Radiological Primer
Understanding Radiological Terms

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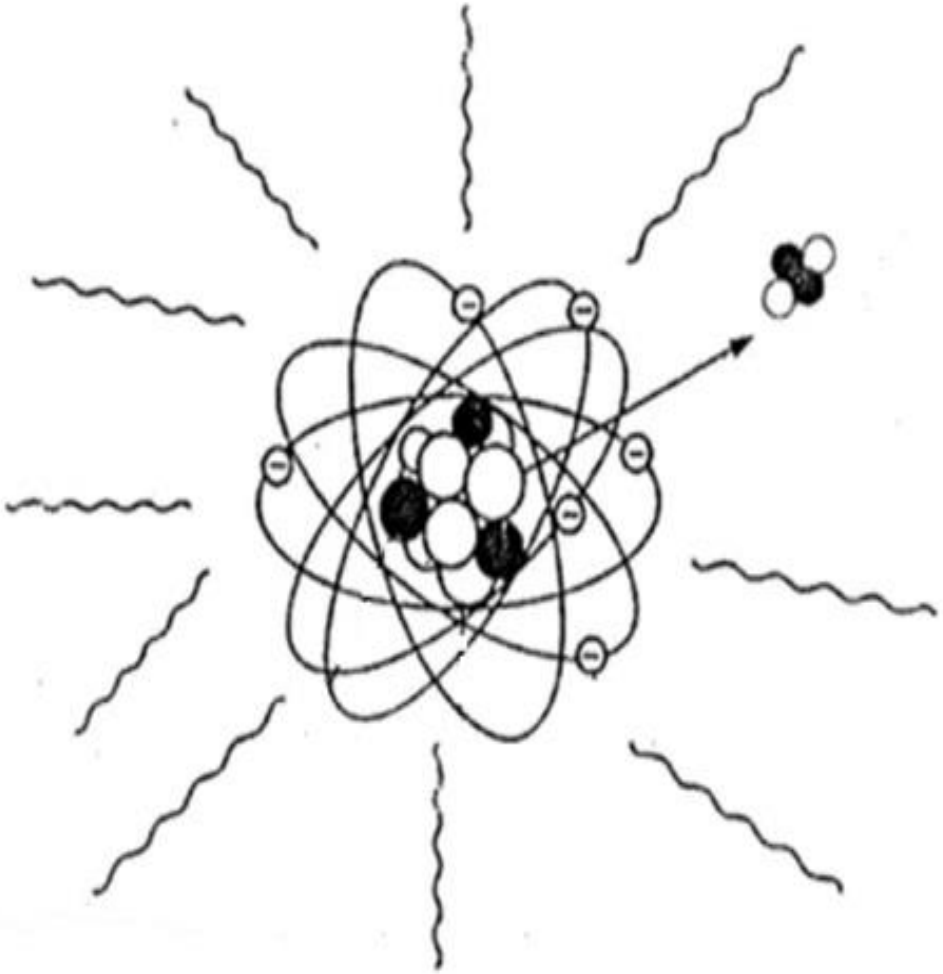
Radioactivity vs. Radiation

- What is radioactivity?
  - Property exhibited by certain types of matter of emitting radiation spontaneously.
- What is radiation?
  - Process by which energy is emitted from a source
- Forms of **ionizing** radiation
  - Gamma (photons) (Typical for Cesium (Cs))
  - Beta (electrons) (Typical for Cesium and Strontium (Sr)
  - Alpha (helium nucleus) (Typical for transuranics)
  - Neutron (neutrons)
  - *Cosmic rays*



Radiation Facts of Life

- Radiation is present everywhere
- We are all exposed to radiation at varying levels
- Radiation protection standards are set to minimize exposure
- Extensive research on the health effects of radiation has been conducted

Radiation – Units

- Radiation energy deposited per unit mass–
  - 100 rad = 1 Gray (Gy)
- Units reflecting radiation effect on humans
  - 100 rem = 1 Sievert (Sv)
  - 100 mrem = 1 mSv
  - 1 mrem = 1/1000 rem = 10 μSv
- Personal exposure is cumulative
  - Background radiation* = 310 mrem/year (3.1 mSv/yr)
  - Medical and Occupational* + 300 mrem/year (3 mSv/yr)

