



Office of Nonproliferation and International Security (NIS)

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Baseline and Routine Environmental Radiological Monitoring Around Nuclear Power Reactors (Nuclear Facility)

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Safeguard nuclear material to prevent its diversion for illicit use.



Control the spread of WMD-related material, equipment, technology and expertise.



Verify nuclear reductions and compliance with international nonproliferation treaties and agreements.



Develop and implement nonproliferation and arms control policy.



- **Provide a General Overview of the Major Requirements of a Typical Radiological Environmental Monitoring Program for Nuclear Power Plant**
- **Discuss Monitoring Program:**
 - **Baseline (pre-operational) Phase**
 - **Normal Operational Stage**
- **Discuss Monitoring Plans**
 - **Sources monitoring**
 - **Environmental monitoring**
 - **Person (receptor) monitoring**

Normal Operational Measurement Environmental Monitoring – Results



- When environmental monitoring is carried out to assess the impact of a particular practice or source, it is referred to as source related environmental monitoring.
- A source related environmental monitoring program should be such as to enable the verification of the results of source monitoring by means of samples taken from and measurements made in carefully chosen locations in the vicinity of the facility, selected in view of their correlation with different discharges or accidental releases.

Normal Operational Measurement Environmental Monitoring – Results



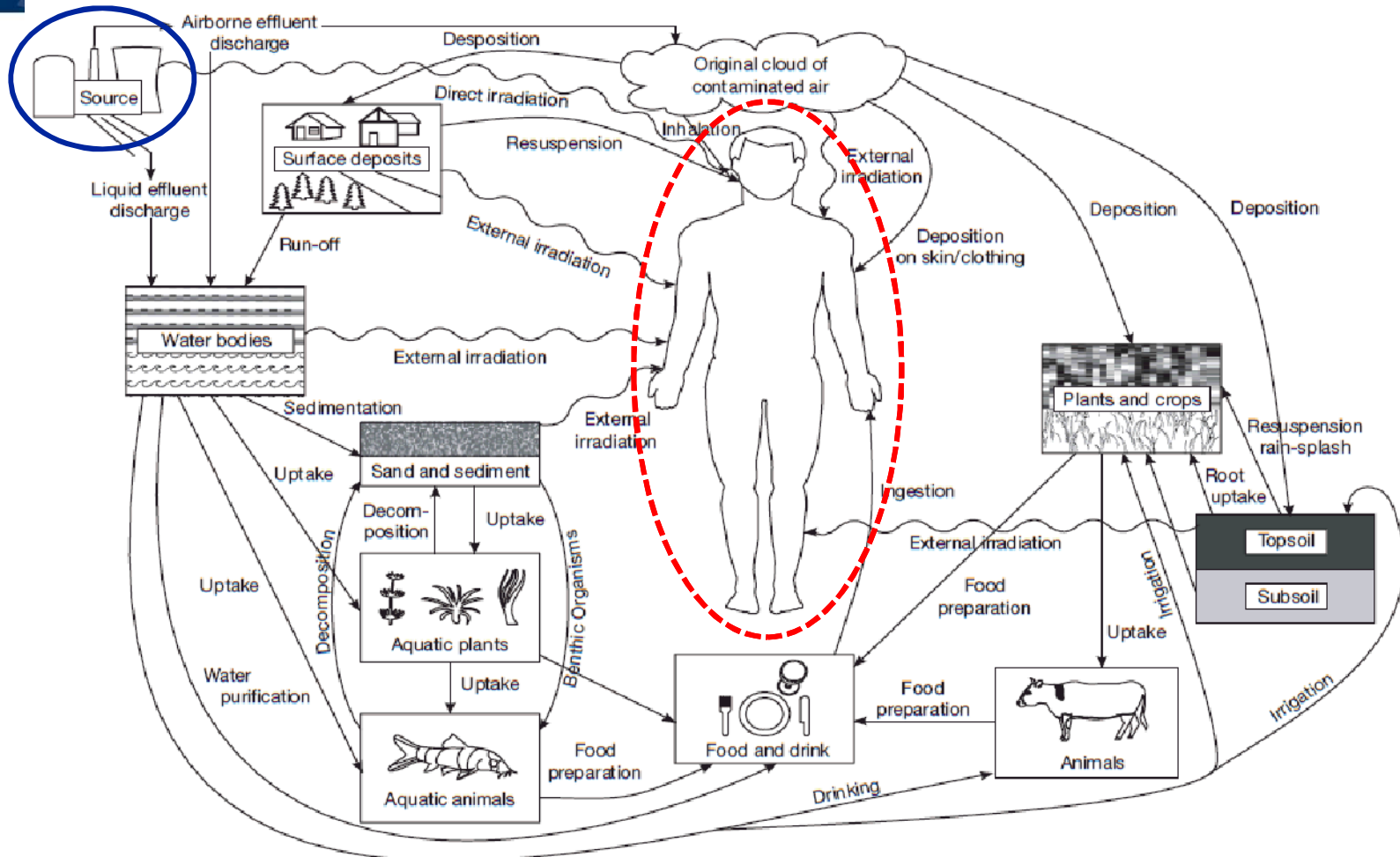
- It should also enable the assessment of the doses due to external exposure of members of the public outside the boundary of the facility.
- Person related environmental monitoring should be carried out where there are several practices or sources giving rise to the potential exposure of the same group of individuals.

