

Radiation 101 for Laboratorians

April 14, 2011



Overview

- **What is Radiation?**
- What types of monitoring happen in the US?
- What methods are used to detect radioactivity?

What is Radiation

Robert L. Jones, PhD

Inorganic and Radiation Analytical Toxicology Branch

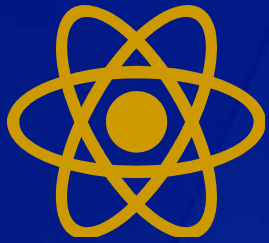
APHL Webinar

4/14/2011

National Center for Environmental Health
Division of Laboratory Sciences

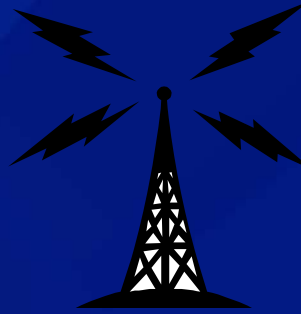


What is Radiation?

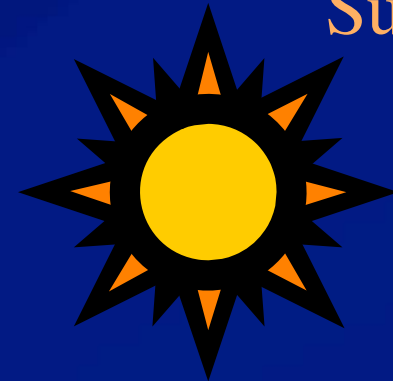


Nuclear

Radio/TV



Sun



Light

Heat



Microwave

What is Radiation?

radiation: Energy propagated through space in the form of electromagnetic waves or particles

ionizing radiation: Electromagnetic radiation (x or gamma rays) or particulate radiation (alpha particles, beta particles, electrons, positrons, protons, neutrons, and heavy charged particles) capable of producing ions by direct or secondary processes in passage through matter.

nonionizing radiation: Electromagnetic radiation that includes the ultraviolet, visible, infrared, microwave, radiofrequency, and extremely low- frequency portions of the electromagnetic spectrum. Unlike ionizing radiation, nonionizing radiation is unable to ionize atoms in its interactions with matter.

Common Radioactive Nuclides or Isotopes

- Natural

e.g., ^{14}C , ^{40}K , ^{238}U

- Medical

e.g., $^{99\text{m}}\text{Tc}$, ^{201}Tl , ^{131}I

- Nuclear Fallout

e.g., ^{60}Co , ^{137}Cs , ^{239}Pu

There are 3,031 radionuclides

Priority Radionuclides

Radionuclides	Urine bioassay detection	Primary radiation emission
Uranium (^{235}U , ^{238}U), Thorium	yes	alpha and beta particles
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	

Radionuclides of concern can be found at:
www-pub.iaea.org/MTCD/publications/PDF/Pub1309_web.pdf
www.energy.gov/media/RDDRPTF14MAYa.pdf

The "Grand Rounds" presentation and slides can be found at:
www.cdc.gov/about/grand-rounds/archives/2010/03-March.htm

