Chapter 10

Environmental Radiological Monitoring

Objectives

- Discuss the reasons for developing and maintaining an environmental radiological monitoring program
- List three major environmental exposure pathways
- Discuss the direct radiation exposure pathway

Objectives

- Discuss the airborne radioactivity exposure pathways
- Discuss the waterborne radioactivity exposure pathways
- Discuss environmental radiological measurement methods and equipment

Objectives

- Discuss environmental laboratory quality assurance
- Discuss environmental transport modeling

Reasons for a Program

- Ensure the health and safety of members of the public
- To ensure that effluent monitoring program is robust
- Ensure compliance with NRC/EPA regulations (10 CFR 20, 10 CFR 50 and 40 CFR 190)

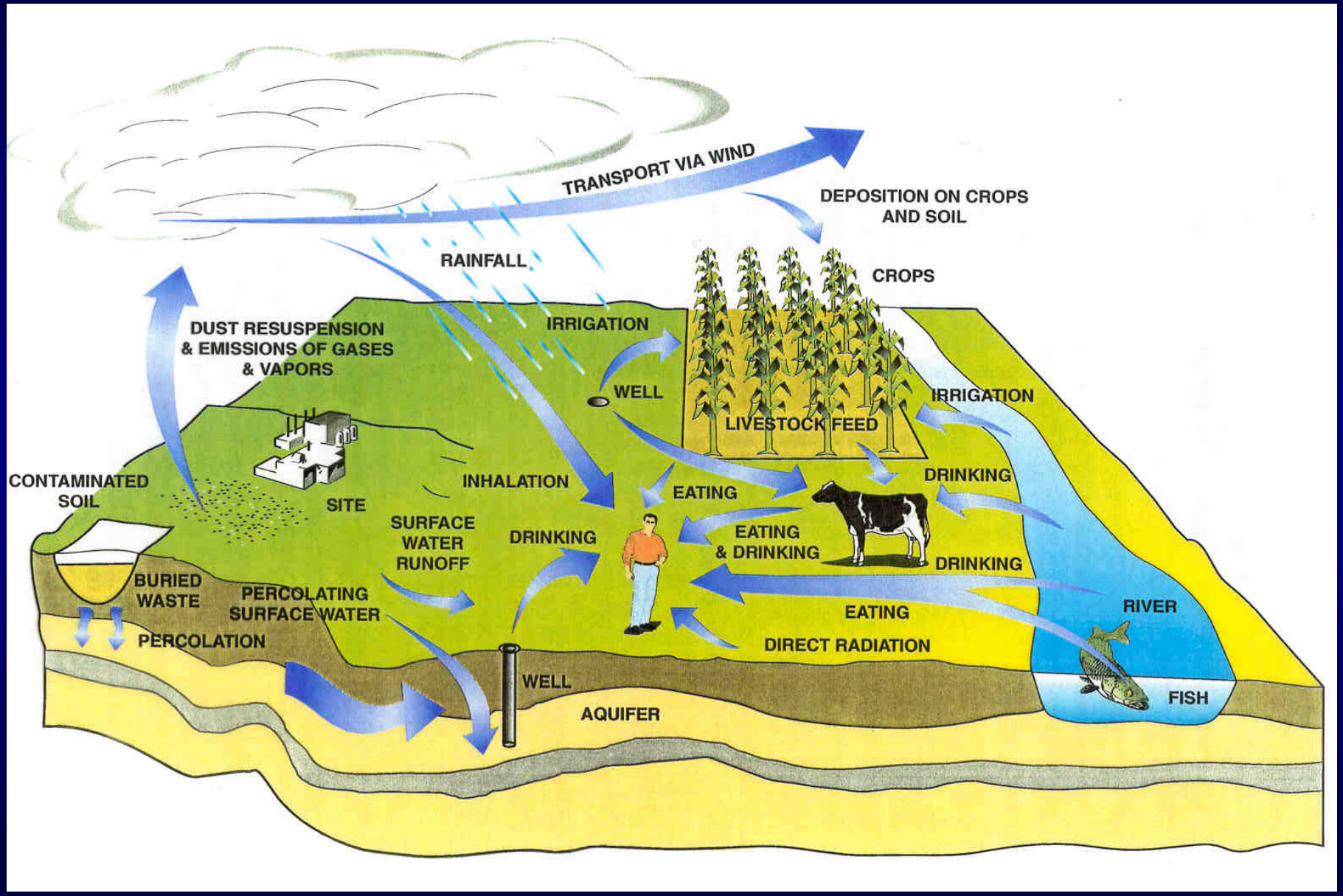
Reasons for a Program

- 10 CFR 20 - 100 mrem/yr TEDE to member of public
- 40 CFR 190 - 25 mrem/yr to whole body and other organs; 75 mrem/yr to thyroid for a member of public from entire fuel cycle
- Appendix I to 10 CFR 50 - 5 mrem/yr from gaseous effluents and 3 mrem/yr from liquid effluents

Reasons for a Program

- Monitor possible buildup of radioactivity in the environment
- Verification that systems are performing as required
- Establish baseline prior to facility operation
- Test environmental transport models (e.g. Offsite Dose Calculation Manual, ODCM)

Environmental Pathways



Environmental Pathways

- Three major exposure categories:
  - Direct radiation
  - Airborne contaminants
  - Waterborne contaminants

Direct Radiation

- Direct gamma (outside liquid storage tanks, radwaste storage areas, facility itself)
- Skyshine - gamma radiation traveling in a skyward direction is scattered or reflected back toward the ground
- N-16 in steam system of a BWR (gamma energies as high as 7.11 MeV)

Airborne Contaminants

- **Noble gases are an external hazard only. Examples include isotopes of Xe, Kr, and Ar**
