National Analytical Management Program (NAMP)
U.S. Department of Energy Carlsbad Field Office

Radiochemistry Webinars

Environmental/Bioassay Radiochemistry Series

Bioassay

In Cooperation with our University Partners

Meet the Presenter…

Robert Jones

Dr. Jones is the Chief of the Inorganic and Radiation Analytic al 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")?

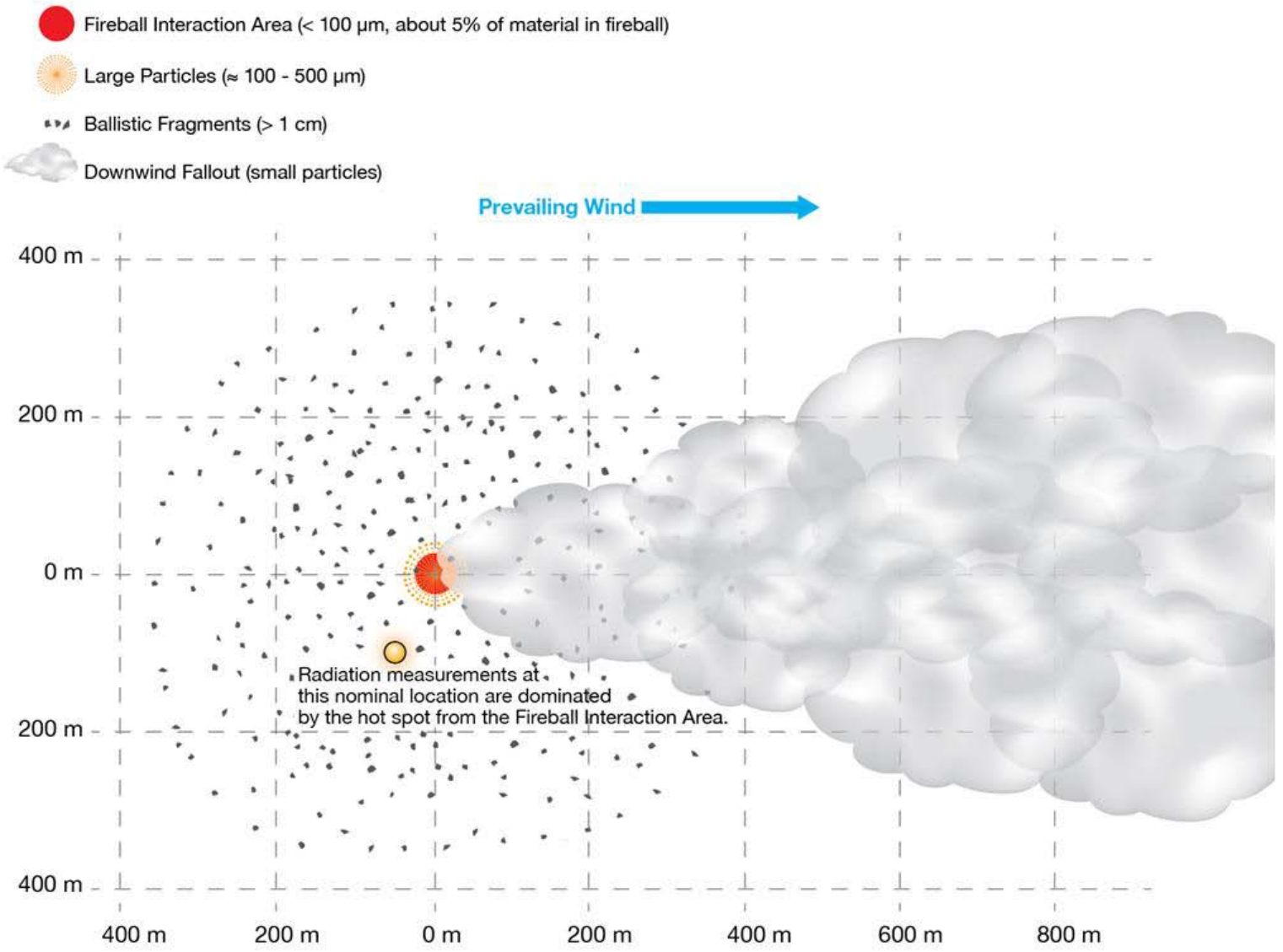
Bioassay Objective

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?

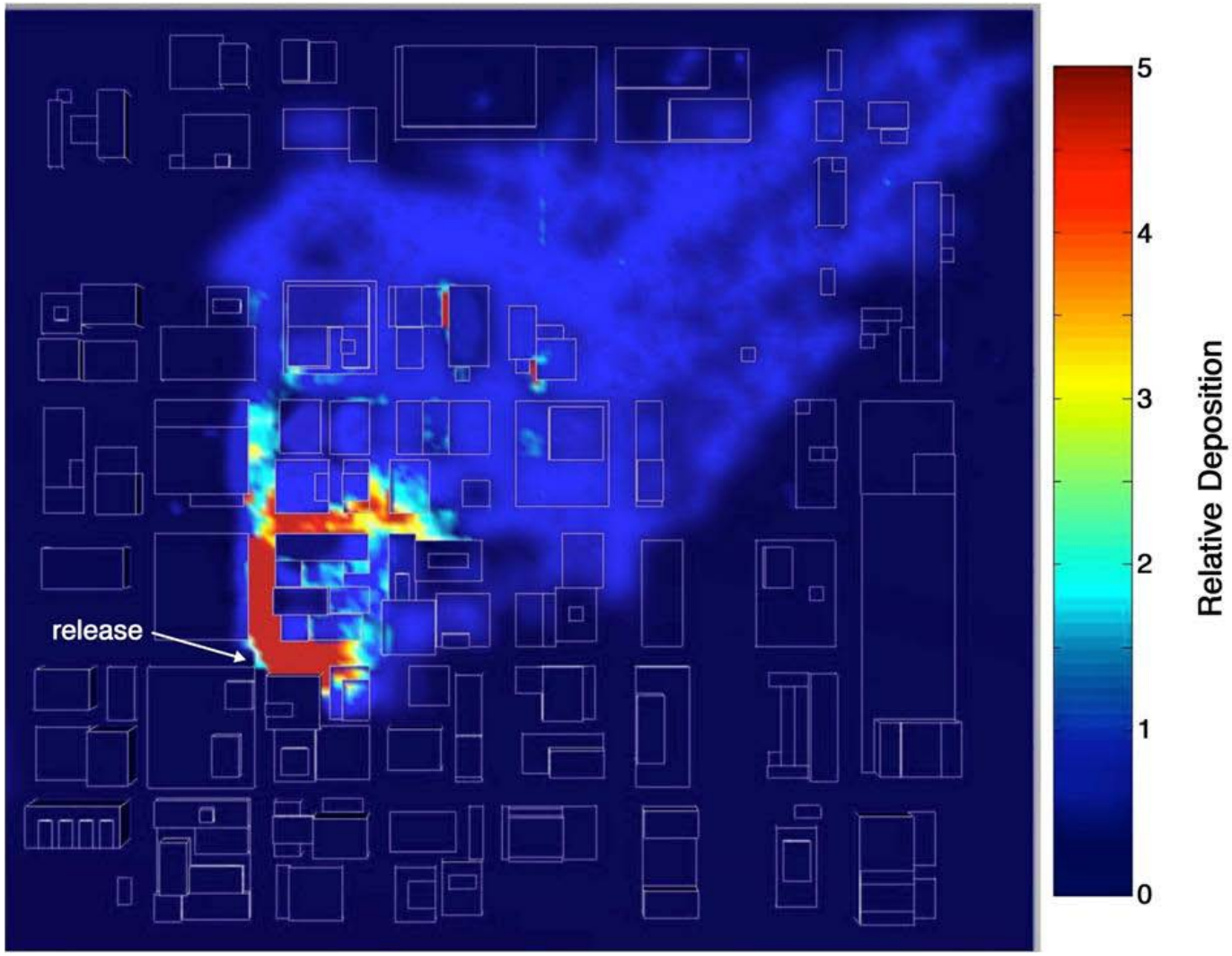
The decision to medically treat people will depend on our ability to **rapidly** and accurately **identify** and **quantify** internal contamination