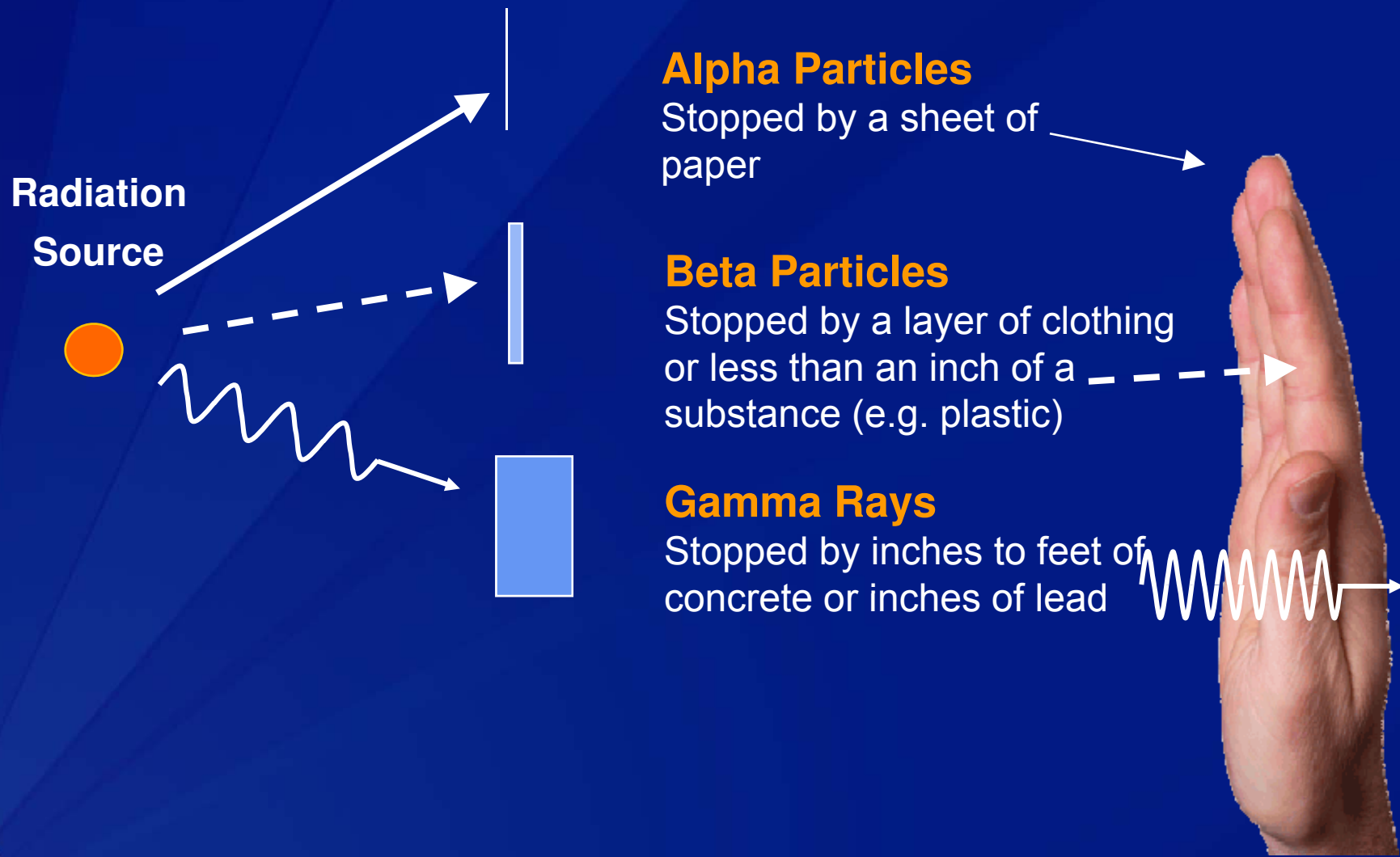
Major Types of Nuclear Radiation

Alpha - He nucleus - 2 protons, 2 neutrons, no electrons, +2 charge, very short range (2 - 5cm in dry air)

Beta - electron-sized particle, + or - charge, medium penetrating power (~ 1 meter in dry air)

Gamma - no charge, no rest mass, 'infinite' penetrating power

Penetration Abilities of Different Types of Radiation



Alpha Particles

Stopped by a sheet of paper

Beta Particles

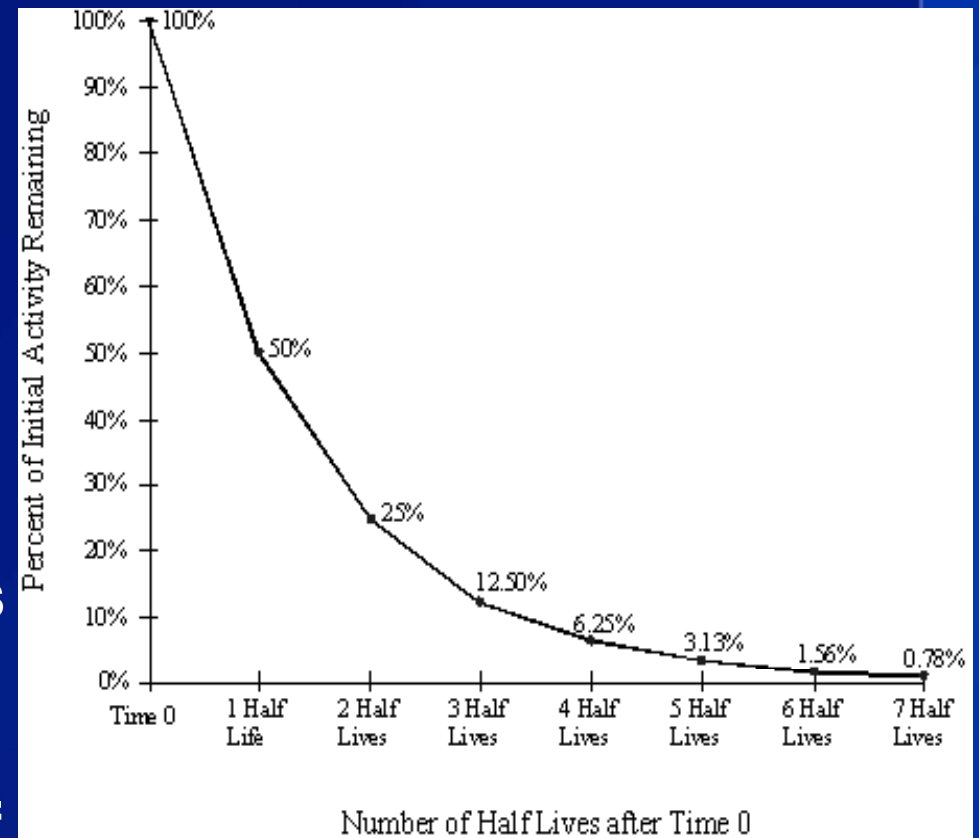
Stopped by a layer of clothing or less than an inch of a substance (e.g. plastic)