- **Iodines - I-131, etc. Goat milk pathway gives 6 times the dose from the cow milk pathway**
- **Particulates - Sr-90, Cs-137, Co-60, etc.**
- **H-3 and C-14 - being basic elements in all life forms, they enter easily into biological pathways (e.g. H-3 can enter the body through direct skin absorption)**

Waterborne Contaminants

- Discharges to rivers
- Groundwater transport
- Direct radiation from swimming or standing on contaminated shorelines
- Food pathways - fish, clams, etc.

Assessment Methodology

- Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors (Reg. Guide 1.111)

- Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I (Reg. Guide 1.109)

- Applicable Regulations:
  - 40 CFR 190, Environmental Dose Standard for Uranium Fuel Cycle (includes direct dose component)
  - 40 CFR 141, Drinking Water Standard (default concentration limits)
  - Clean Air Act (CAP-88)
  - Decommissioning requirements (RESRAD, DandD)

Environmental Pathway Analysis

- Ingestion rates for water, meat, milk, fish, crops
- Inhalation rates: residential and occupational, age adjusted
- Source term: activity emitted by the facility by nuclide from routine operations – both liquid and gaseous
- Physiological considerations to exposed population (age specific, e.g., respiration rate, water intake, excretion rates, age dependent organ mass, etc.)
- Exposure factors, e.g., amount of time per year spent swimming, fishing, boating (for dose from materials in water)
- Dose conversion factors per unit activity intake, e.g., Sv/Bq

Effluent Dose Calculation Parameters

- Four age groups are used:
  - Infant – to age 1
  - Child – age 1 to 11
  - Teenager – age 12 to 17
  - Adult - > age 17
- Average and maximum exposed individual determinations – “maximum” with respect to food consumption, occupancy, and “other habits representing reasonable deviations from the average for the population in general.