* Source NRC

Orders of Magnitude

mega (M) = 10^{6} = 1,000,000

unity = 10^{0} = 1

milli (m) = 10^{-3} = 0.001

micro (μ) = 10^{-6} = 0.000001

pico (p) = 10^{-12} = 0.000000000001

Radiation – Sources

- Personal Annual dose variants:
  - Terrestrial (5 – 100 mrem)
  - Cosmic (Altitude) (30 – 90 mrem)
  - Radon (150 – 1,800+ mrem)
  - Food/Drink (40 – 100 mrem)
  - ✚Air Travel (5 – 50+ mrem)
  - ✚Medical (1 – 5,000+ mrem)
  - ✚Smoking (1,000 – ? mrem)

Radiation Limits
As Low As Reasonably Achievable (ALARA)

- Occupational limit – 5,000 mrem/year
- DOE Administrative On-site Limits = ALARA
  - General public/non-rad worker = 100 mrem/year*
  - Rad Worker = 500 mrem/year (above background)
  - Embryo/fetus = 500 mrem/gestation
  - Derived Concentration Standard (DCS) Water/ Air = 100 mrem/year (1 mSv/year)

* Limited to ¼ (25 mrem) from single source

Radiation Limits
As Low As Reasonably Achievable (ALARA)

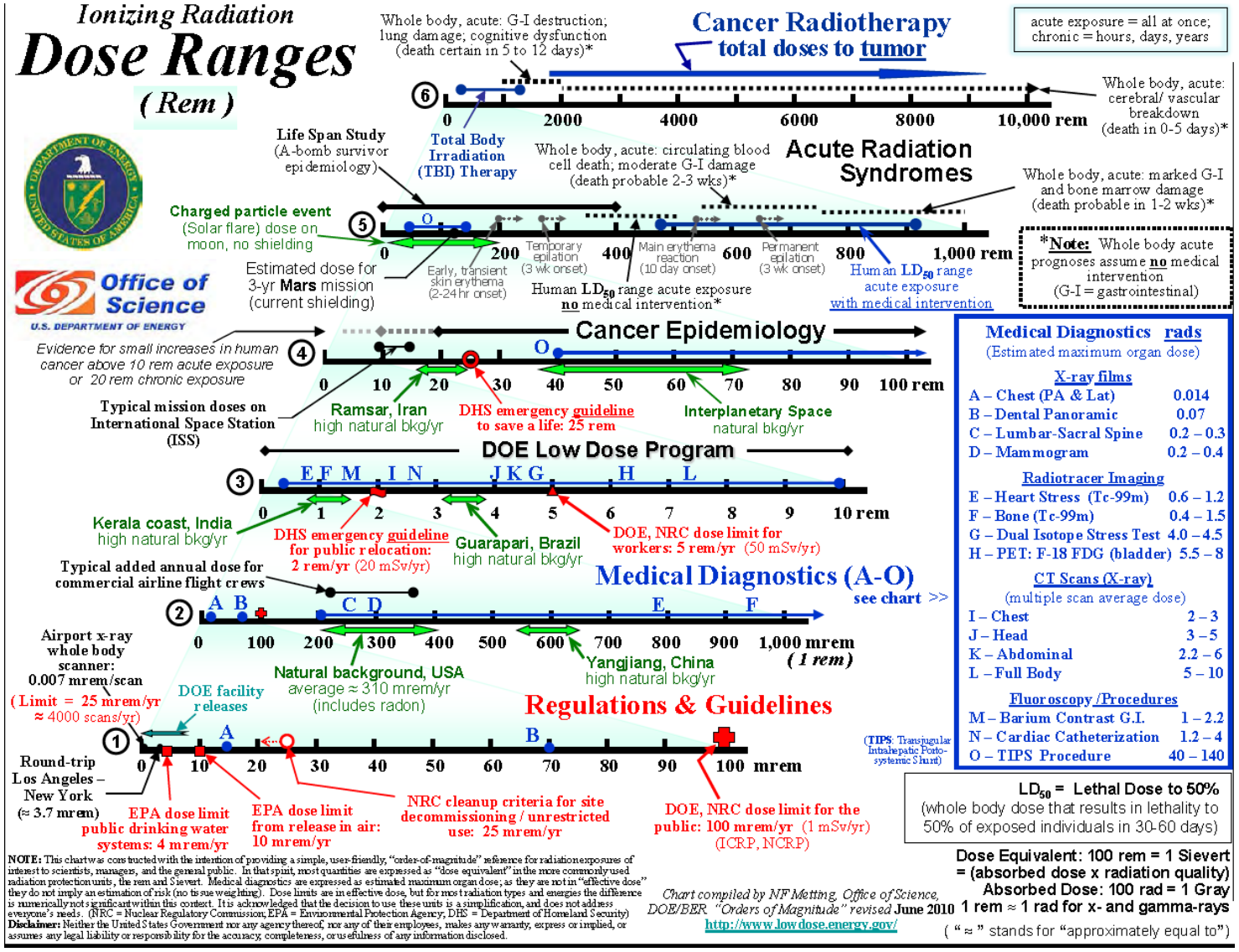
- Off-site limits
  - Washington State Clean Air Act Ambient Air Standard
  - = 10 mrem/year
  - Drinking Water up to 35 mrem/year
    - Beta - 4 mrem/year (eg. Sr/tritium)
    - Alpha – 15 pCi/L (~11 mrem/year*)
    - Radium – 5 pCi/L (~20 mrem/year*)