Dispersal Pattern



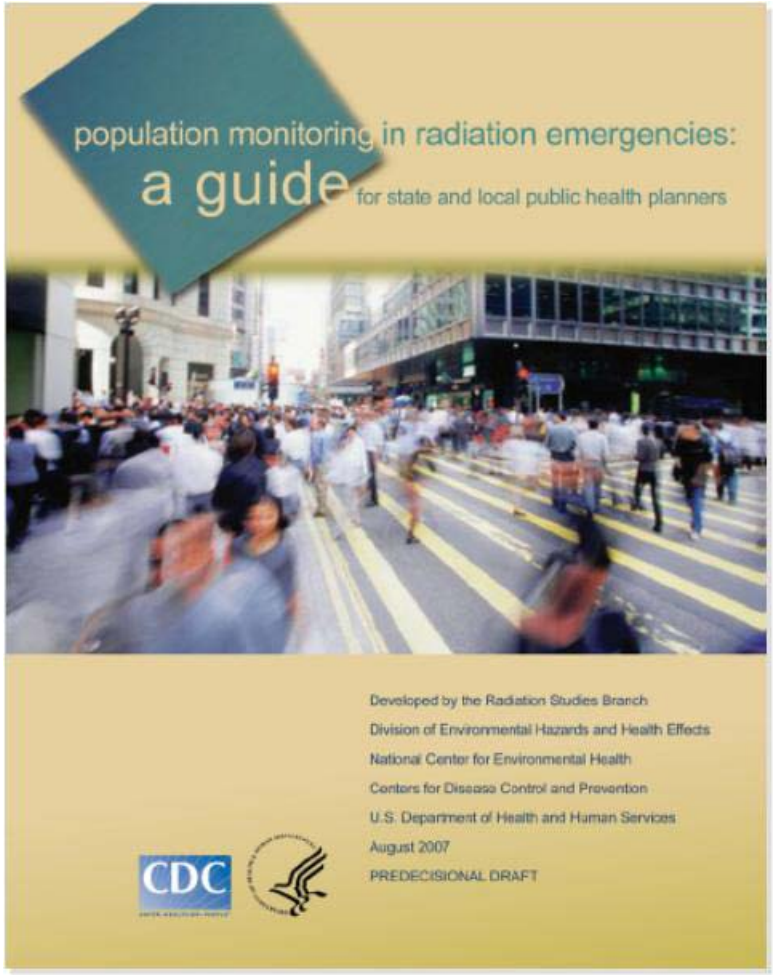
Was it a Widespread Dispersal?

(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



http://emergency.cdc.gov/radiation/pdf/population-monitoring-guide.pdf

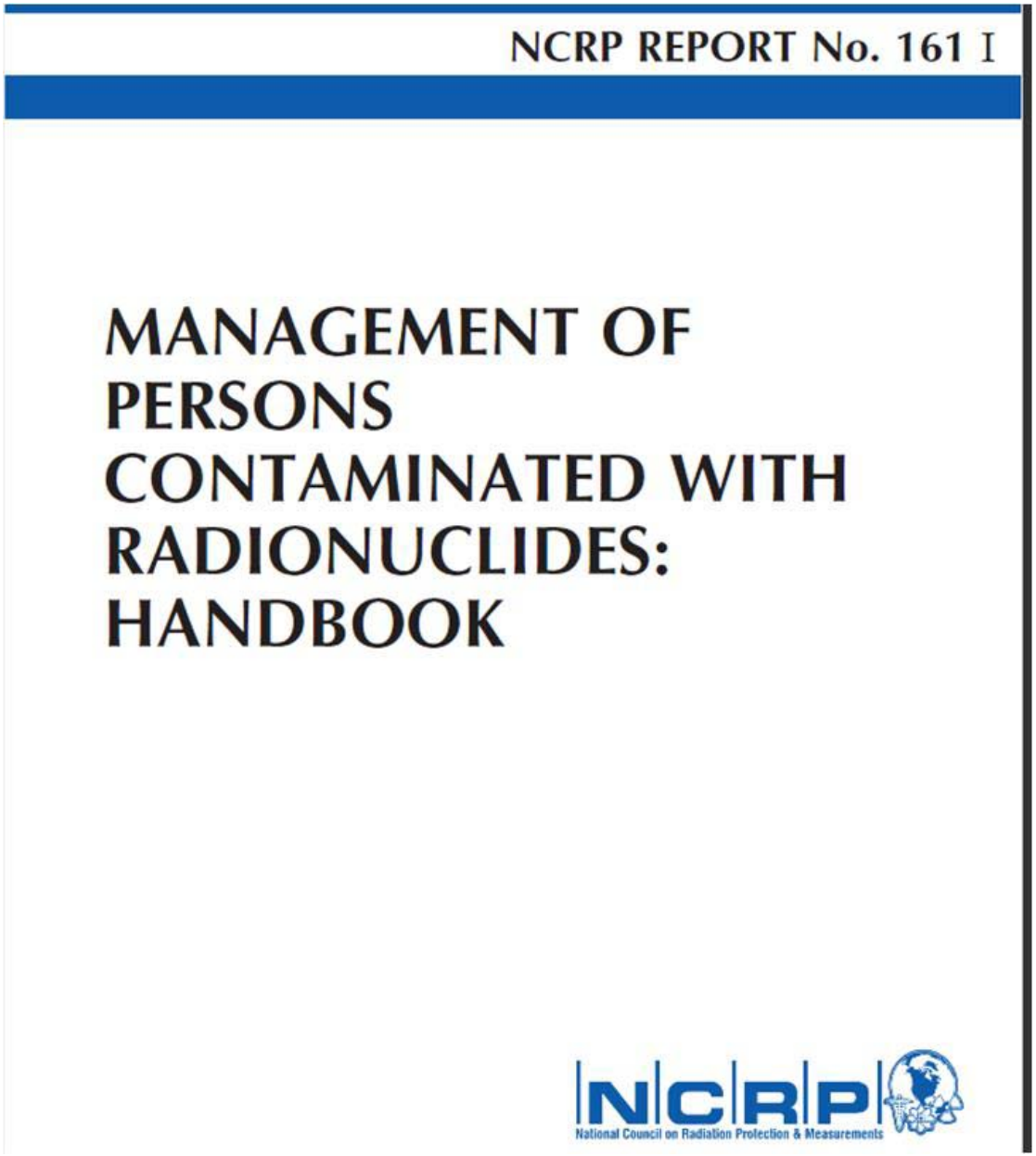
Examples of Contamination Triage Testing

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

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

External
(Alpha/Beta/Gamma) Testing

External/Internal
(Gamma) Testing


NCRP REPORT No. 161 I
MANAGEMENT OF PERSONS CONTAMINATED WITH RADIONUCLIDES: HANDBOOK
NCRP
National Council on Radiation Protection & Measurements

Clinical Decision Guide (Adult)

Nuclide	Route	Class/ chem	AMAD	ALI (Bq)	CDG (Bq)	(Bq/d)	(Bq/ml)	(Bq/L)
Co-60	Inhalation	M	1 um	7.40E+06		1.23E+05	8.54E+01	8.54E+04
Co-60	Inhalation	M	5 um		3.50E+07	7.00E+05	4.86E+02	4.86E+05
Sr-90	Inhalation	F	1 um	1.48E+05		3.41E+03	2.37E+00	2.37E+03
Sr-90	Inhalation	F	5 um		8.30E+06	5.64E+05	3.92E+02	3.92E+05
Sr-90	Ingestion	n/a	n/a	1.11E+06		4.96E+04	3.45E+01	3.45E+04
Sr-90	Ingestion	n/a	n/a		8.90E+06	4.98E+05	3.46E+02	3.46E+05
Cs-137	Inhalation	F	1 um	7.40E+06		4.21E+04	2.92E+01	2.92E+04
Cs-137	Inhalation	F	5 um		5.80E+07	1.28E+06	8.86E+02	8.86E+05
Cs-137	Ingestion	n/a	n/a	3.70E+06		8.35E+04	5.80E+01	5.80E+04
Cs-137	Ingestion	n/a	n/a		2.80E+07	1.26E+06	8.78E+02	8.78E+05
Pu-239	Inhalation	M	1 um	2.22E+02		3.61E-02	2.51E-05	2.51E-02
Pu-239	Inhalation	M	5 um		7.60E+03	1.60E+00	1.11E-03	1.11E+00

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

	"Traditional" Radionuclide methods: DOE	New "Rapid" methods: CDC
Time to first analytical results for 40-200 samples	About 3-6 ***days***	Less than **24 *hours***
Sample Requirements	***24 hour*** collection	"***spot***" collection
Sample Size Requirement	1 -2 **L**	15-70 **mL**
Number of radionuclides with validated clinical methods	Limited to contract	22 + "fission products" (14 current)
Sample throughput	**10-20** samples per day	**250 -3000 samples** per day
CLIA Certified Methods	no	yes
Scalable for "Surge Capacity"	minimal	yes

Bioassay: Key Issue
Detection of Internal Contamination

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

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/RDDRPTF14MAYa.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