Average/Maximum Individual Intake

Pathway	Max Child	Avg Child	Max Teen	Avg Teen	Max Adult	Avg Adult
Fruit, Grain, Vegetables (kg/yr)	520	200	630	240	520	190
Milk (L/yr)	330	170	400	200	310	110
Meat, poultry (kg/yr)	41	37	65	59	110	95
Fish (kg/yr)	6.9	2.2	16	5.2	21	6.9
Seafood (kg/yr)	1.7	0.33	3.8	0.75	5	1
Drinking water (L/yr)	510	260	510	260	730	370
Shoreline Recreation (hr/yr)	14	9.5	67	47	12	8.3
Inhalation (m^3/yr)	3700	3700	8000	8000	8000	8000

- Regulatory Guide 1.109

Calculation Example:

What is the annual dose to the average child's thyroid from drinking water that contains 1 pCi/L of I-131?

$R_{aipj} = C_{ip} U_{ap} D_{aipj}$

C_{ip} = 1 pCi/L (radionuclide i, pathway p)

U_{ap} = 260 L/yr (usage factor, age group a, pathway p)

D_{aipj} = 5.7E-3 mrem/pCi ingested to thyroid (organ j)

R_{aipj} = (1 pCi/L)(260 L/yr)(5.7E-3 mrem/pCi)

R_{aipj} = 1.5 mrem/yr

Reference: Reg. Guide 1.109

Environmental Monitoring Programs

- EPA: RadNet - monitors accidents and weapons testing
- Homeland Security: Global Network Program (GNP) conducted by the Environmental Measurements Laboratory (formerly with DOE)
- Chinese: National Radioactivity Contamination Monitoring System (NRCMS)

U.S. Environmental Monitoring Programs

- **EPA: RadNet - monitors accidents and weapons testing**
  - **Monitoring capabilities: 180 fixed air monitors; 40 truck-based deployable monitors**
  - **Sampling:**
    - **Air – analyzed for gross beta, gamma if unusual results**
    - **Precipitation – analyzed for tritium, gross beta**
    - **Drinking water – analyzed for tritium, some I-131 analysis**
    - **Milk – 36 sampling locations, gamma spectroscopy for I-131, Ba-140, Cs-137, Sr-90 (less frequent)**
  - **Isotopic analysis: H-3, Sr-90, I-131, Ba-140, Cs-137, Ra-226, Ra-228, Pu-238, Pu-239/240, U-234, U-235, and U-238.**
- **http://www.epa.gov/enviro/html/erams/**