General Objectives - Environmental Radiological Monitoring Program



- Determine and Mitigate Radiological Impact of the Plant Operation on the Public and the Environment
 - Establish baselines and characterize trends in the physical, chemical, and biological condition of effluent and environmental media;
 - Identify potential environmental problems and evaluate the need for remedial actions or measures to mitigate the problems;
 - Detect, characterize, and report unplanned releases;
 - Evaluate the effectiveness of effluent treatment and control, and pollution abatement programs.
- Verify and support compliance with applicable federal, state, and local environmental laws, regulations, permits, etc.
- Determine compliance with commitments made in environmental impact statements, environmental assessments, safety analysis reports, or other official documents.

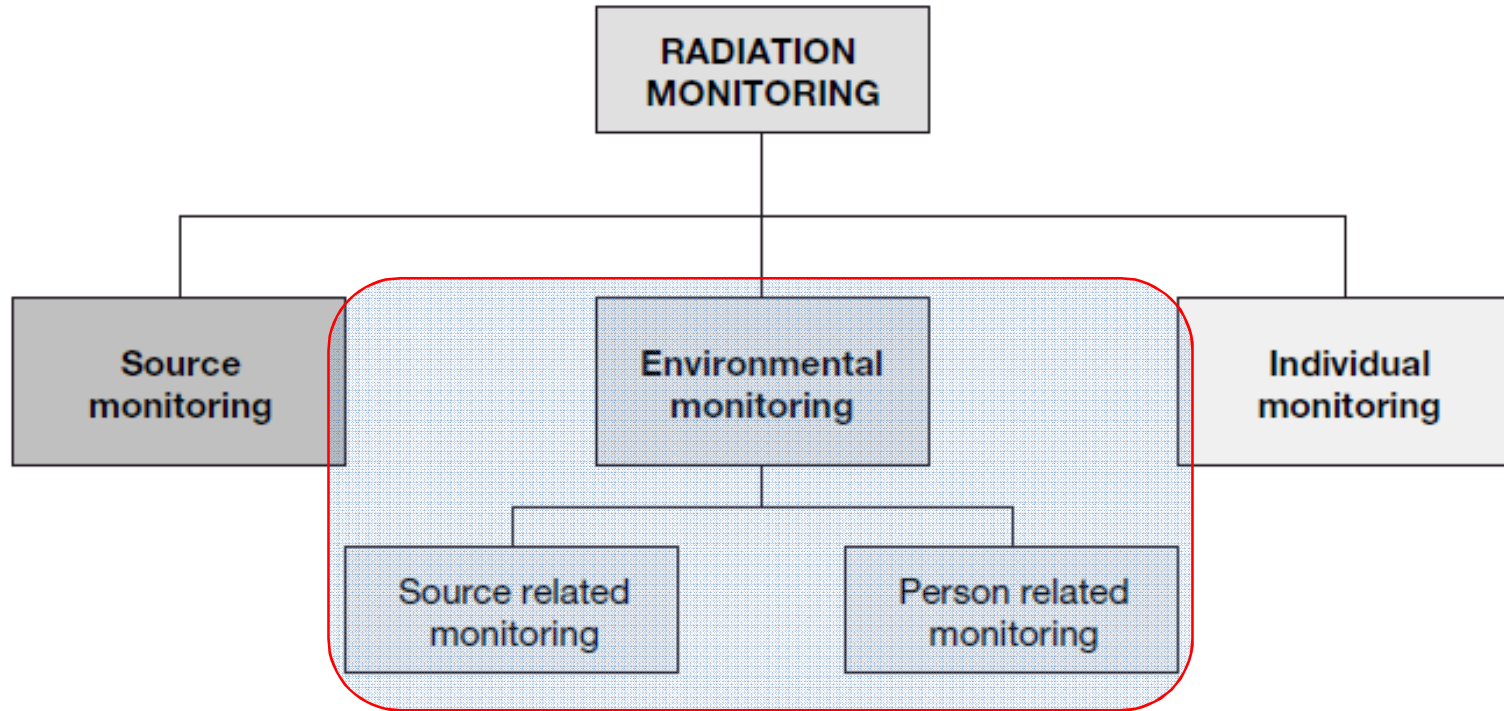
Program Objectives and Exposure Pathways



Specific Objectives of Environmental Monitoring – per IAEA



- To verify the results of source monitoring and the associated modeling to ensure that the predictions are consistent and that exposure limits are not exceeded;
- To check environmental radiation conditions for compliance with the authorized environmental limits, if applicable;
- To provide information to enable the assessment of actual or prospective doses to members of the critical group resulting from authorized practices or sources;
- To detect any unpredicted changes in activity concentrations and to evaluate long term trends in environmental radiation levels as a result of the discharge practice;
- To provide information for the public.