Gamma Rays

Stopped by inches to feet of concrete or inches of lead

Radioactive Decay

- ❑ Radioactive decay is the process where an unstable atom emits radiation.
- ❑ Radioactive decay changes unstable atoms into more stable atoms.
- ❑ Half-life is the time it takes for 1/2 the atoms of a particular radioactive element to transform itself by decay.



Half life and Biological Removal

- **Effective Half-Life** – approximate time period for half of the original radioactive material intake to be removed by a combination of physical and biological processes
 - **Physical Half-Life** – Time required for radioactive material to lose half of its amount by decay
 - **Biological Half-Life** – time required for biological system to eliminate half its amount by excretion

Uranium (238 and 235) Decay

	Uranium-238 Series, Includes ^{234}U Series					Uranium-235 Series				
Np										
U	^{238}U 4.5E9		^{234}U 2.5E5y			^{235}U 7.1E8 y				
Pa	↓	^{234}Pa 1.2 m	↓			↓	^{231}Pa 3.3E4 y			
Th	^{234}Th 24 d		^{230}Th 8E4y			^{231}Th 25.5 h	↓	^{227}Th 18.7 d		
Ac			↓				^{227}Ac 21.8 y	↓		
Ra			^{226}Ra 1600 y				↓	^{223}Ra 11.4 d		
Fr			↓				^{223}Fr 21.8 m	↓		
Rn		^{222}Rn 3.82 d						^{219}Rn 4.0 s		
At		↓	^{218}At 2s				↓	^{215}At 1E-4s		
Po		^{218}Po 3.05 m	↓	^{214}Po 1.6E-4s			^{210}Po 138 d	↓	^{215}Po 1.8E-5	^{211}Po 0.5 s
Bi		↓	^{214}Bi 19.7 m	↓	^{210}Bi 5.0 d		↓	^{211}Bi 2.15 m	↓	
Pb		^{214}Pb 26.8 m	↓	^{210}Pb 22.3y	↓	^{206}Pb stable		^{211}Pb 36.1 m	↓	^{207}Pb stable
Tl			^{210}Tl 1.3 m		^{206}Tl 4.2 m			^{207}Tl 4.79 m		

↓ alpha decay; ↗ beta decay; half life (d = days; m = minutes; s = seconds; y = years)

Radionuclides in People

Natural

Uranium-235/238

Polonium-210

Radon-222

Potassium-40

“Man Made”

Cesium-137

Cobalt-60

Plutonium-239

Strontium-90

Contamination vs. Exposure

- Exposure: coming in contact with radioactive waves or particles, e.g., having a chest x-ray
- Contamination: deposition of radioactive material in undesired locations

A person can be exposed but not contaminated – think x-ray exams!

Health Effects of Radiation Exposure

- In general, the amount and duration of radiation exposure affects the severity or type of health effect
 - Lethal: in high doses
 - Mutagenic: damage to the genes
 - Carcinogenic
 - Can have other biological effects, especially at high doses



Long term Effects of Radiation Exposure

- ❑ **Radiation can transform cells, leading to:**
 - Late effects, primarily cancer
 - Years (decades) may pass between exposure and the effect

- ❑ **Health effects highly influenced by variety of factors**
 - radiation dose
 - age and gender of person exposed
 - organ or tissue irradiated

Reference: ICRP 96: Protecting People Against Radiation Exposure in the Event of a Radiological Attack, October 2005

Analytical Method Types

Screening: Screen for the presence of any radionuclides

- Identifies presence of alpha, beta or gamma emitting radionuclides
- Hand held or portable radiation detectors
- Laboratory based instruments

Identification and Quantification: Identify and quantify specific radionuclides

- Radiochemistry separation followed by radioactivity counting techniques
- Spectrometry: radioactivity counting (e.g. HPGe)
- Spectrometry: mass spectrometry (e.g. ICP-MS)

Isotopic Ratios: Identify the isotopic contributions

- Radiochemistry separation followed by radioactivity counting techniques
- Spectrometry: radioactivity counting (e.g. HPGe)
- Spectrometry: mass spectrometry (e.g. ICP-MS)
- Example is Uranium: Depleted, natural, or enriched ($^{235}\text{U}/^{238}\text{U}$ ratio)