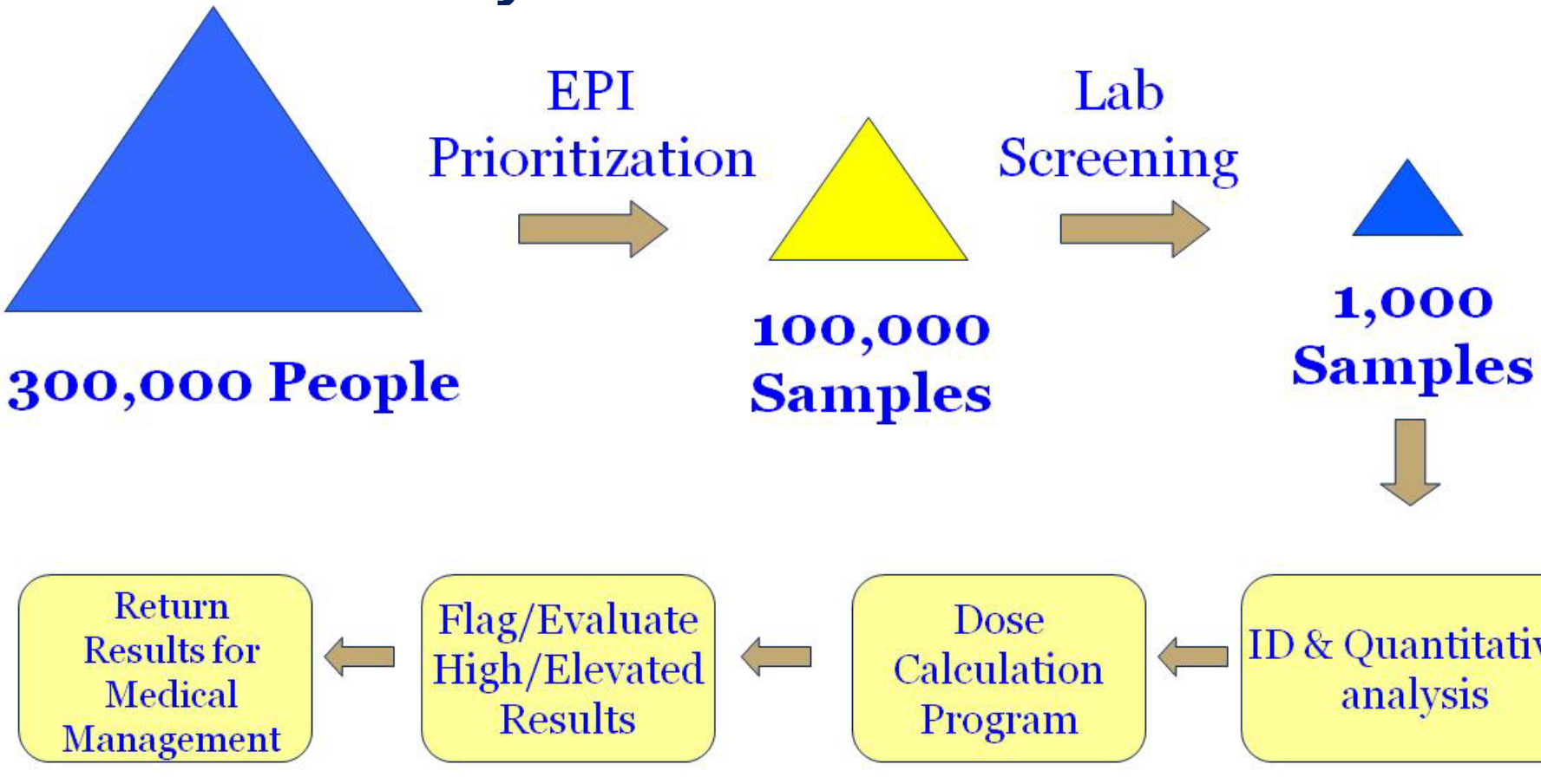
Examples of Mass Screening/Analysis

- 1987 Goiania – ^{137}Cs - **112,000 tests**
- 1995-1996 U.S. Methyl parathion – **16,000 tests**
- 2001-2002 U.S. Anthrax (clinical) - **250,000** tests
- 2001-2002 U.S. Anthrax (environmental) – **1,000,000**
- 2005 NV Mercury exposure – **280** tested
- 2006 London - ^{210}Po - **800** tested

Concerned Citizen Multiplier

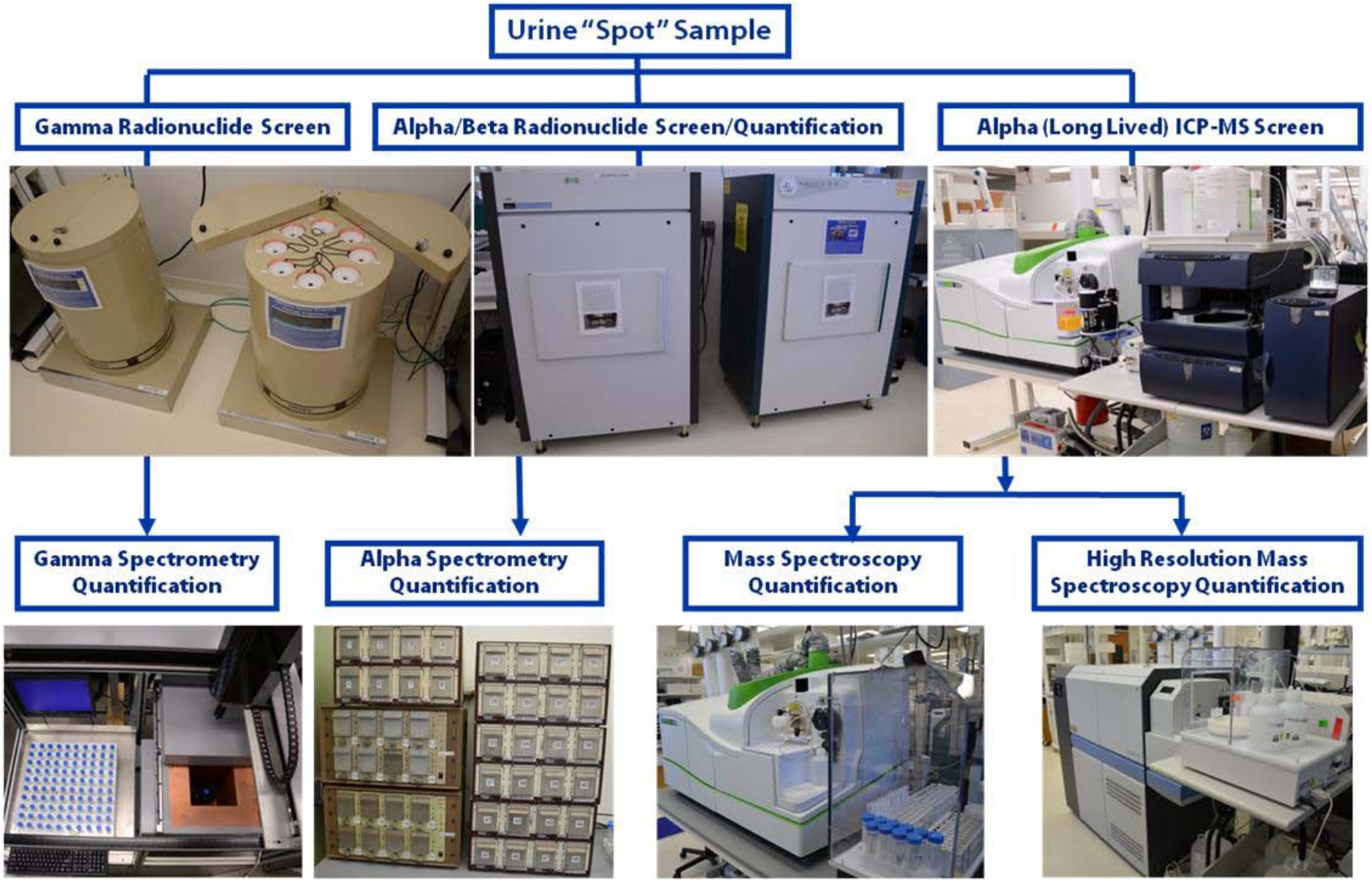
- 1987 Goiania – ^{137}Cs – 50 treated / 112,000 tested = **2240 "concerned citizen multiplier"**
- 1995-1996 U.S. Methyl parathion – **16,000**
- 2001-2002 U.S. Anthrax (clinical) – 30 casualties or infected / 250,000 tests = **8,500**
- 2005 NV Mercury exposure – 1 contaminated /280 tested = **280**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