Exposure Pathways, Design of Monitoring, and Data Collection Objectives



- Direct external radiation exposure to radiation from the source;
- Internal dose from inhalation of airborne radionuclides from the Source (related to NESHAP)
- Internal dose from ingestion of
 - Plant foods grown in the contaminated soil and irrigated with contaminated water,
 - Meat and milk from livestock fed with contaminated fodder and water,
 - Drinking water from a contaminated well or water body,
 - Fish or shellfish from a contaminated water, and
 - Contaminated soil.

NESHAP: National Emission Standards for Hazardous Air Pollutants (40 CFR Part 61 Subpart H)

Data Quality Objectives

(Many Available Sources of Information)



- NRC Regulatory Guide 4.1, “Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants”
- NRC Regulatory Guide 4.15 – “Quality Assurance for Radiological Monitoring Programs – Effluent Streams and the Environment”
- EPA Data Quality Objective (DQO) process (EPA QA/G-4-2006)
- The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)
- Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP)
- Mixed Analyte Performance Evaluation Program (MAPEP)
- DOE Order 485.1 “Radiation Protection of the Public and the Environment”
- DOE/EH-0173T, “Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance”
- HASL-300 - EML Procedures Manual, 28th Edition



- DOE primary standard:
 - 100 mrem (1 mSv) effective dose equivalent to members of the public in a year
- ICRP recommendation
 - limit the long-term average effective dose equivalent to 100 mrem (1 mSv) per year, or less
- A higher dose limit, not to exceed 500 mrem effective dose equivalent recommended by ICRP as an occasional annual limit, may be authorized for a limited period, if it is justified by unusual operating conditions.

ICRP: The International Commission on Radiation Protection

Non-radiometric Assay – A Note



- Even though U & Pu are radioactive, they have LONG half-lives and LARGE atomic numbers
- LARGE atomic number lends itself to ICP-MS (or other non-radiometric assay)
- Advantages: Low detection limits and accurate isotope ratios for long-lived isotopes

ICP-MS: Inductively coupled plasma mass spectrometry

Data Validation - Purpose Procedure for Chemical and Radiochemical Data



- To identify, through the evaluation of supporting documentation, those data that do not meet the expected precision and accuracy of an analytical method
- Not intended to eliminate the need for professional judgment in evaluating the data quality
- Data validator may be more or less stringent in evaluating the results based on experience and familiarity with the analytical techniques, historical data, sample matrices, or intended use of the data.
- Product of procedure is a data validation report that includes information regarding the overall quality of the data and the resulting data qualifiers.

Design of Monitoring Program Conditions to Take into Account



- Radioactive inventory and radionuclide composition at the source;
- Space and time features of the radiation fields around the source;
- Authorized discharges and discharge rates;
- Possible contributions from any nearby practices or sources, discharge pathways, exposure pathways, environmental features at the site, and features and habits of the population involved;
- Significance of the annual average doses of the critical group(s) and the environmental radiation levels from planned radioactive releases and possible releases.



Baseline (pre-operational) Measurements - Purpose

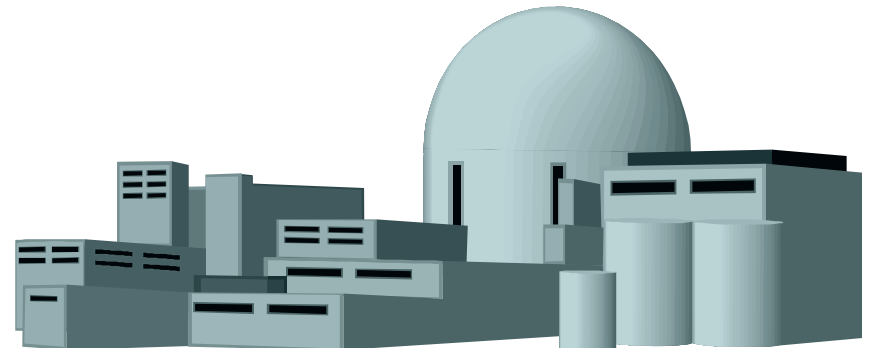


- Establish ‘baseline’ environmental radiation levels and activity concentrations for the purpose of subsequently determining the impacts of the source;
- Make assessments of the expected inventories of radionuclides during operation of a facility, the possible discharge pathways and the likely amounts that will be discharged to the environment,
 - with due consideration of the effluent treatment systems that will be installed

Baseline (pre-operational) Measurements - Purpose



- Provide basic environmental data for use in the prediction of doses to the public and discharges to the environment
- Establish basis for authorized limits on discharges and conditions of discharge to the environment
- Establish basis for the monitoring program design