Radiation Activity Units

- ❑ **Activity** – sometimes described as how strong or “hot” the radioactive material is
- ❑ **Curie (Ci)**
 - U.S. unit (often expressed with international equivalent)
 - Activity of 1 gram of radium
- ❑ **Becquerel (Bq)**
 - International unit
 - Defined as one disintegration per second

1 Ci = 37 Billion Bq (disintegrations per second)!

Radiation Dose Measurement Units

□ Absorbed dose

Energy absorbed per unit mass of tissue

rad (USA) or **gray** (international)

1 gray (Gy) = 100 rads

□ Effective dose

Health and biological effects-based dose following exposure to radiation (e.g. alpha, beta, gamma, etc...)

rem (USA) or **sievert** (International)

1 sievert (Sv) = 100 rem

Contact

Robert L. Jones, PhD

Centers for Disease Control and Prevention

4770 Buford Hwy

Mailstop F-50

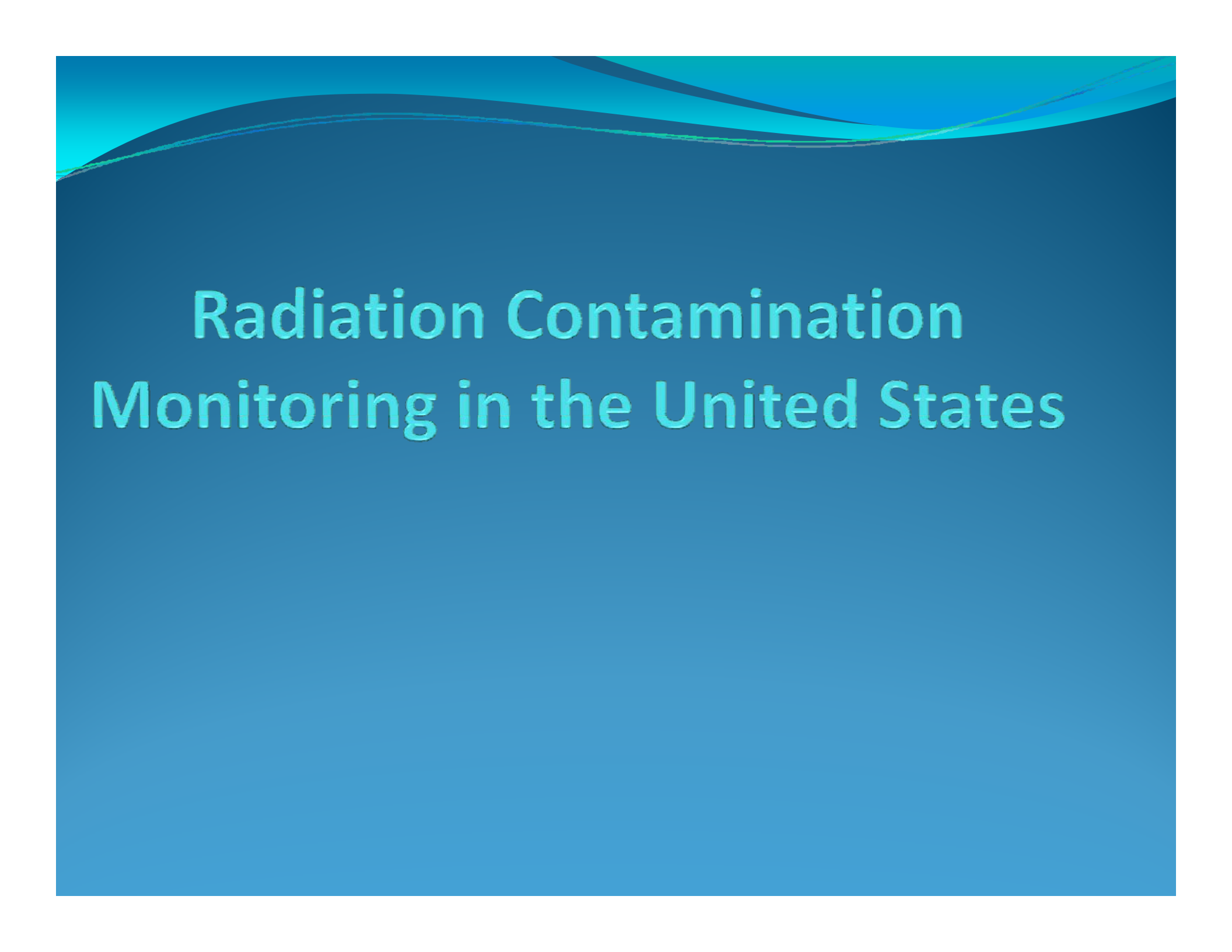
Atlanta, GA 30341-3724

RLJones@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.”