Rapid Response: Epidemiologic, Laboratory and Health Physics Coordination

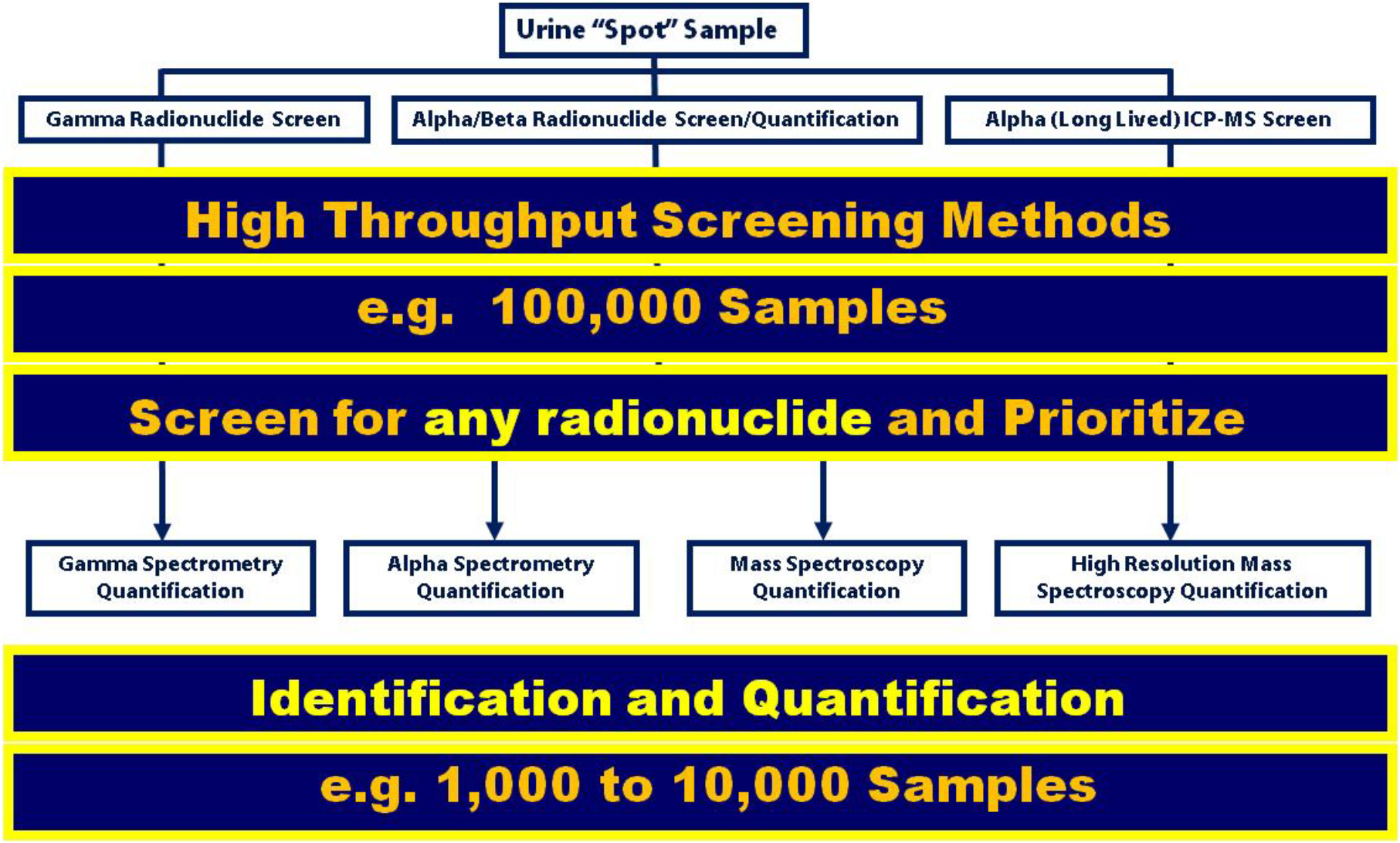


15 mL Sample Tubes

CDC's Urine Radionuclide Screen



CDC's Urine Radionuclide Screen



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

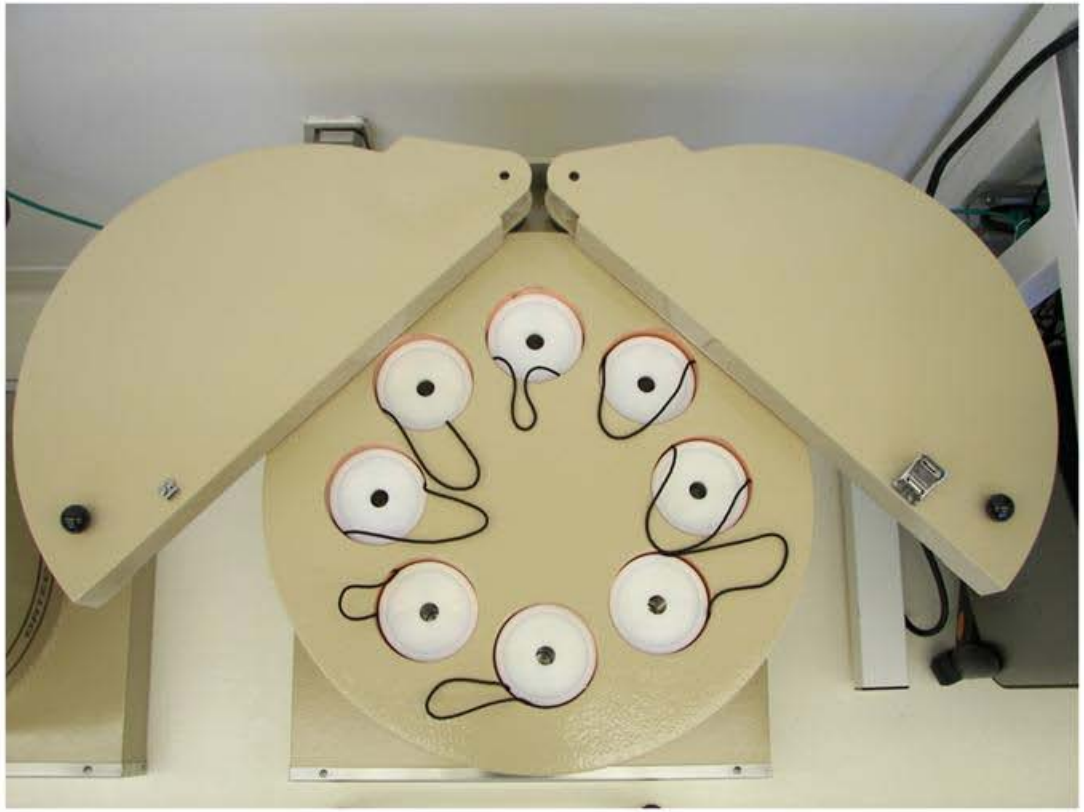
Gamma Emitters

General Method Parameters (NaI)

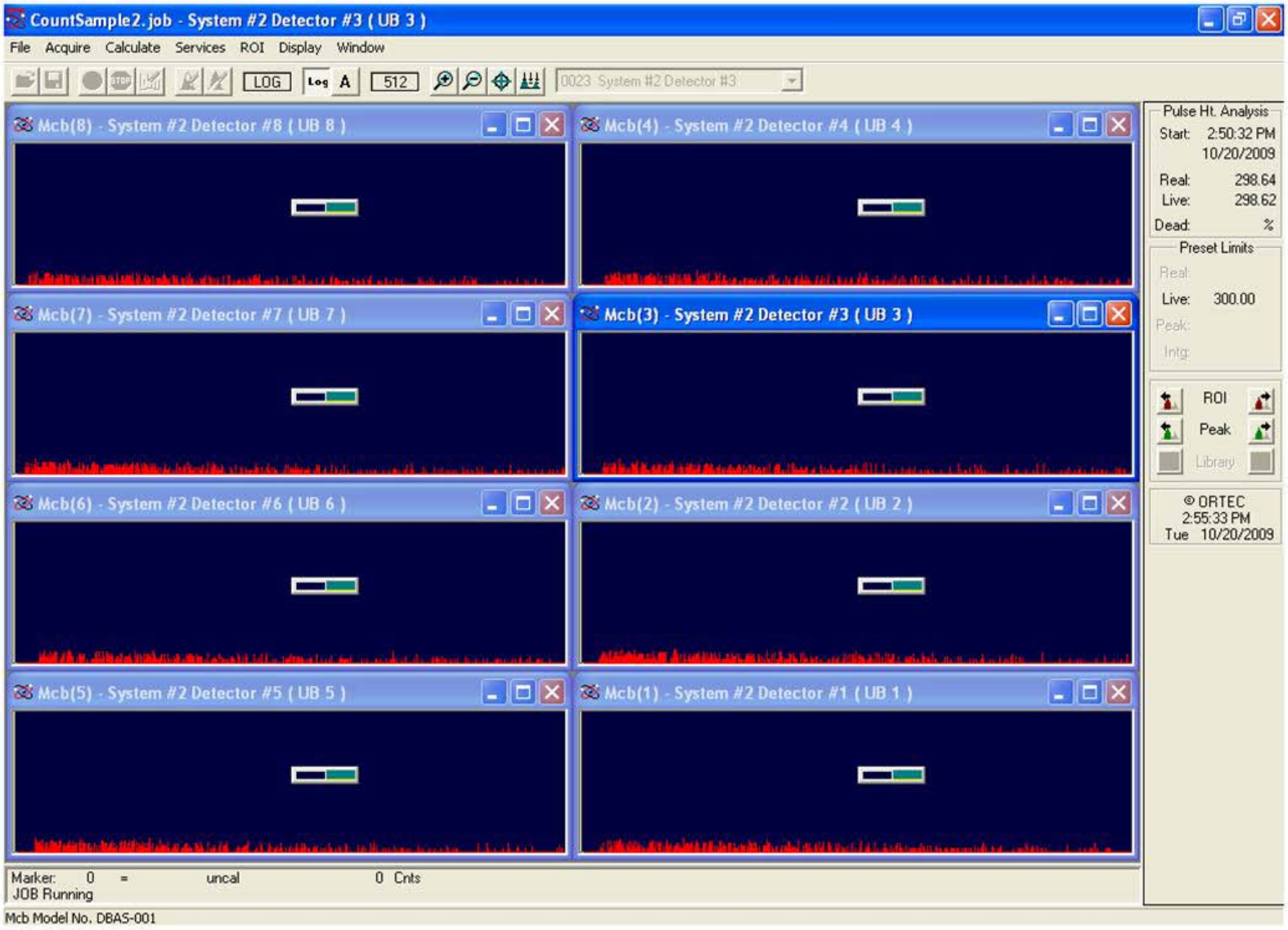
- **Screening Method:** rapid analysis for the screening of gamma emitting radionuclides in clinical samples
- **Concept:** allow for “screening” in 5 to 10 minutes, to determine if above a “baseline level”
- **Automation (Autosampler):** currently being evaluated