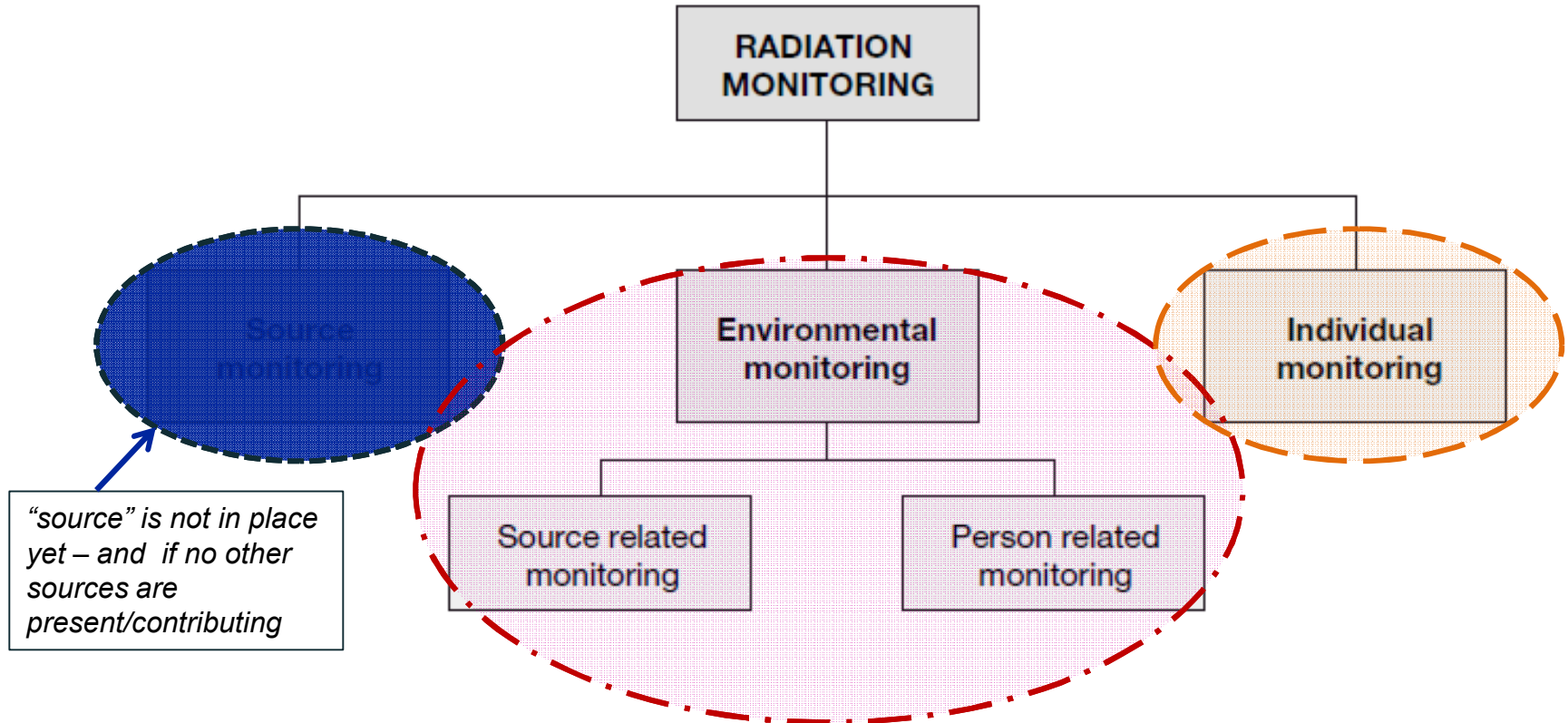
Baseline (pre-operational) Measurements - Should Determine



- The expected activity inventory and radiation characteristics of the source;
- The types and activities of radionuclides that will be discharged, their physical and chemical forms, the methods and routes of discharge and the rates of discharge;
- The mechanisms for the transfer of radionuclides through environmental media, including dispersion and reconcentration mechanisms, and their seasonal variation;



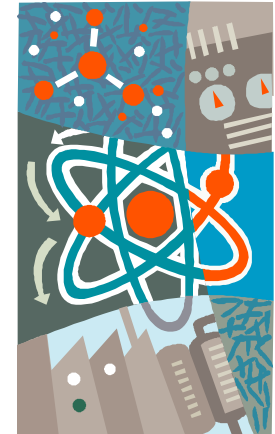
Baseline (pre-operational) Measurements – Elements of Monitoring Program



Baseline (pre-operational) Measurements - Should Determine



- The natural and artificial features of the environment that will affect this transfer (e.g. geological, hydrological and meteorological conditions, vegetation or the presence of reservoirs or harbors);
- The ecological characteristics of the water body planned to receive liquid discharges (e.g. its fauna and flora, annual variability, state of eutrophication and expected changes in ecosystems);
- The utilization of the environment for agriculture, the supply of water and food, industry, habitation and recreation;



Eutrophication: The process by which a body of water becomes enriched in dissolved nutrients (as phosphates) that stimulate the growth of aquatic plant life - usually resulting in the depletion of dissolved oxygen.