* Calculated based on DOE standard

EPA "Rad Net" Data Base Link for monitoring data

http://iaspub.epa.gov/enviro/erams_query_v2.simple_query

Dose Ranges



10,000 rem

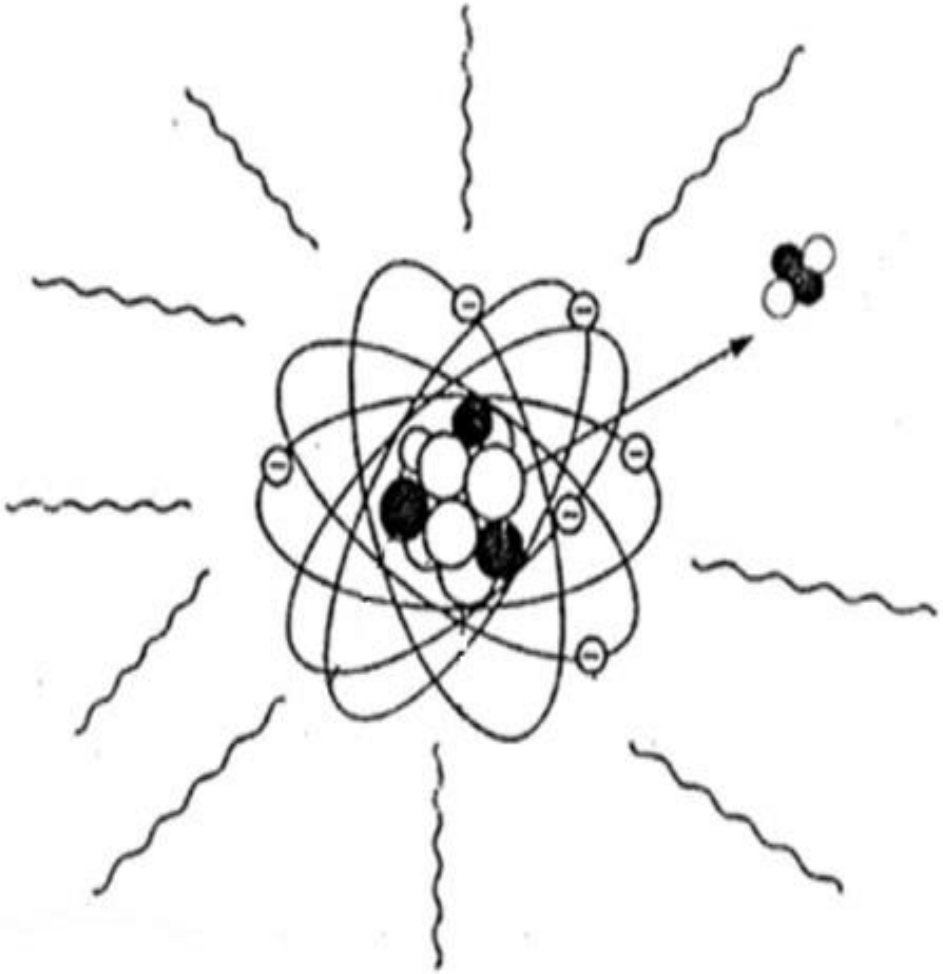
1,000 rem

100 rem

10 rem

1 rem

100 mrem



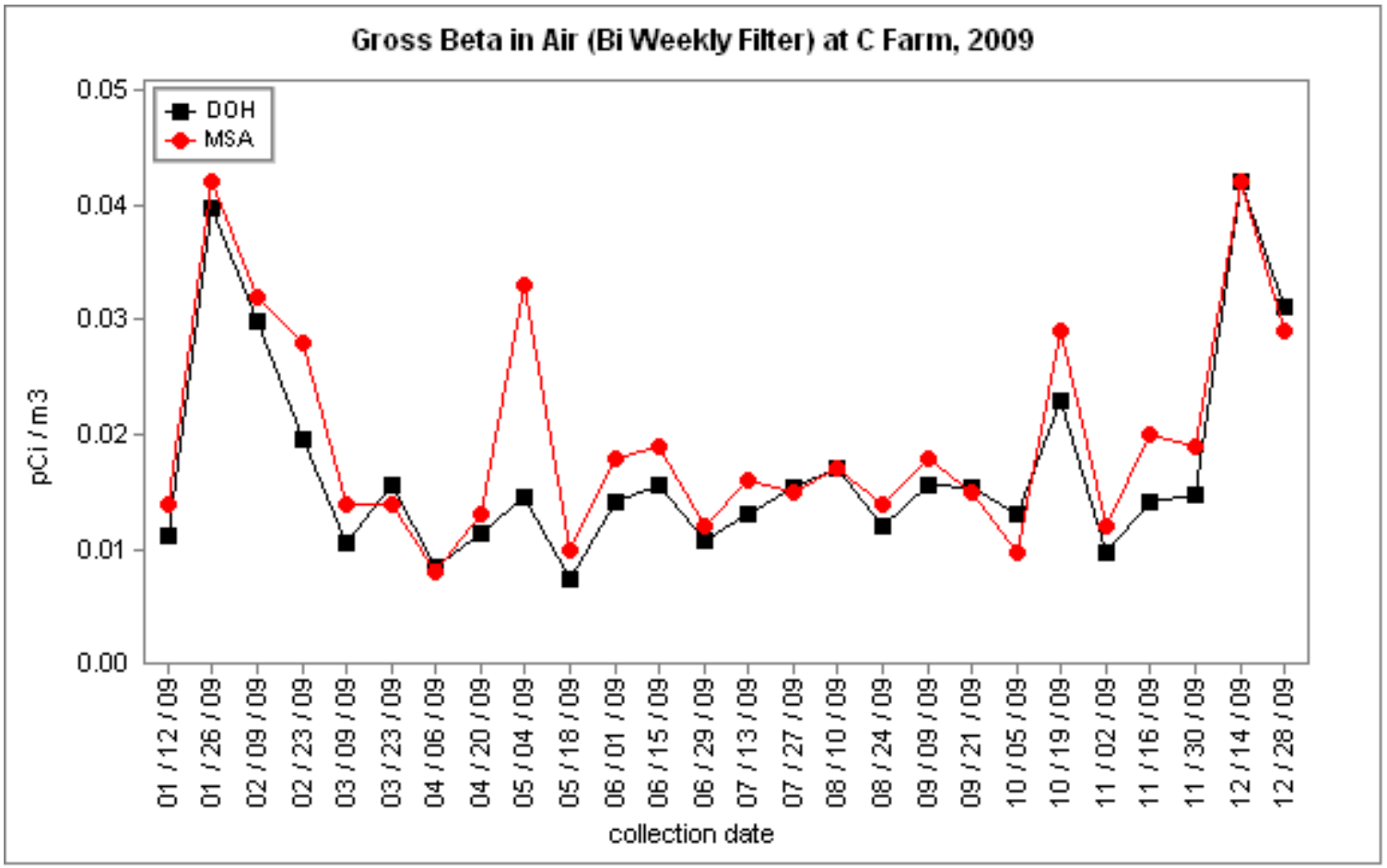
Radioactivity Measurement

- Becquerel (Bq) (SI Units)
  - 1 Bq = one decay (disintegration) per second
  - **1 Bq = 27 pCi =2.7 10^{-11} Ci**
- Curie (Ci)
  - 1 Ci = 3.7 × 10^{10} disintegrations per second (~# disintegrations per second in a gram of radium)
- Disintegrations per minute (dpm)
  - 60 dpm = 1 Bq
  - 1 dpm = ~ ½ pCi
- Counts per minute (cpm)
  - Detector measurement
  - Need to multiply by a factor to get dpm