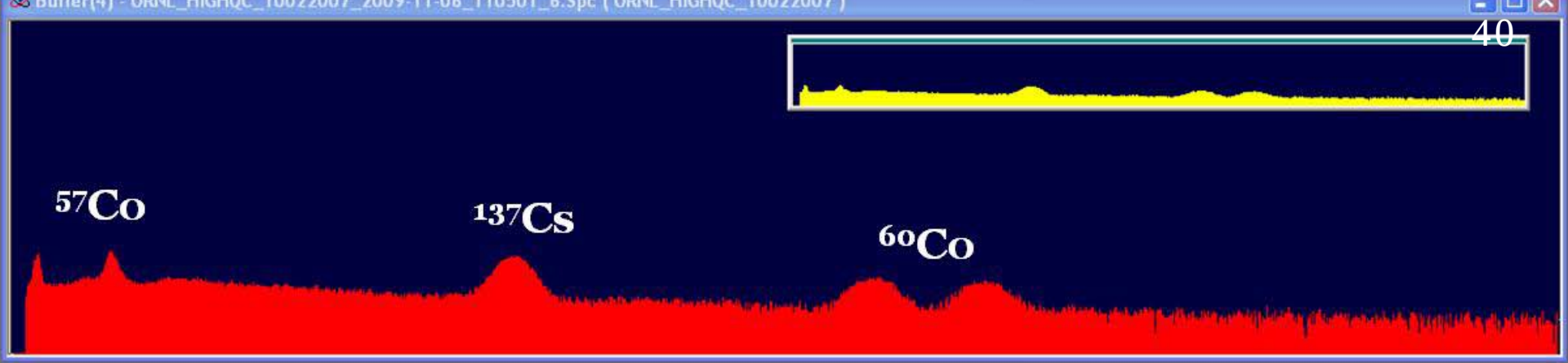
Emergency Response Urine Containers

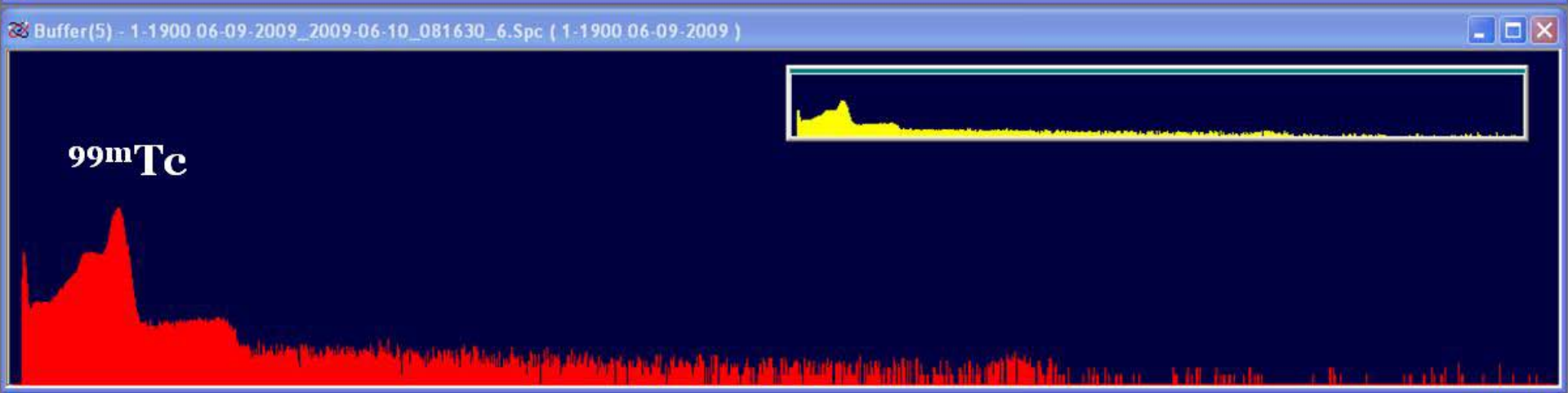
New Custom NaI Well Detector

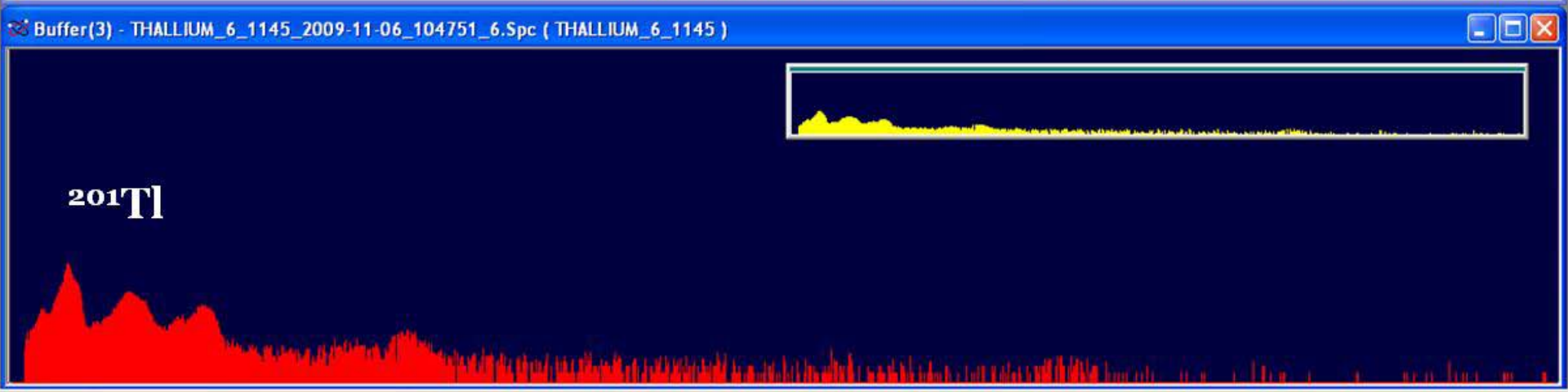


Count Sample - 300 sec









Marker: 0 = uncal 0 Cnts

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 = **240 / 20 hours (3 Instruments)**

* Evaluating a 10mL sample size (tube geometry) in a large well detector

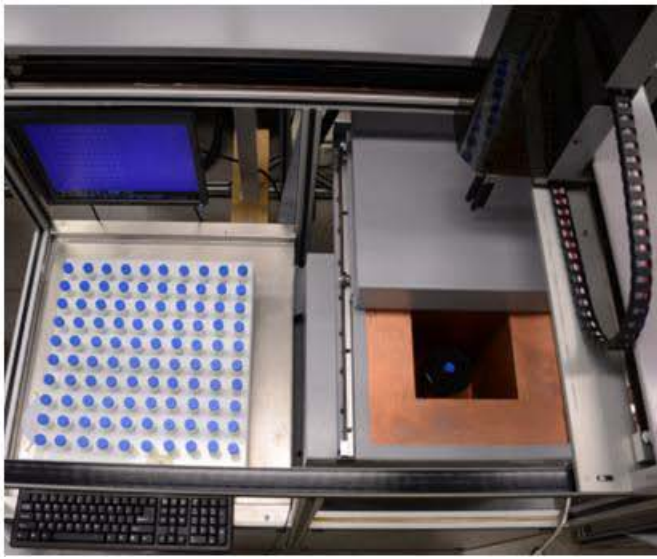
CDC Rad Lab Updates

- Gross Gamma Autosampler

  425 - 10mL vials

- HPGe Autosamplers:

  100 - 10mL vials, 49 - 50mL cups



Actinides

Actinides by ICP-MS: The Issues

Polyatomic ions

^{236}UH and ^{237}Np

^{237}NpH and ^{236}U

^{238}UH and ^{239}Pu

^{240}PuH and ^{241}Am

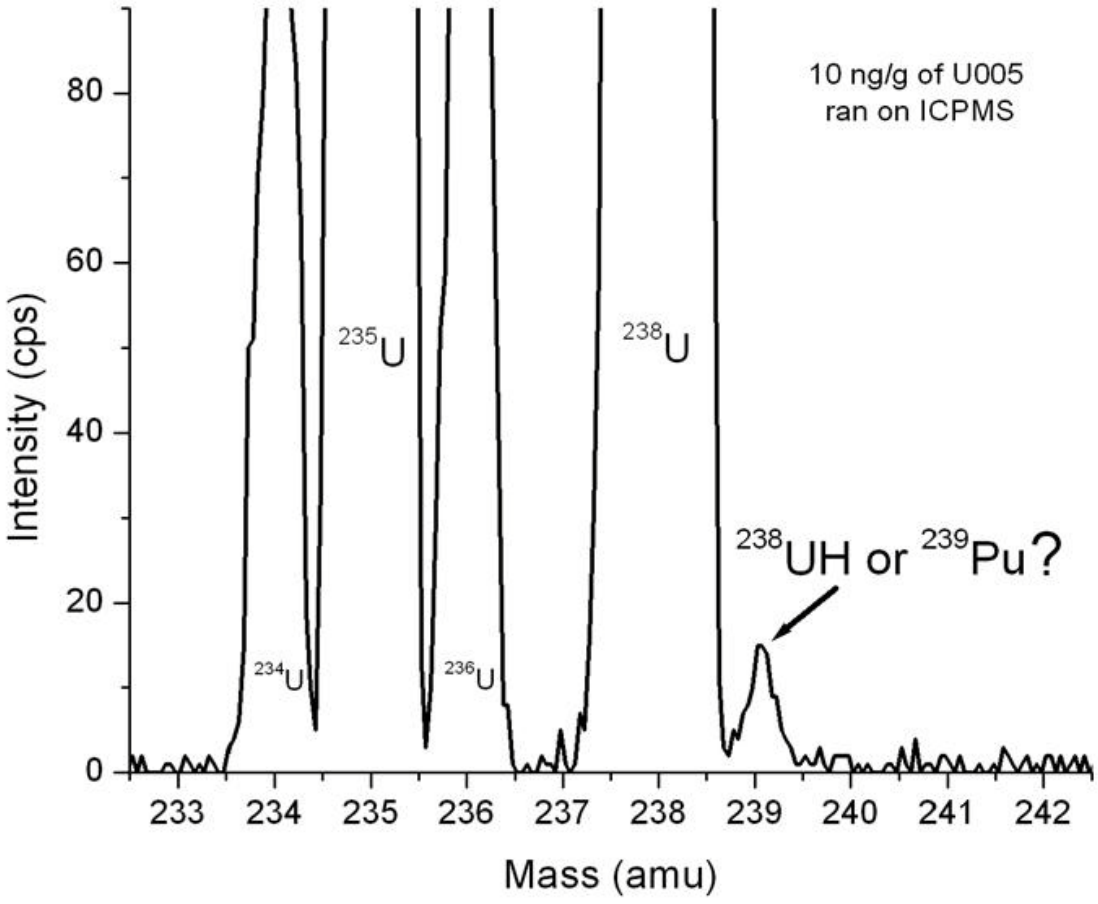
^{242}PuH and ^{243}Am

Isobars

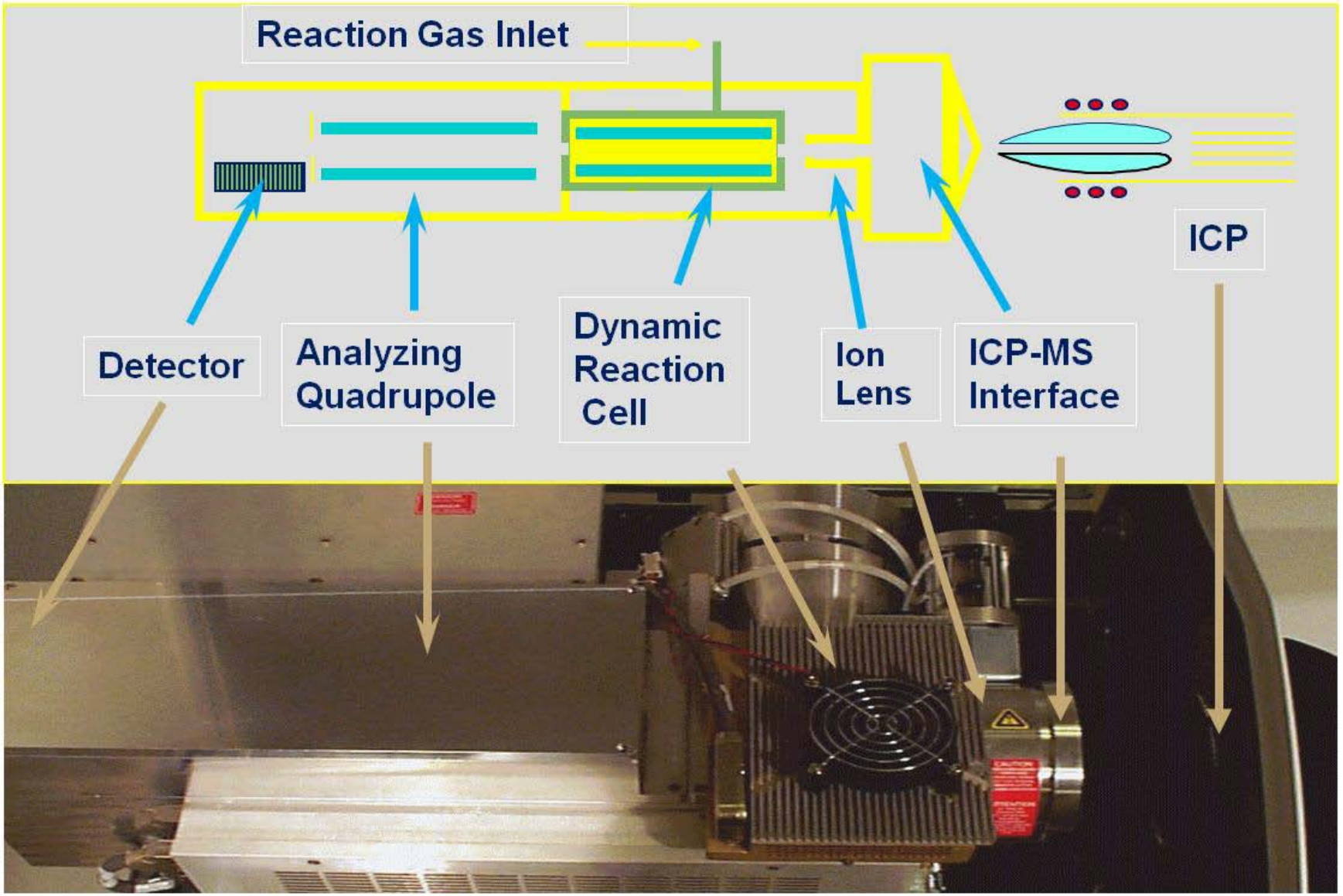
^{236}U and ^{236}Np

^{238}U and ^{238}Pu

^{241}Pu and ^{241}Am

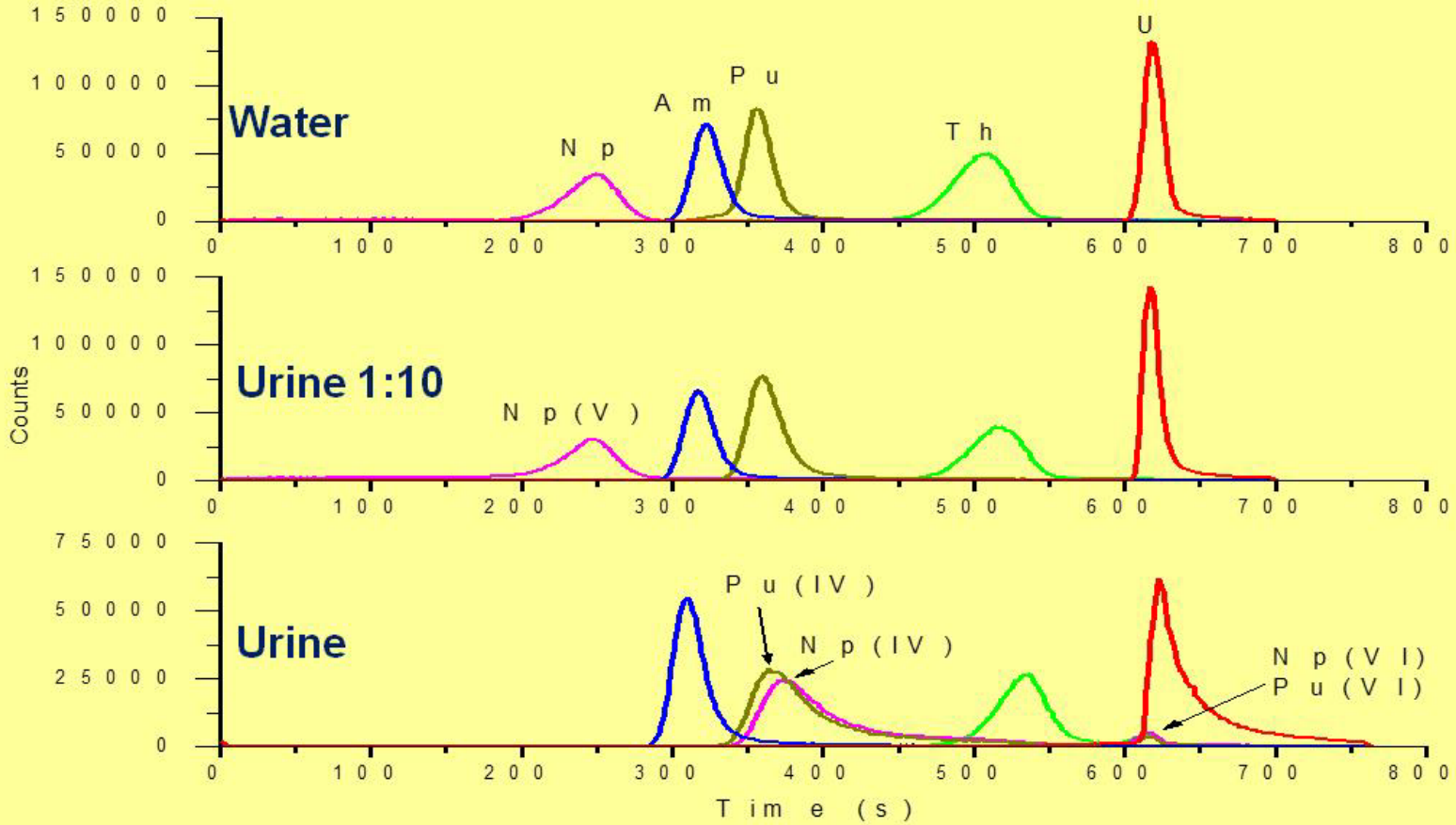


Schematic and Layout of ICP-DRC-MS



Actinides by IC-ICP-MS

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



Actinides

- Inductively Coupled Plasma – Mass Spec (ICP-MS) – [quadrapole]
  - $^{235}U + ^{238}U$ ("Total" Uranium)
  - $^{235/238}U$ Isotope Ratio
- Magnetic Sector (MS-ICP-MS)
  - ^{235}U, ^{238}U, $^{234/235/236/238}U$ Isotope Ratios, ^{239}Pu, ^{232}Th, ^{241}Am