Baseline (pre-operational) Measurements - Should Determine



- The density of population, its distribution according to age and to dietary, occupational, domestic and recreational habits;
- Possible critical groups;
- Existing levels of radionuclides in the environment and their variability;
- The existence of any physical or chemical pollutants that may affect the transfer of radionuclides.

Normal Operational Measurement Source Monitoring - Purpose



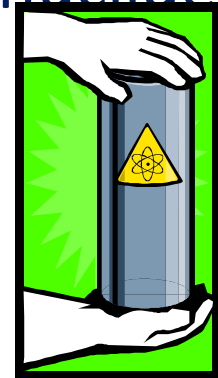
Note: Discharges to the environment may be in the form of gases, aerosols or liquids

- To verify compliance with the authorized limits on discharges for airborne and liquid discharges;
- To provide information necessary for checking whether systems for effluent treatment and control are performing properly;
- To provide early warning of any deviations from normal authorized operation;

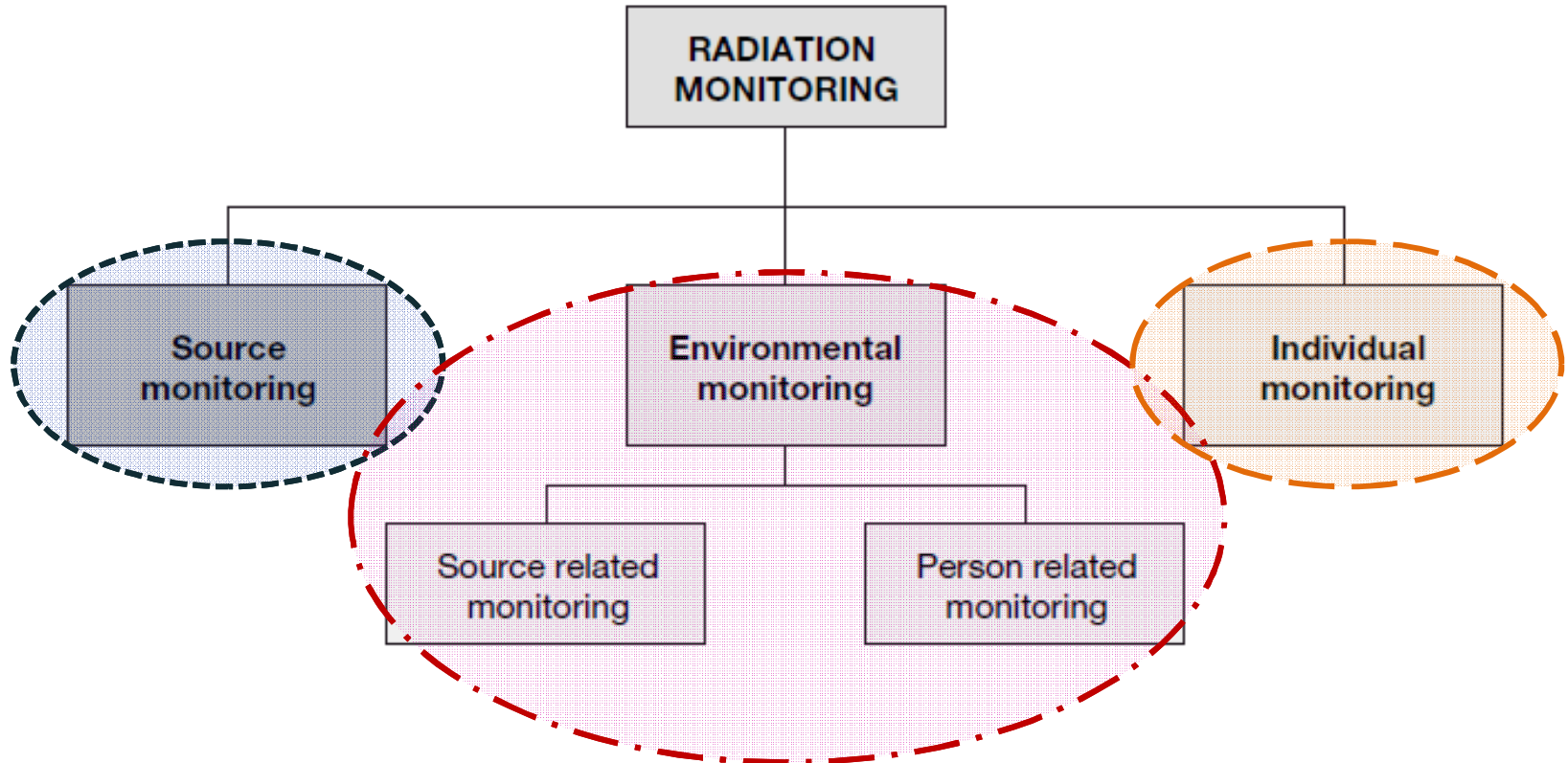
Normal Operational Measurement Source Monitoring - Purpose



- To provide data on the discharge of radionuclides to the environment, as a basis for the estimation by predictive modeling of environmental radiation levels and activity concentrations and exposure of the public (e.g. rates of discharge and radionuclide compositions).



