td>
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<td>1 um</td>
<td>7.40E+06</td>
<td>4.21E+04</td>
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<td>1.60E+00</td>
<td>1.11E-03</td>
<td>1.11E+00</td>
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</table>

**DRAFT Calculations** - Adult, 1 day Post exposure
Bioassay Testing

• **Capability:** Rapid *screening*, *identification* and *quantitative* assessment of *internal* incorporation of radionuclides to quantify exposure or dose ("health risk")

• **Capacity:** ID and Quantify approximately 300 samples per day

• **Dose Range:**
  - 0.0001 to >2 Sieverts (Sv) - analytical sensitivity
  - Medical Treatment Threshold –
    - 0.05 Sv Children and Pregnant Women,
    - 0.25 Sv for the general population (CDG)

• Provide initial identification of a possible poisoning (e.g. $^{210}$Po)

• Assist with the Epidemiological (EPI) investigation

  CDG = Clinical Decision Guide
Rapid Radionuclide Bioassay Analytical Methods: Traditional Versus New Methods

<table>
<thead>
<tr>
<th>Time to first analytical results for 40-200 samples</th>
<th>&quot;Traditional&quot; Radionuclide methods: DOE</th>
<th>New &quot;Rapid&quot; methods: CDC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>About 3-6 days</td>
<td>Less than 24 hours</td>
</tr>
<tr>
<td>Sample Requirements</td>
<td>24 hour collection</td>
<td>&quot;spot&quot; collection</td>
</tr>
<tr>
<td>Sample Size Requirement</td>
<td>1 - 2 L</td>
<td>15-70 mL</td>
</tr>
<tr>
<td>Number of radionuclides with validated clinical methods</td>
<td>Limited to contract</td>
<td>22 + &quot;fission products&quot; (14 current)</td>
</tr>
<tr>
<td>Sample throughput</td>
<td>10-20 samples per day</td>
<td>250-3000 samples per day</td>
</tr>
<tr>
<td>CLIA Certified Methods</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Scalable for &quot;Surge Capacity&quot;</td>
<td>minimal</td>
<td>yes</td>
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</table>
Bioassay: Key Issue
Detection of Internal Contamination

<table>
<thead>
<tr>
<th>Radionuclides</th>
<th>Urine bioassay detection</th>
<th>Primary radiation detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium ((^{235}\text{U}, {238}\text{U})), Thorium</td>
<td>yes</td>
<td>alpha and beta</td>
</tr>
<tr>
<td>Strontium, Plutonium ((^{238}\text{Pu}, {239}\text{Pu}))</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Americium, Californium, Neptunium,</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Phosphorus, Curium, Polonium</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Cesium, Cobalt ((^{57}\text{Co}, {60}\text{Co})), Radium</td>
<td>yes</td>
<td>Gamma rays</td>
</tr>
<tr>
<td>Iodine ((^{125}\text{I}, {131}\text{I})), Technetium-99m</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Selenium, Molybdenum, Iridium</td>
<td>yes</td>
<td></td>
</tr>
</tbody>
</table>

Internal radiation screening via hand held detectors or portals is only applicable for gamma emitting radionuclides.

Radionuclides of concern can be found at:
www-pub.iaea.org/MTCD/publications/PDF/Pub1309_web.pdf
www.energy.gov/media/RDDRPTF14MYa.pdfc

The “Grand Rounds” presentation and slides can be found at:
www.cdc.gov/about/grand-rounds/archives/2010/03-March.htm
Examples of Contamination Triage Testing for Alpha Emitters

External Testing: **Alpha/Beta/Gamma** Emitters
Pre-Decon

External (Alpha/Beta/Gamma)
Internal (Gamma only)
Testing:
Post-Decon

External (Alpha/Beta/Gamma)
Testing

External/Internal (Gamma only)
Testing
Examples of Mass Screening/Analysis

• 1987 Goiania – $^{137}$Cs - \textbf{112,000 tests}

• 1995-1996 U.S. Methyl parathion – \textbf{16,000 tests}

• 2001-2002 U.S. Anthrax (clinical) - \textbf{250,000 tests}

• 2001-2002 U.S. Anthrax (environmental) – \textbf{1,000,000}

• 2005 NV Mercury exposure – \textbf{280} tested

• 2006 London - $^{210}$Po - \textbf{800} tested
Concerned Citizen Multiplier

- 1987 Goiania – $^{137}$Cs – 50 treated / 112,000 tested = 2240 “concerned citizen multiplier”
- 1995-1996 U.S. Methyl parathion – 16,000
- 2001-2002 U.S. Anthrax (clinical) – 30 casualties or infected / 250,000 tests = 8,500
- 2005 NV Mercury exposure – 1 contaminated / 280 tested = 280
- 2006 London - $^{210}$Po – 1 casualty / 800 tested = 800
Rapid Response: Epidemiologic, Laboratory and Health Physics Coordination