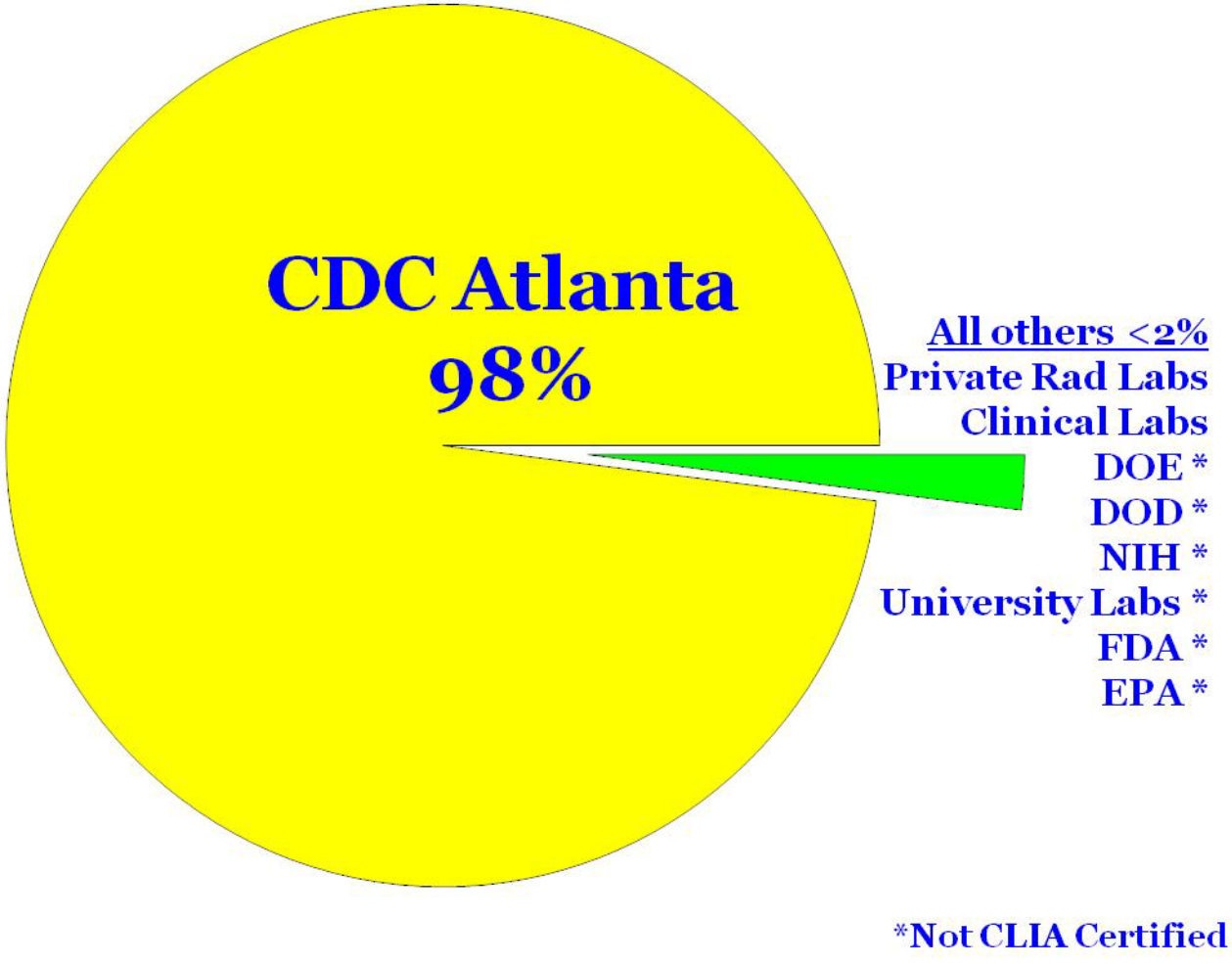
MS-ICP-MS Method Parameters

- 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)**

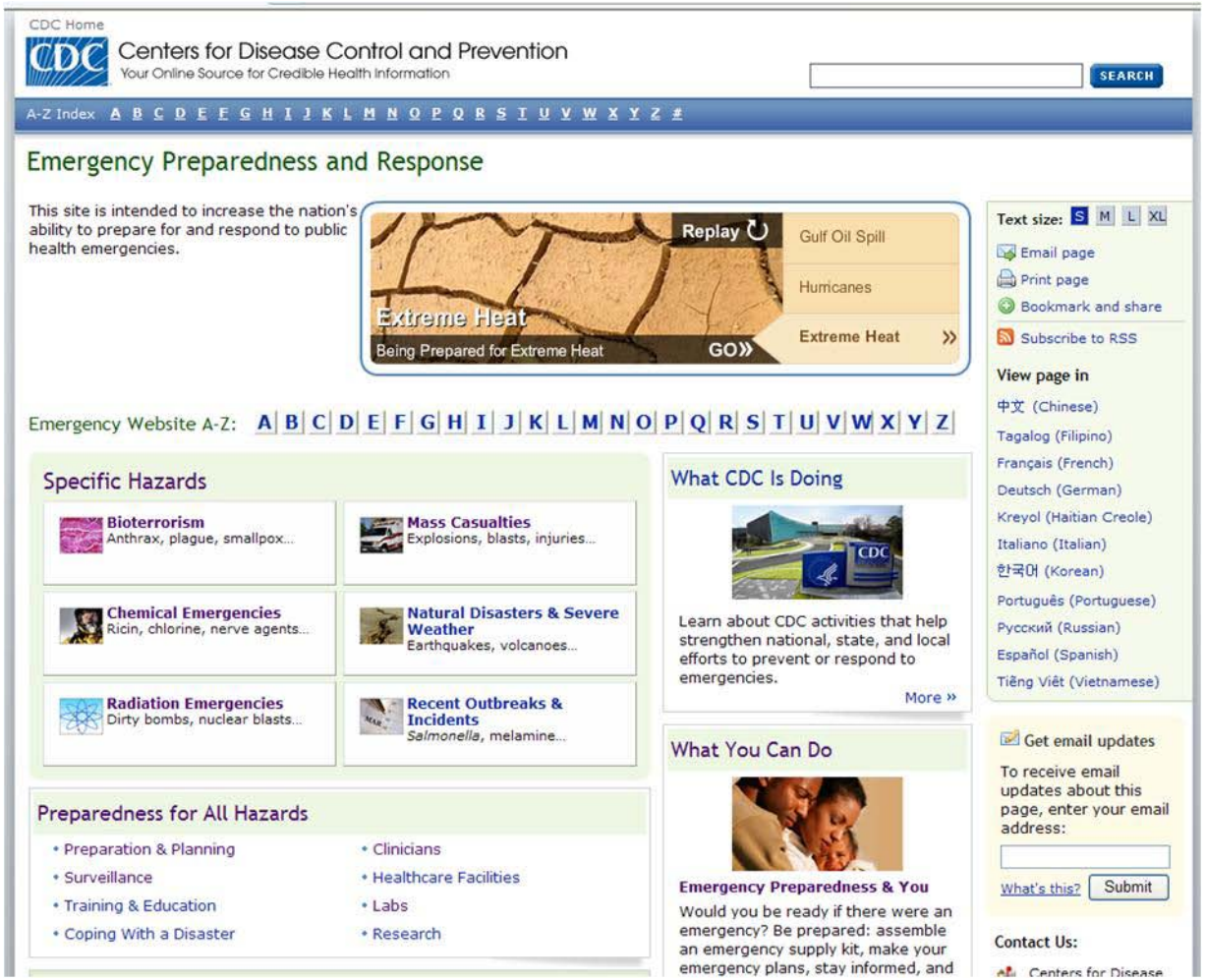
Coordination with Other Laboratories

- 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

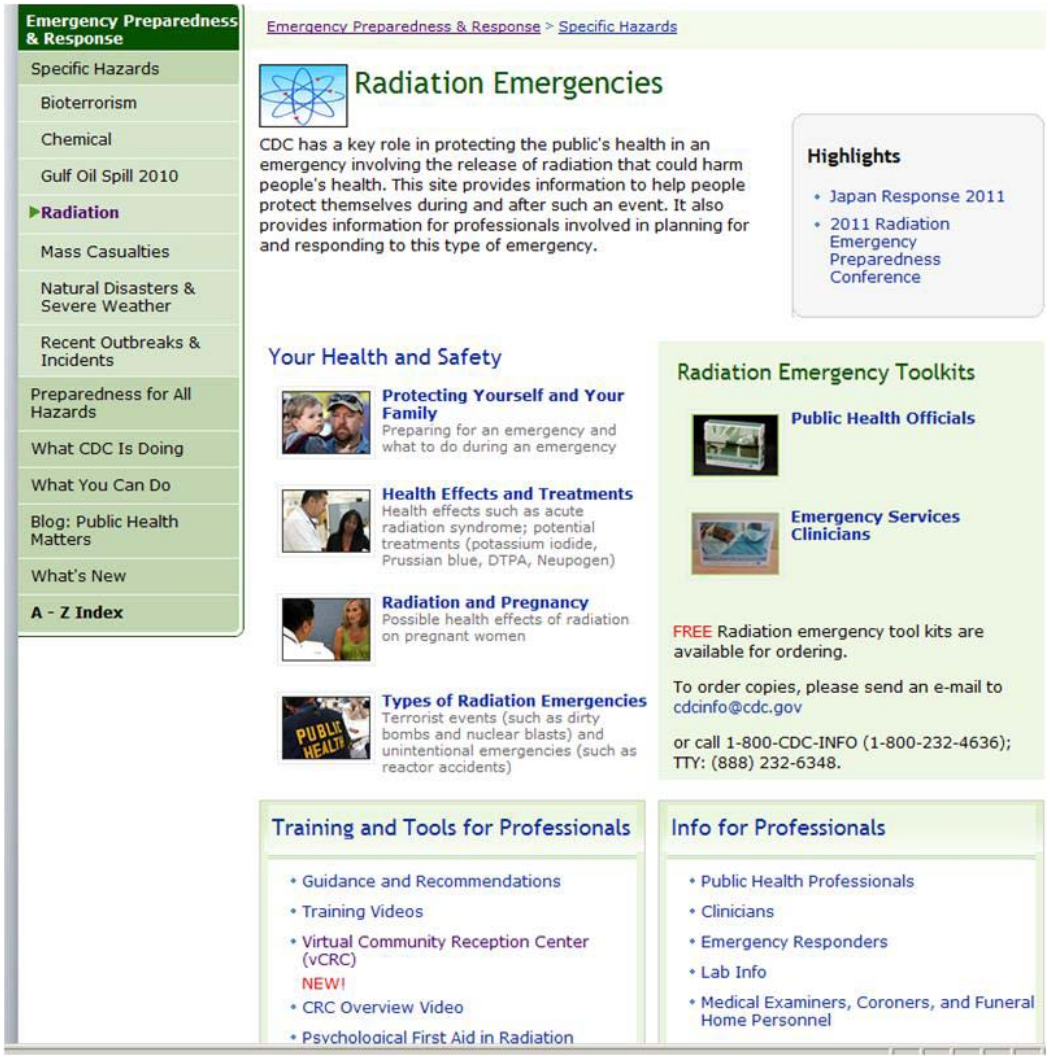


CDC Website for Emergency Preparedness and Response



emergency.cdc.gov

CDC Website for Radiation Emergency Preparedness and Response



http://emergency.cdc.gov/radiation

Urine Collection and Processing

Centers for Disease Control and Prevention
Specimen-Collection Protocol for a Radiological/Nuclear-Exposure Event

For detailed instructions, see the Centers for Disease Control and Prevention's "Shipping Instructions for Specimens Collected from People Who May Have Been Exposed to Radiological/Nuclear -Terrorism Agents."

For each person, collect 70 mL or more of urine in a screw-cap urine cup by following the steps below:

Wash hands with soap and water.

Collect 70 mL or more of urine in a screw- cap urine cup.

Deliver specimen to clinic personnel.

Label the urine cup with the appropriate bar-coded label, indicating the method of collection if other than "clean catch."

Place bar-coded label on all cups so that when upright, the barcode looks like a ladder.

Freeze samples (optimally at -70° C or use dry ice).

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
Office Phone: 770-488-7227
Email: SampleLogistics@CDC.gov

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

7/2010

emergency.cdc.gov/radiation/pdf/UrineCollectionFlowChart.pdf

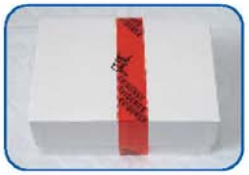
Urine Shipping Instructions

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 Packing Instruction (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."

To separate urine cups, use a grid and/or individually wrap the urine cups. Place absorbent material in the bottom of the box and insert the cups.



Use one continuous piece of evidence tape to seal the box containing the urine cup(s). Write initials half on the evidence tape and half on the box or bag.

Wrap the box with absorbent material and secure with tape. Seal the box inside a Saf-T-Pak inner leak-proof polybag (or equivalent).

Place the sealed Saf-T-Pak inner leak-proof polybag (or equivalent) inside a white Tyvek® outer envelope (or equivalent).