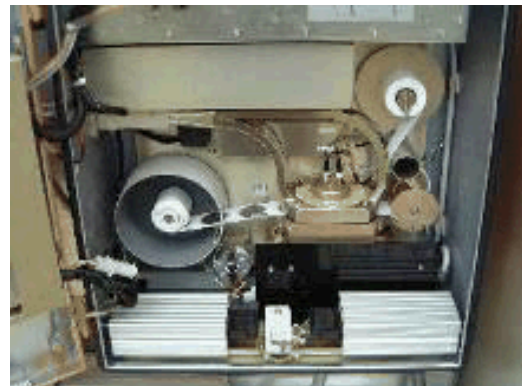
Normal Operation – Elements of Monitoring Program



Normal Operational Measurement Source Monitoring - Design



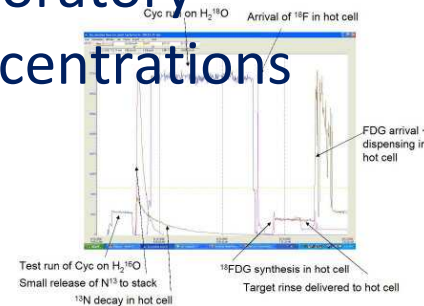
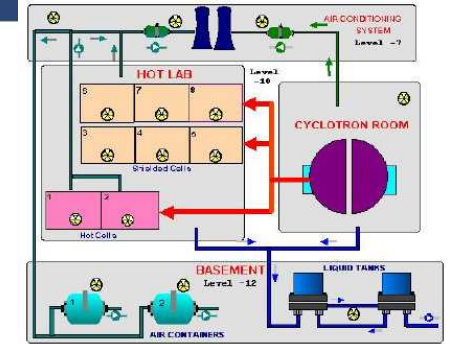
- Should be such as to enable the verification of compliance with the authorized limits on discharges and the criteria for discharges specified by the regulatory body
- Measurements should normally be carried out before dilution occurs or at the point of discharge (e.g. at the stack for atmospheric discharges or the discharge pipeline for a liquid discharge).



Normal Operational Measurement Source Monitoring – Measurement Types



- For both airborne and liquid effluents three types of measurement are possible:
 - On-line monitoring of discharges;
 - Continuous sampling and laboratory measurements of activity concentrations in the sample;
 - Intermittent sampling and laboratory measurements of activity concentrations in the sample



Normal Operational Measurement Source Monitoring – Choice of Sampling



Will depend on:

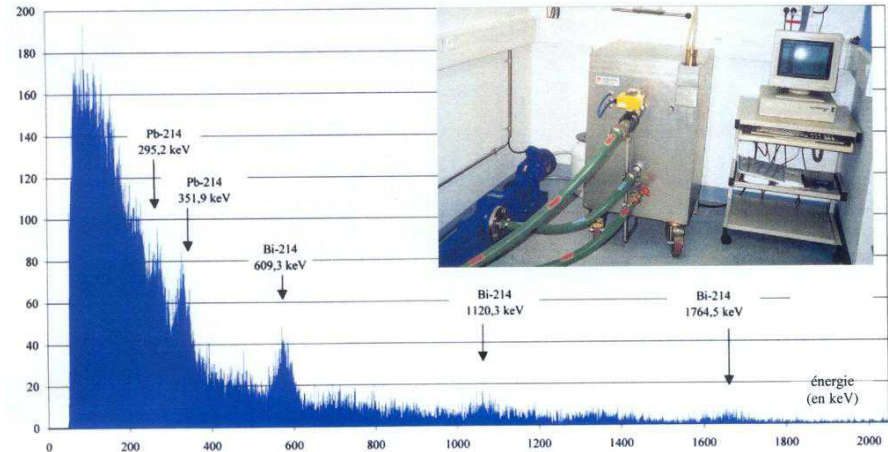
- The characteristics and amounts of discharged radionuclides and the sensitivity of the measurement system;
- The expected variation with time, if any, in the discharge rates of the radionuclides;
- The likelihood of unplanned discharges requiring prompt detection and notification.



Normal Operational Measurement Source Monitoring – Other Considerations



- Accurate determination of the volume of material discharged as a function of time;
- Relevant meteorological and hydrological dispersion data will also be needed



- Other parameters that might be helpful for evaluating the impact of the discharge:
 - The physical and chemical form and solubility of the radionuclide(s) discharged;
 - The particle size distribution in the case of airborne discharges;
 - The pH in the case of water based liquid discharges.