Overview

- What is Radiation?
- **What types of monitoring happen in the US?**
- What methods are used to detect radioactivity?



Radiation Contamination Monitoring in the United States

- 
- Types of Monitoring
 - Environmental
 - Food
 - Clinical
 - Other Monitoring Considerations



The Plume is Here

- Not unexpected
- Extremely low levels detected to date
 - We are able to detect extremely low levels of radioactivity
- Levels detected below any public health concern
- Ongoing monitoring is occurring
- Gamma Spectroscopy is the primary analytical tool
 - Counting time used is driven by project data quality objectives



Environmental Monitoring

- EPA has been the lead agency in the environmental monitoring effort
 - Some state laboratories have been performing additional testing
- Radnet
 - EPA has a network of over 100 stations across the country that have been monitoring air, precipitation, water and milk for over 35 years
 - Not all Radnet stations perform all testing



Radnet

- Developed because of need to monitor radiation associated with nuclear weapons testing
- Mission was expanded to monitor the aftermath of radiation emergencies and to generate data on background levels of radioactivity
- Near real time monitoring for gamma and beta
- Air particulate filters sent to EPA twice a week
 - Preliminary counting for beta radiation done before filters are sent to EPA
- Some Radnet stations also collect air samples on charcoal cartridges
- Precipitation samples sent to EPA after rain/snow event

Radnet Station





Environmental Monitoring

- In response to the current emergency, EPA has set up a website with monitoring information:
 - <http://www.epa.gov/radiation/index.html>
- The data on the site is updated several times per week.
- The good news is that the levels of radioactivity are trending down
- EPA has not called on the Capacity Enhancement Grant laboratories for surge capacity at this point in time



Environmental Monitoring

- Some states are doing their own monitoring as well
 - The amount and type of monitoring varies from state-to-state
 - States with power plants already doing routine monitoring
 - Water, vegetation, fish, milk, air....
- Laboratory capacity for radiochemistry is limited
 - This is true for all types of monitoring



Food Monitoring

- FDA issued import alert 99-33 about the import of foods from the affected prefectures in Japan
 - Parallels the list of items on the Japanese Ministry of Health list
- Those products will be Detained without Inspection
- If analysis of foods is needed, the FDA Winchester Engineering and Analytical Center (WEAC) will be the primary laboratory