Note: If primary receptacles do not meet the internal pressure requirement of 95 kPa, use compliant secondary packaging materials.

Seal the opening of this outer envelope with a continuous piece of evidence tape. Write initials half on the evidence tape and half on the envelope.

Use a polystyrene foam-insulated, corrugated fiberboard shipper to ship boxes to CDC. Place an absorbent pad in the bottom of the shipper.

Place a layer of dry ice in the bottom of the shipper on top of the absorbent material. DO NOT use large chunks or flakes of dry ice.

Place the packaged urine cups in the shipper. Use absorbent material or cushioning material to minimize shifting while box is in transit. Place additional dry ice on top of samples.

Place the urine shipping manifest in a sealable plastic bag and put the bag on top of the packaged samples inside the shipper. Keep chain-of-custody documents for your files. Place lid on the shipper.

Secure the outer container lid with filamentous shipping tape. Place your return address in the upper left-hand corner of the shipper top and put the CDC receiving address in the center (see Instruction 13. below for address).

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: SampleLogistics@CDC.gov

Add the UN 3373 label and the words "Biological Substance, Category B" on the front of the shipper. UN 3373 is the code identifying the shipper's contents as "Biological Substance, Category B."

Place a Class 9/UN 1845 label on the front of the shipper. This label is to indicate the use ofdry ice (in kg) in the shipper and the proper name (either dry ice or carbon dioxide, solid)

Send shipment to:
Centers for Disease Control and Prevention
Attention: Sample Logistics
4770 Buford Hwy, NE
Building 110, Loading Dock
Atlanta, GA 30341
Phone: 770-488-7227

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

7/2010

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

- David Saunders, PhD
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- Carl Verdon, PhD

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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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4770 Buford Hwy
Mailstop F-50
Atlanta, GA 30341-3724
RLJones@cdc.gov

For more information please contact
Centers for Disease Control and Prevention

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Future NAMP Radiochemistry Webinars

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