Low Activity Radioactivity Measurement

- Airborne
  - Picocurie per cubic meter (pCi/m^3)
  - Microcurie/milliliter (μCi/ml)
  - DAC (Derived Air Concentrations)
- Solid
  - Microcurie/gram (μCi/g)
  - Picocurie per cubic meter (pCi/m^3)
- Water
  - Picocurie/liter (pCi/l)
- Surface contamination/swipe
  - Disintegrations per minute per 100 cm^2

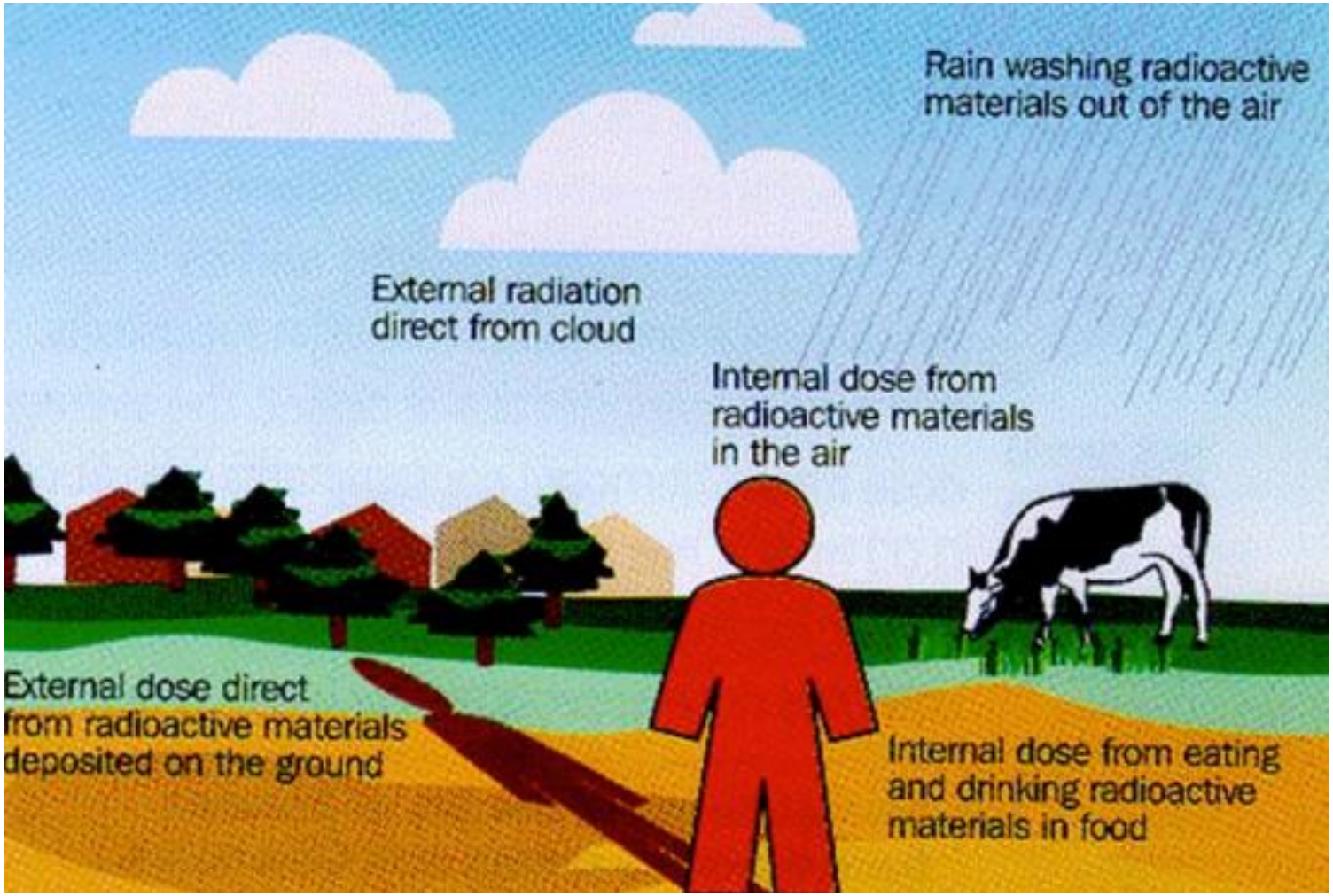
Air Measurements