300,000 People

EPI Prioritization

100,000 Samples

Lab Screening

1,000 Samples

Return Results for Medical Management

Flag/Evaluate High/Elevated Results

Dose Calculation Program

ID & Quantitative analysis
15 mL Sample Tubes

~75,000
CDC's Urine Radionuclide Screen

Urine "Spot" Sample

- Gamma Radionuclide Screen
- Alpha/Beta Radionuclide Screen/Quantification
- Alpha (Long Lived) ICP-MS Screen

- Gamma Spectrometry Quantification
- Alpha Spectrometry Quantification
- Mass Spectroscopy Quantification
- High Resolution Mass Spectroscopy Quantification
CDC's Urine Radionuclide Screen

Urine "Spot" Sample

- Gamma Radionuclide Screen
- Alpha/Beta Radionuclide Screen/Quantification
- Alpha (Long Lived) ICP-MS Screen

High Throughput Screening Methods

- e.g. 100,000 Samples

Screen for any radionuclide and Prioritize

- Gamma Spectrometry Quantification
- Alpha Spectrometry Quantification
- Mass Spectroscopy Quantification
- High Resolution Mass Spectroscopy Quantification

Identification and Quantification

- e.g. 1,000 to 10,000 Samples
Method Validation Issues for CLIA

- Specificity (Definitive Identification)
- Accuracy (at action level(s))
- Precision (at action level(s))
- Linearity (over the calibration range)
- Range (analytical and reportable)
- Recovery
- LOD (MDA)
- Stability (analyte/matrix/method)
- Robustness/Ruggedness
- Proficiency Testing (availability)
Alpha & Beta Emitters
Liquid Scintillation: Gross Alpha/Beta Screen, Sr-90 Quantitative (in development)
Liquid Scintillation: Gross Alpha/Beta "Screen"

- Cocktail: Ultima Gold AB
- Sample volume: 5 mL
- Cocktail volume: 15mL
- Sample analysis time: 7 min
- LOD: Gross Alpha – 5.3 Bq/L
- LOD: Gross Beta – 31 Bq/L
Liquid Scintillation: P-32 and H-3

- Cocktail:
- Sample volume: 5 mL
- Cocktail volume: 15 mL
- Sample analysis time: 7 min
- LOD: P-32 – 23.6 Bq/L
- LOD: H-3 – 28.7 Bq/L
Alpha Emitters
Alpha Spec:
Po-210

- Sample volume: 10 mL
- Sample prep time: 1.8 hours
- Sample count time: 1 hour
- LOD: 0.65 Bq/L

Not fully validated at this time
Gamma Emitters
General Method Parameters (NaI)

- **Screening Method**: rapid analysis for the screening of gamma emitting radionuclides in clinical samples

- **Concept**: allow for “screening” in 5 to 10 minutes, to determine if above a “baseline level”

- **Automation (Autosampler)**: currently being evaluated
Emergency Response Urine Containers
New Custom Nal Well Detector
Count Sample - 300 sec
HPGe Detectors
HPGe Method Parameters

- Energy Range: 40 – 2000 keV
- LODs:
  - $^{57}$Co 92 Bq/L
  - $^{137}$Cs 57 Bq/L
  - $^{60}$Co 76 Bq/L
  - $^{192}$Ir 26 Bq/L
- Sample Size* = 50 mL
- Count Time = 900 seconds
- Samples per 900 seconds = 3 (3 Instruments)
- Samples per hour = 12 (3 Instruments)
- Samples per day = $\frac{240}{20}$ hours (3 Instruments)

* Evaluating a 10mL sample size (tube geometry) in a large well detector
CDC Rad Lab Updates

• Gross Gamma Autosampler
  425 - 10mL vials

• HPGe Autosamplers:
  100 - 10mL vials, 49 - 50mL cups
Actinides
Actinides by ICP-MS: The Issues

Polyatomic ions
- $^{236}\text{U}H$ and $^{237}\text{Np}$
- $^{237}\text{Np}H$ and $^{236}\text{U}$
- $^{238}\text{U}H$ and $^{239}\text{Pu}$
- $^{240}\text{Pu}H$ and $^{241}\text{Am}$
- $^{242}\text{Pu}H$ and $^{243}\text{Am}$

Isobars
- $^{236}\text{U}$ and $^{236}\text{Np}$
- $^{238}\text{U}$ and $^{238}\text{Pu}$
- $^{241}\text{Pu}$ and $^{241}\text{Am}$
Schematic and Layout of ICP-DRC-MS
Actinides by IC-ICP-MS

Wei Hang, Wenwan Zhong, Luwang Zhu, Cynthia Mahan
Los Alamos National Laboratory

Water

Urine 1:10

Urine

Counts

Counts

Time (s)

Time (s)
Actinides

- Inductively Coupled Plasma – Mass Spec (ICP-MS) – [quadrapole]
  - $^{235}\text{U} + ^{238}\text{U}$ ("Total" Uranium)
  - $^{235}/^{238}\text{U}$ Isotope Ratio

- Magnetic Sector (MS-ICP-MS)
  - $^{235}\text{U}$, $^{238}\text{U}$, $^{234}/^{235}/^{236}/^{238}\text{U}$ Isotope Ratios, $^{239}\text{Pu}$, $^{232}\text{Th}$, $^{241}\text{Am}$
MS-ICP-MS Method Parameters