Normal Operational Measurement Source Monitoring – Other Considerations



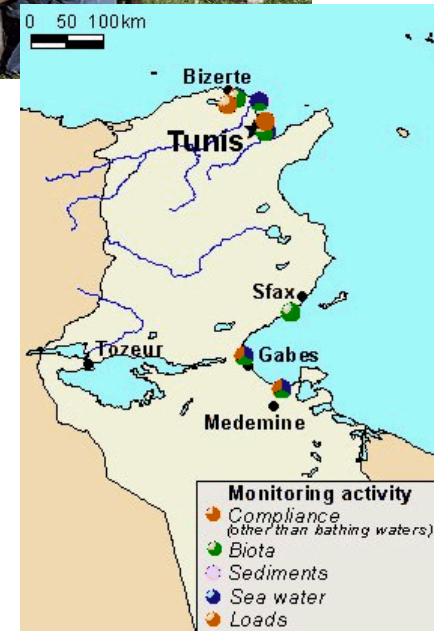
- There should be good coordination between the source monitoring and the environmental monitoring programs.
- In the case of normal discharges, the activity concentrations detected in environmental monitoring are usually very low, and consequently in most cases the dose calculations are based on source monitoring data and appropriate modeling.



Normal Operational Measurement Environmental Monitoring - Design



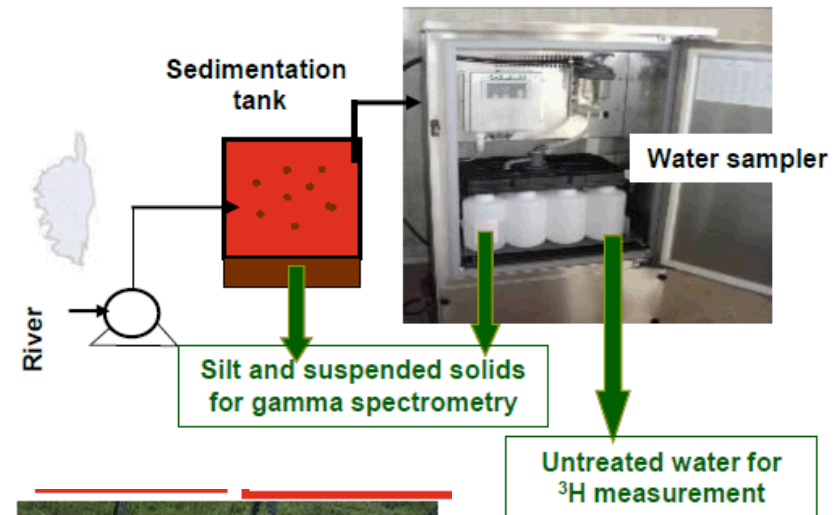
- The design should be consistent with the objectives of monitoring;
- The need for and the scale of the program will be determined primarily by the significance of the expected doses to the critical group;
- Measurements should be made and sampling carried out at appropriate locations accessible to the public outside the operations boundary of the facility;



Normal Operational Measurement Environmental Monitoring - Design



- Measurements should include measurements of external radiation levels and of radionuclide concentrations in all relevant environmental samples, food products and drinking water;
- The locations for measurements and sampling should be determined on a site specific basis with the aim of determining the highest radiation doses to the public and identifying the areas most contaminated with radionuclides.



Normal Operational Measurement Environmental Monitoring – Results



- Should enable the verification of the predictions made on the basis of the results of source monitoring and the assessment of doses to the public. So,
- Samples should be taken and measurements should be made at a number of locations selected on the basis of the dispersion pattern of the discharges.
- Additionally, the most relevant sampling procedure should be determined on the basis of knowledge of the habits and consumption patterns of the critical group of the population.



Normal Operational Measurement Environmental Monitoring – Results



- Consideration should be given to the measurement of activity concentrations in natural or artificially added ‘indicator’ organisms or materials such as seaweeds, lichen or suspended particulate matter which are not always direct parts of food chains.
 - Because of the concentration mechanism, radionuclides in indicator materials are usually more readily detectable than in foodstuffs, so the indicator organisms or materials provide a more sensitive indicator of environmental contamination





References



- IAEA Environmental and Source Monitoring for Purposes of Radiation Protection; Safety Guide No. RS-G-1.8
- FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).
- FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, OFFICE FOR THE CO-ORDINATION OF HUMANITARIAN AFFAIRS OF THE UNITED NATIONS, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GS-R-2, IAEA, Vienna (2002).



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- <http://www.epa.gov/rpdweb00/marssim/>
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SUPPLEMENTAL SLIDES