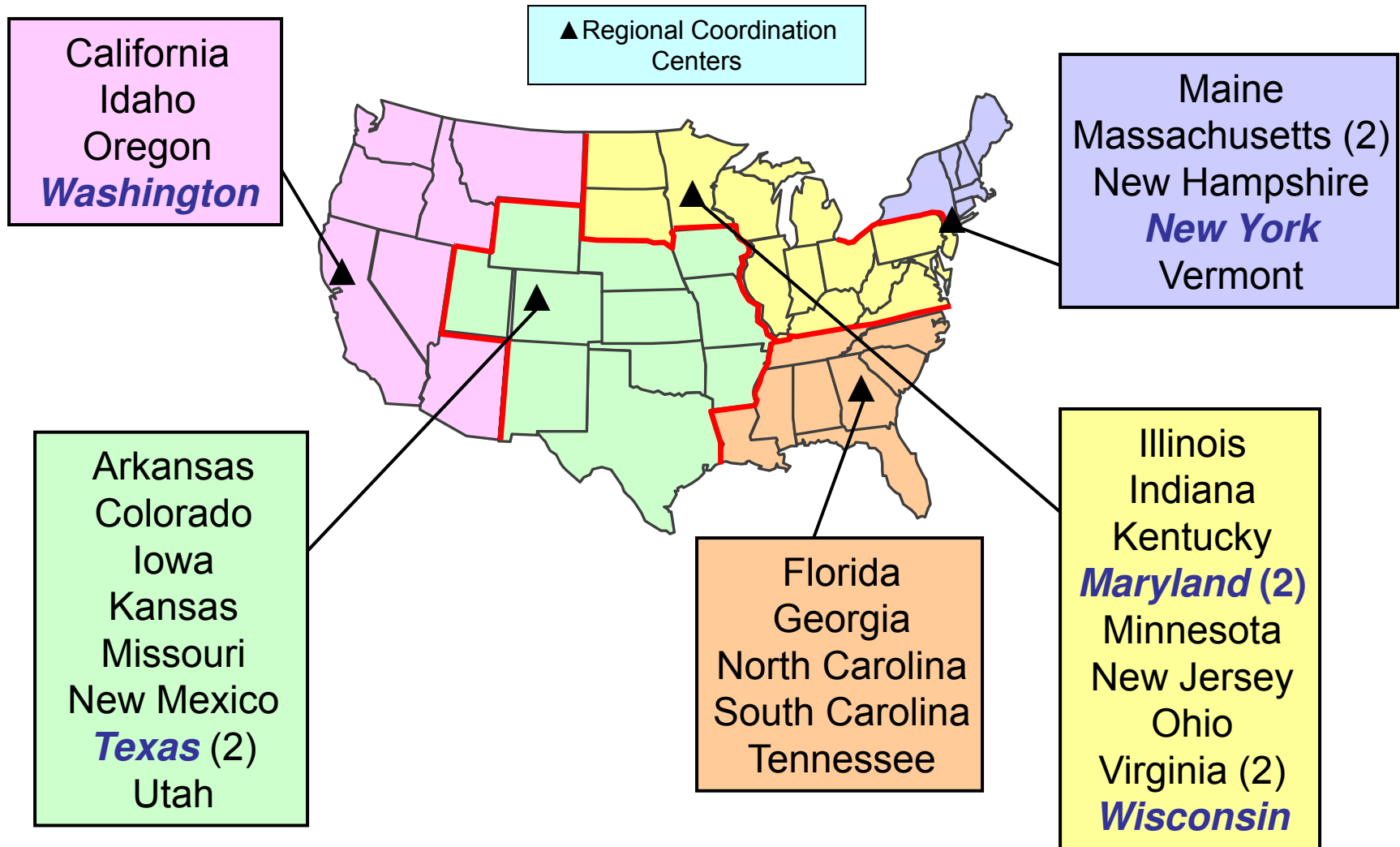


Food Monitoring

- The Food Emergency Response Network (FERN) Radiological Laboratories have been surveyed to determine their available
 - Will be used if surge capacity is needed
 - The FDA funded laboratories will be used before the non-FDA funded laboratories
- FDA has posted the SOP for the method that will be used if required:
 - <http://www.fda.gov/downloads/ScienceResearch/FieldScience/UCM248262.doc>

Food Emergency Response Network

Radiological Federal, State and Local Laboratories





Food Monitoring

- Other food monitoring activities
 - States with nuclear power plants routinely test milk from dairy farms within the 10 mile Emergency Planning Zone (EPZ)
 - This is in addition to the samples EPA takes for Radnet
 - Some states on the West coast are considering having fish and seawater samples analyzed



Clinical Monitoring

- Besides CDC, there is only one laboratory in the United States that is approved by CLIA for radiobioassay
 - There are laboratories that perform radiobioassay for worker exposure, but they are not certified by CLIA for diagnostic testing
 - This testing has also has a different purpose than emergency response testing
- CDC can test about 500 samples/day for gamma emitting radioisotopes in human clinical samples
- The CDC tests determines (and quantifies) specific isotopes
 - For example, Cs-137 at a detection limit of 100 Beq/L



Clinical Monitoring

- Two levels of testing
 - Screening
 - Five minute count on a NaI multi-well detector
 - Able to determine if greater than background
 - Definitive analysis
 - Fifteen minute count on a HpGe detector

Clinical Monitoring

- The World Health Organization has a network of biodosimetry laboratories (BioDoseNet)
 - For estimating radiation doses in people overexposed to radiation
- Currently 21 labs, worldwide, make up BioDoseNet
 - CT, MD, and TN maintain biodosimetry laboratories in the U.S.
- Labs perform dicentric analysis (cytogenetic bioassays)
 - Correlates the frequency of chromosome damage to the radiation dose
 - Estimates of radiation dose are critical for predicting health outcomes and for guiding clinical management



Clinical Monitoring

- The estimated sample throughput of BioDoseNet is approximately 300 to 400 samples/week
- Early on, BioDoseNet was placed on “stand-by” but has since stood-down



Other monitoring considerations

- There are only a small number of laboratories that have significant capability and capacity to perform radioanalytical testing
 - Has been viewed as a field with limited growth potential
- There are significant challenges to expanding capacity if it is needed quickly

Challenges

- NRC license needed
- Need to develop Radiation Safety Plan
 - Will also need a Radiation Safety Officer
- Will the building infrastructure be adequate?
 - Instruments can weigh 3000 lbs
- Contamination control is essential
 - A few atoms can make a difference!
- Sample storage
 - The more samples, the more activity
 - This is not a significant concern for the monitoring samples that we in the USA could receive from Japan
 - Will be concern for the laboratories that will be involved in the cleanup activities round the plant

Overview

- What is Radiation?
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- **What methods are used to detect radioactivity?**