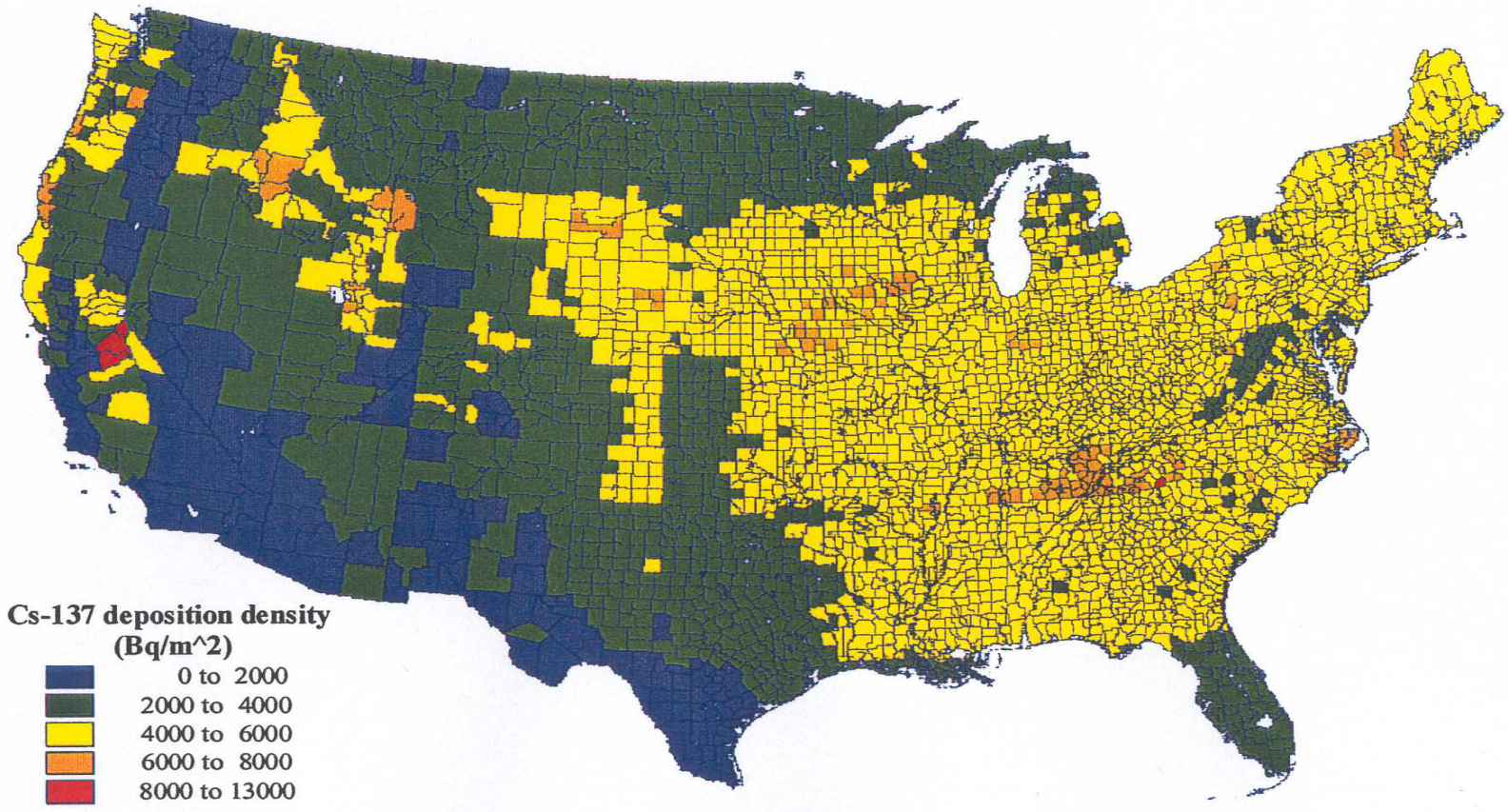
U.S. Environmental Monitoring Programs

EML: Global Network Program

- **Fallout GNP – worldwide network of over 100 sites. 'Sr-90 has a high fission yield and long half-life. Sr-90 is an alkaline earth element that mimics calcium in biological systems and eventual retention in bone tissue makes it a significant contributor of dose to humans.' Data used for UNSCEAR modeling of dose to humans.**
- **Surface air sampling program at 41 sites worldwide including Artic and Antarctic regions. Provided information on worldwide dose from the Chernobyl accident and the 1993 release from the Russian Tomsk-7 complex.**
- **Remote Atmospheric Measurements Program (RAMP) – air data is relayed via NOAA satellites**

Cesium-137 Fallout

http://www.ieer.org/offdocs/csdepglo.pdf



Environmental Sampling

Measurement of Direct Radiation

- Area TLDs around the facility, especially nuclear power plants
- Real-time measurements with radiation detectors

Environmental TLDs

Radiation detector on a roof in New York City

Air Sampling for Gases and Particulates

- Noble gases sampled at point of discharge and doses to public calculated using computer code
- H-3 and C-14 sampled using silica gel and/or molecular sieve
- Particulates sampled using filter samplers (air filters with pump)
- Charcoal filters/cartridges for radioiodines

Air Sampling

Water Sampling

- Grab or composite samples
- Continuous samplers
- Surface vs depth samples
- Well samples for groundwater