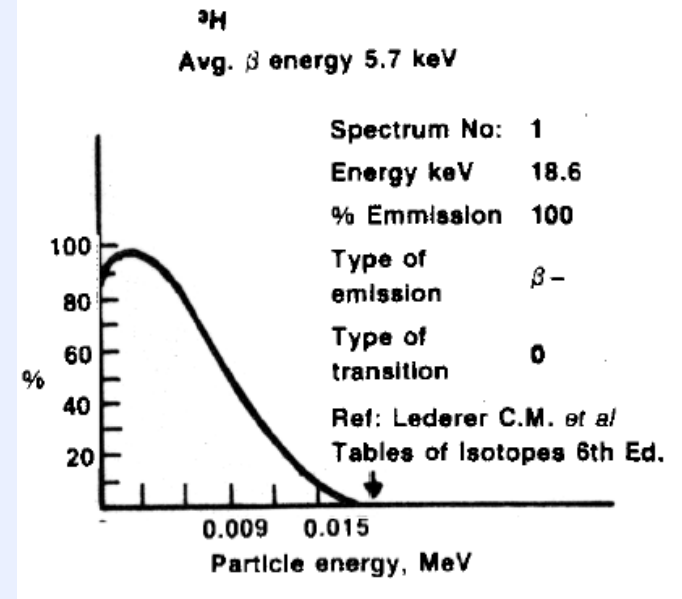
Part 1: Basic Principals -- Tritium

Sources of Tritium

- **Natural Sources:**
 - $^{14}\text{N}(n,t)^{12}\text{C}$ and $^{16}\text{O}(n,t)^{14}\text{N}$ in Atmosphere
 - Almost exclusively HTO
 - Ave Concentration in Env water:
 - 100 – 600 Bq/m³
- **Man-Made Sources:**
 - Nuclear Industry: $\sim 4 \times 10^4$ TBq/y
 - HWR: 3×10^2 – 2×10^3 TBq
 - **LWR: 30 TBq/y per Reactor**

Uses of Tritium

- **Luminising Industry: 10 – 100 TBq/y**
- **Research and Teaching: 1 – 100 GBq/y**



Reactor Accident Release Some Radionuclides of Concern (Supplemental slide - 1)



- H^3
- I^{131}
- Xe^{133}
- Co^{60}
- Sr^{90}
- Cs^{137}
- U^{235}
- U^{238}
- Pu^{239}

Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA General Safety Guide, No. GSG-2, 2011.

IAEA Safety Standards

for protecting people and the environment

Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency

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FAO, IAEA, ILO, PAHO, WHO



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General Safety Guide

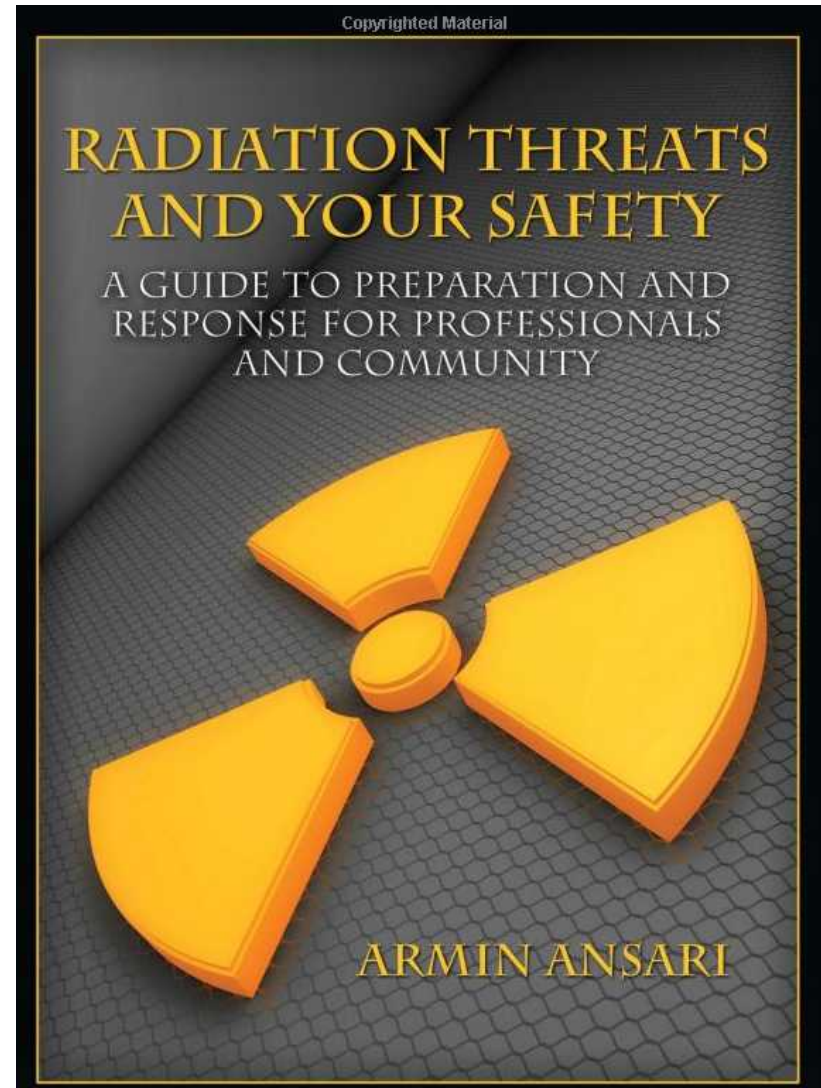
No. GSG-2



IAEA

International Atomic Energy Agency

[Radiation Threats and Your Safety: A Guide to Preparation and Response for Professionals and Community](#), 2010, \$75.



[Actions for Survival: Saving Lives in the Immediate Hours after Release of Radioactive or Other Toxic Agents.](#) by Allen Brodsky