Methods for Detection of Radioactivity

Bob MacKenzie

Program Manager New Technologies

Radiation Measurement and Security Instrumentation

April 14th 2011

Agenda

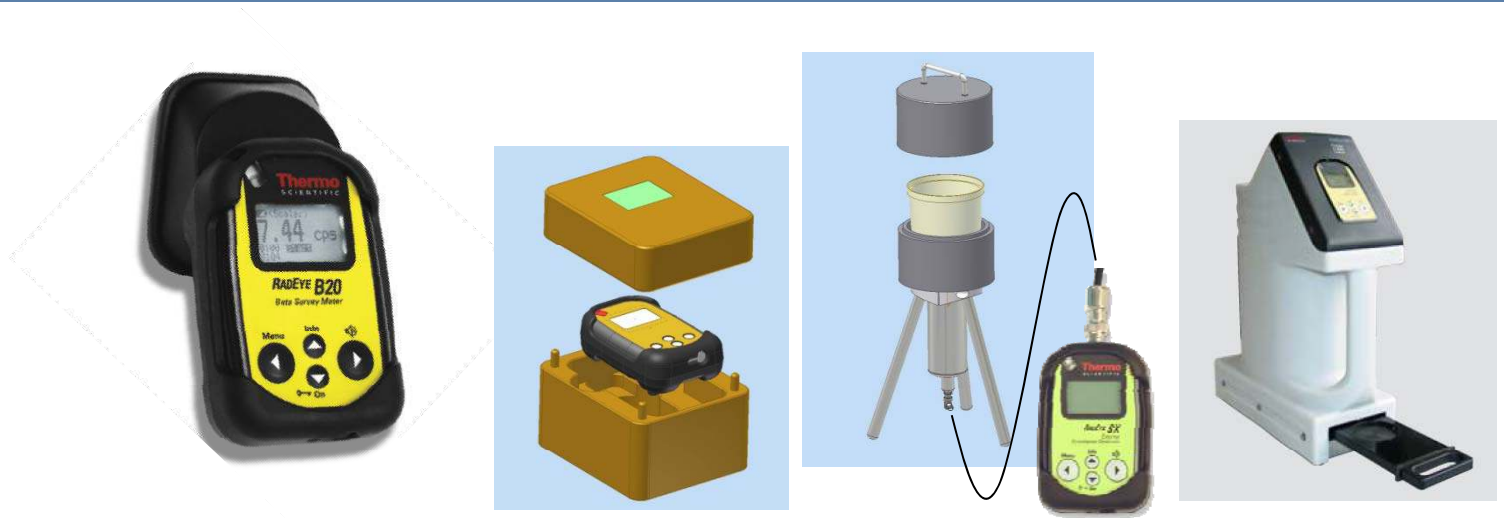
- Overview of Measurement Tools
- Quantitative Instruments
- Specific Nuclide Instruments
- Available methods of analysis
- Measurement Considerations
- Radiation Measuring Laboratory
- Disposal
- Contact Information



Overview of Measurement Tools

	Surface Monitoring for Contamination	Bulk Monitoring (Gross Gamma Radiation)	Bulk Monitoring (Simple Gamma Spectroscopy)	Bulk Monitoring (Sophisticated Gamma Spectroscopy)
What?	On lettuce, grass, swipes	Drinking Water, Milk, Meat, Fish, Mushrooms, Nuts, etc.	Drinking Water, Milk, Meat, Fish, Mushrooms, Nuts, etc.	Drinking Water, Milk, Meat, Fish, Mushrooms, Nuts, etc.
Sensor Used	Geiger Mueller Tube	Scintillator (e.g. NaI(Tl))	NaI(Tl) Scintillator	High-Purity Germanium Detector
Who?	Emergency Responder	Radiation Safety Technologist Emergency Responder	Technologist	Technologist Food Safety Scientist Gamma Spectroscopist
When?	Hours, Days after Accident	Days, Weeks, Months after Accident	Weeks, Months, Years	Months, Years
Where?	Local Agricultural Environment Use weather information Food Distribution Chain	Agricultural Regions Drinking Water Supply Fisheries Milk Production Sites Laboratory	Monitoring Program with Frequency and Location Determined by Analysis	Monitoring Program with Frequency and Location Determined by Analysis
Detection Limits for I-131 (Typical)	~ 4 kBq/l	~300 Bq/l	~60 to 120 Bq/L (w/wo Lead)	Very Low
Instrument Needs	Fast: Go/No Go Decision Easy to Use: Emergency Response Low Cost: Many monitoring points	Analysis: Semi-quantitative Easy to Use: Many users Low Cost: Many Measurements	Analysis: Semi-quantitative Easy to Use: Many users Moderate Cost: Extensive Program	Analysis: Fully Quantitative Cost: Not a Driving Factor

RadEye Quantitative Measurement Instruments



Product	B20-ER	PRD-S	SX/SPA3	HEC
Category	Surface	Bulk	Bulk	Surface
Beta radiation	✓ ✓ ✓			✓ ✓ ✓
Gamma radiation	✓	✓ ✓	✓ ✓ ✓	
Alpha/beta radiation				✓ ✓ ✓
Detection Limit I-131, 1 min (Bq/l)	~4000	~300	~120 (60 w/ Pb shield)	na