Groundwater Sampling

Composite Surface Water Sampling

Soil Sampling

- Grab samples
- Borings
- Individual analysis vs composite analysis

Soil/Sediment Sampling

Sediment Sampling

Sampling Frequency

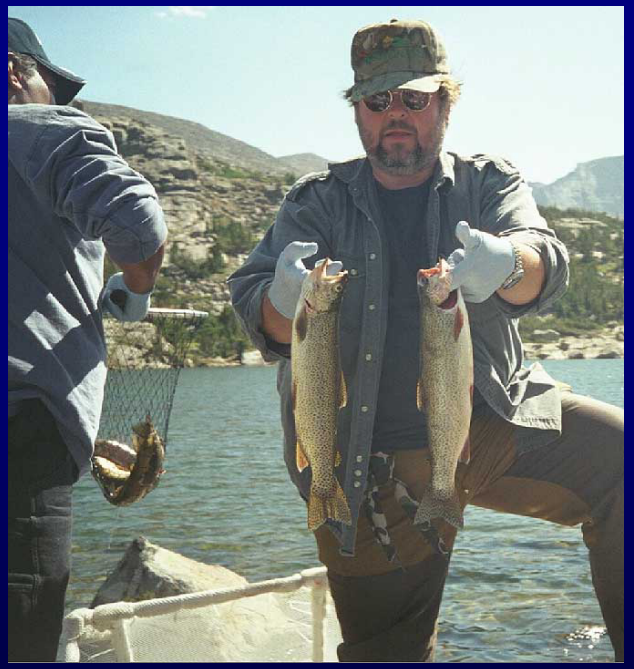
- Sample types and frequency usually specified in nuclear power plant technical specifications or in facility licensee
- Sample types/frequency should be periodically evaluated and adjusted based on analyses of results
- Sampling frequency should be consistent with the pathway monitored

Sampling Frequency

- TLD changeout monthly or quarterly
- Air samples changeout weekly
- Milk samples collected when animals are on pasture (intercontinental sampling program)
- Soil/sediment once or twice per year
- Fruits/vegetables sampled during harvest times

Vegetation Sampling

Sampling Fish Population



Milk Sampling

Laboratory Analysis of Environmental Samples

- Chain of custody, labeling, and cross-contamination
- Gross beta/alpha analyses
- Gamma spectroscopy - Co-60, Cs-137, etc.
- Liquid scintillation counting for H-3 and C-14

Environmental Sample Analysis and Quality Assurance

Environmental Transport Modeling

- Used at nuclear power plants (ODCM) to comply with 10 CFR 50, Appendix I
- Appendix I dose limits (e.g. 5 mrem/yr gaseous effluents) are below TLD threshold, requiring modeling to show compliance
- Used to help design environmental monitoring programs and modify programs as necessary
- Can be compared to results of environmental sampling as a cross-check

Annual Reporting

- Radioactive Effluent Report
- Environmental Report
- Submitted to NRC (On Public Website)
- http://www.nrc.gov/reactors/operating/ops-experience/tritium/plant-info.html

QUESTIONS?

END OF ENVIRONMENTAL RADIOLOGICAL MONITORING

Review Questions

- What is the 10 CFR Part 20 dose limit to a member of the public?
- What are the 40 CFR Part 190 dose limits to MOPs?
- What are the 10 CFR Part 50 Appendix I dose limits?
- List three major environmental radiological exposure pathways.

Review Questions

- Define direct radiation.
- What is skyshine?
- _____ is the radioisotope in the steam system of a BWR that creates direct radiation hazards.
- Radioactive noble gases are considered to be only an _____ hazard?
- List three radioactive noble gases.

Review Questions

- List some radioactive particulates that might be released from a nuclear power plant.
- List two low-energy beta emitters that incorporate easily into biological pathways.
- List three waterborne radiological exposure pathways
- List a measurement method to detect environmental gamma radiation.

Review Questions

- How might one sample for airborne radioactive particulates? for radioiodines?
- List two methods for sampling radioactivity in water.
- List two exposure pathways from radioactivity deposited in soil.
- What radioanalytical method would normally be used for H-3 and C-14?

Review Questions

- Why is sample chain of custody an important part of a radioanalytical laboratory quality assurance program?
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