- LOD: $^{241}$Am 0.028 Bq/L or 0.22 pg/L
- Sample Size: 10 mL
- Sample Prep time: 2.5 hours
- Analysis Time: 7.5 minutes
- Samples per day: 300 / 20 hours (3 Instruments)
Coordination with Other Laboratories

- Environmental Protection Agency
- Food and Drug Administration
- Department of Homeland Security
- Department of Defense
- Department of Commerce
- Federal Bureau of Investigation
- Department of Energy
- States, Cities, Other Agencies
- Integrated Consortium of Lab Networks
National Radio-Bioassay Capacity for Emergency Response

CDC Atlanta 98%

All others <2%

- Private Rad Labs
- Clinical Labs
- DOE *
- DOD *
- NIH *
- University Labs *
- FDA *
- EPA *

*Not CLIA Certified
CDC Website for Emergency Preparedness and Response

This site is intended to increase the nation's ability to prepare for and respond to public health emergencies.

Specific Hazards
- Bioterrorism
- Chemical Emergencies
- Mass Casualties
- Natural Disasters & Severe Weather
- Radiation Emergencies
- Recent Outbreaks & Incidents

Preparedness for All Hazards
- Preparation & Planning
- Surveillance
- Training & Education
- Coping With a Disaster
- Clinicians
- Healthcare Facilities
- Labs
- Research

What CDC Is Doing
Learn about CDC activities that help strengthen national, state, and local efforts to prevent or respond to emergencies.

What You Can Do
Emergency Preparedness & You
Would you be ready if there were an emergency? Be prepared: assemble an emergency supply kit, make your emergency plans, stay informed, and

To receive email updates about this page, enter your email address:

What's this? Submit

emergency.cdc.gov
CDC Website for Radiation Emergency Preparedness and Response

http://emergency.cdc.gov/radiation
For each person, collect 70 mL or more of urine in a screw-cap urine cup by following the steps below:

1. **Wash hands with soap and water.**
2. **Collect 70 mL or more of urine in a screw-cap urine cup.**
3. **Label the urine cup with the appropriate bar-coded label, indicating the method of collection if other than “clean catch.”**
4. **Place bar-coded label on all cups so that when upright, the barcode looks like a ladder.**
5. **Deliver specimen to clinic personnel.**
6. **Freeze samples (optimally at -70°C or use dry ice).**

For questions concerning this process, please contact:
Centers for Disease Control and Prevention
Sample Logististics Laboratory (RAT)
4770 Buford Hwy., NE
Building 110, Loading Dock
Atlanta, GA 30341
Office Phone: 770-488-7227
Email: SampleLogistics@CDC.gov
Urine Shipping Instructions

Instructions for Shipping Urine Specimens to the Centers for Disease Control and Prevention after a Radiological/Nuclear Exposure Event

This guidance is in accordance with the International Air Transport Authority (IATA) 650 for Biological Substance, Category B. For detailed instructions, see the Centers for Disease Control and Prevention (CDC)'s "Shipping Instructions for Specimens Collected from People Who May Have Been Exposed to Radiological/Nuclear Terrorism Agents."

For questions concerning this process, please contact:
Centers for Disease Control and Prevention
Sample Logistics Laboratory (IRAT)
4770 Buford Hwy., NE
Building 110, Loading Dock
Atlanta, GA 30341
Phone: 770-488-7227
Email: Sample.Logistics@CDC.gov

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

emergency.cdc.gov/radiation/pdf/ShippingInstructionsFlowChart.pdf
Future Radionuclide "Biomonitoring"

- Radon-222
- Polonium-210
- Sr-90
- Tc-99m – Mo-99
- Medical isotopes
Radiological Incident Impact

- Loss of life
- Acute radiation exposure
- Potential future cancer risk
- Psychosocial issues
- Economic impact, including area denial (due to contamination)
- Increased anxiety among citizens
Summary

- Radiation Laboratory Methods (bioassay): **rapidly identify** and **quantify specific** radionuclides in people potentially contaminated in a radiological or nuclear event.

- Provides critical information for **effective** medical management of individuals by **assessing risk** for medical management and **follow-up**

- Provides information for population monitoring (populations and population sub-groups)

- Provides "**negative**" results for people who think that they may be contaminated, but, are not truly contaminated.
Acknowledgements

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- Sandia National Labs
- Savannah River National Labs
- Argonne National Labs
- FDA, EPA, NIST, DOD, DOE
Questions
and
Discussions
Thank you

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Telephone: 1-800-CDC-INFO (232-4636)/TTY: 1-888-232-6348
E-mail: cdcinfo@cdc.gov Web: http://www.cdc.gov

"The findings and conclusions in this presentation have not been formally disseminated by the Centers for Disease Control and Prevention/the Agency for Toxic Substances and Disease Registry and should not be construed to represent any agency determination or policy."
Future NAMP Radiochemistry Webinars

- Gamma Spectrometry
  - Part I (September 19)
  - Part II (September 26)
- Overview of EPA Rapid Methods (October 24)
- Subsampling (November 14)