HPGe Specific Nuclide Analysis System

- High Resolution
- Specific nuclide measurement (nuclide vector)
- Components
 - High-Purity Germanium Detector
 - Lead Shield
 - Electronics
 - PC and Software
- Footprint Considerations
 - Weight: >1,000 pounds
 - Form factor: Floor Standing



Methods of Analysis

Sample	Sample prep	Methods of Analysis
Air	Air Sampler and Cartridge/Filter	Nuclide Specific
Water	Desiccate on filter	Low Level Alpha/Beta
Food	Cut and weigh	Gross Gamma
Grass and vegetation	None	Scan with Large Area GM Tube
Packages	None	Scan with Large Area GM Tube

Personnel Protection	Products	Application
Badges	Active and passive dosimetry	Total dose
Instrument (pager)	RadEye – B20	Surface contamination
Instrument (pager)	RadEye – PRD	Dose rate and thyroid

Measurement Considerations

- Food (including milk and drinking water) measurements to Derived Intervention Level (DIL) does not require sophisticated sample preparation
 - Knowledge of weight and volume necessary to normalize results
- Fruits and vegetables (above ground) - surface contamination
 - Swipe or direct measurement
- Measurements to sub-pCi levels require sophisticated sample preparation and HPGe specific nuclide analysis system
- Air sampling (EPA RadNet Program)
- Typically soil measurements are not common (remediation task)

DIL Levels Radionuclide Group (Bq/kg)*	
Iodine-131	170
Cesium-134 + Cesium-137	1200

Radiation Measuring Lab

- In a typical public health program for radiation measurement, contamination of the laboratory should not be a concern (sample levels are low)
- U.S. labs are licensed by state regulatory authority – permit issued
 - Licensing program requires a designated radiation safety officer
- Check sources are generally exempt
- How does a lab get contaminated?
 - Only by introduction of highly radioactive samples
- If contamination is suspected
 - (Minor) Contamination which affects measurement – self assessment and swipe, measure, clean
 - (Major) Danger to employees or public health – call higher authorities (EPA)

Disposal

- Disposal of radioactive waste is governed by state and local authorities
 - Part of permit process
 - Disposal can be complex and must be according to a plan
 - Public Health Labs do not generally use open sources but sealed sources
 - Waste typically goes to a commercial processing facility



Invitation – Thursday April 28 – 10:00 am CST



FOOD SAFETY AND TESTING



Upcoming Webinar:

Crisis in Japan: Radiation Detection for Food Safety

Thursday, April 28 10:00 a.m. CST

Food processors and producers, multi-national food and beverage companies, and consumers worldwide are concerned about the global effects of radiation contamination in Japan.

- Gain a basic, technical understanding of radiation contamination and how it affects food
- Learn about tools for screening, quantitation and detection of radiation in food
- Discover resources for food radiation testing



Guest speaker: Ken Kerns, Consultant to the International Atomic Energy Agency in Vienna, Austria and Associate Director, Environmental Health and Safety at Iowa State University.

[Register now >](#)

Register at www.thermoscientific.com

Thermo Fisher Scientific Contact Information

Radiation Measurement Headquarters USA

27 Forge Parkway
Franklin, MA 02038 USA
+1 (800) 274-4212

United Kingdom

Bath Road Beenham
Reading, Berkshire
RG7 5PR, UK
+44 (0) 118 9712121

China

7th Floor, Tower West,
Yonghe Plaza
No. 28 Andingem East Street
Beijing, 100007 China
+86 10 8419 3588

Japan

SEIKO EG&G Co.,Ltd.
Tokyo Office
+81-3-5542-3104
www.sii.co.jp/segg/

Singapore

11 Biopolis Way #12-07/08
Helios Building
Singapore 138662
+011 65 68729724

Germany

Frauenauracher Strasse 96
Erlangen 91056 Germany
+49 9131 909-226

India

Plot No. C -327,
T.T.C. Industrial Area, Pawne
Navi Mumbai 400 705, India
+91 22 41578800

General sales inquires email: info.eid.thermofisher.com

Japan Crisis Response website: www.thermofisher.com/global/en/products/japan/index.html

RadEye products: www.thermoscientific.com/ecom/servlet/newsdetail?storeId=11152&contentId=52697

Radiation Safety: www.thermoscientific.com/ecom/servlet/productscatalog_11152_10443_80427_-1_4

Food Safety website: www.thermofisher.com/foodsafety

Questions & Answers

Tell us what you thought!

www.surveymonkey.com/s/APHLradiation101eval



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