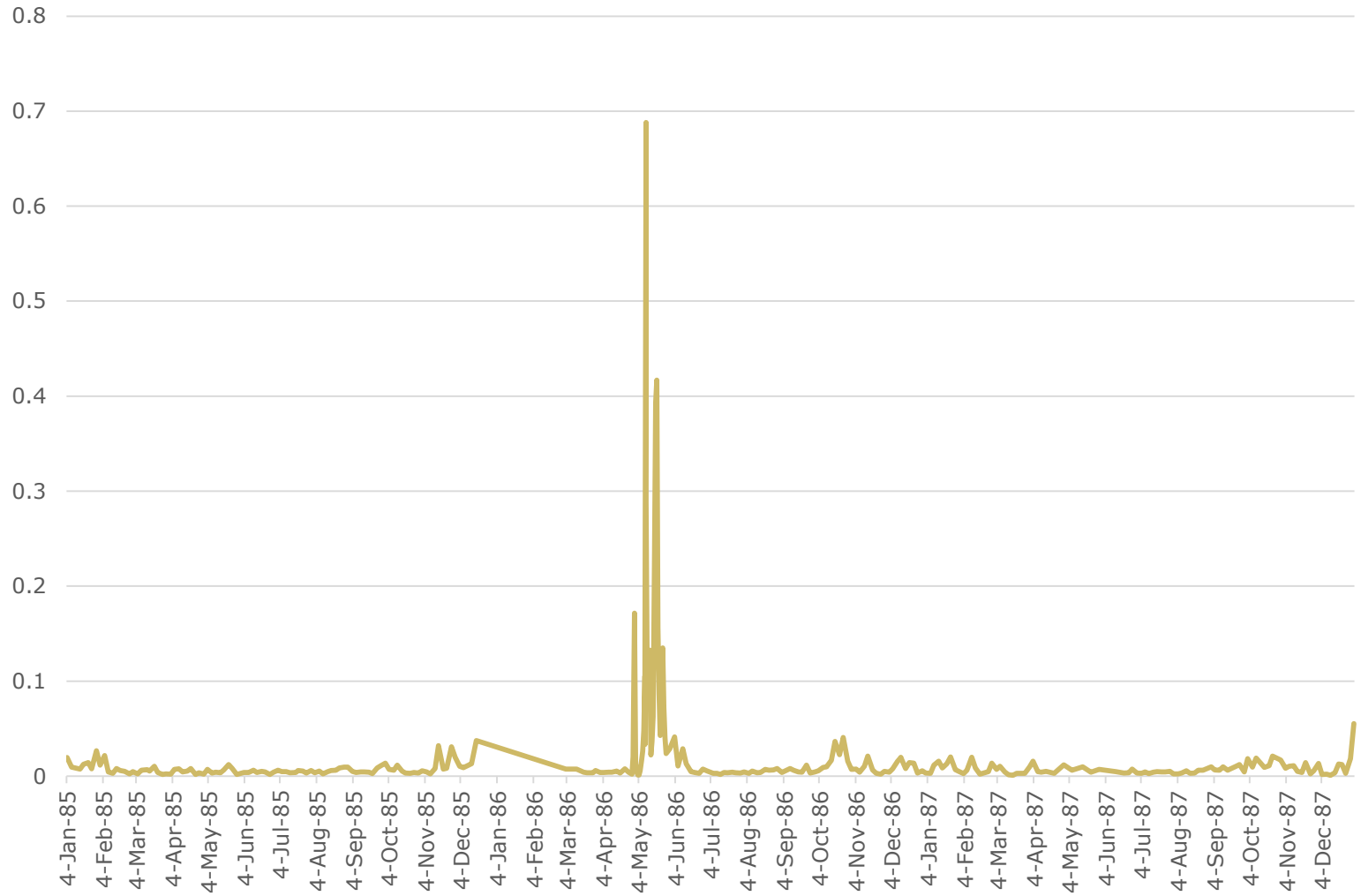
Radioactivity Area Control

- Buffer Area
  - Area used to access controlled areas.
- Radiation Areas (direct dose)
  - Direct radiation dose
- Contaminated Areas
  - Some loose radioactive material
- High Contamination Area
  - Extensive loose radioactive material
- Airborne Contamination Area
  - Potential for inhalation of radioactive material above limits

Releases/Fallout
Routes of Exposure



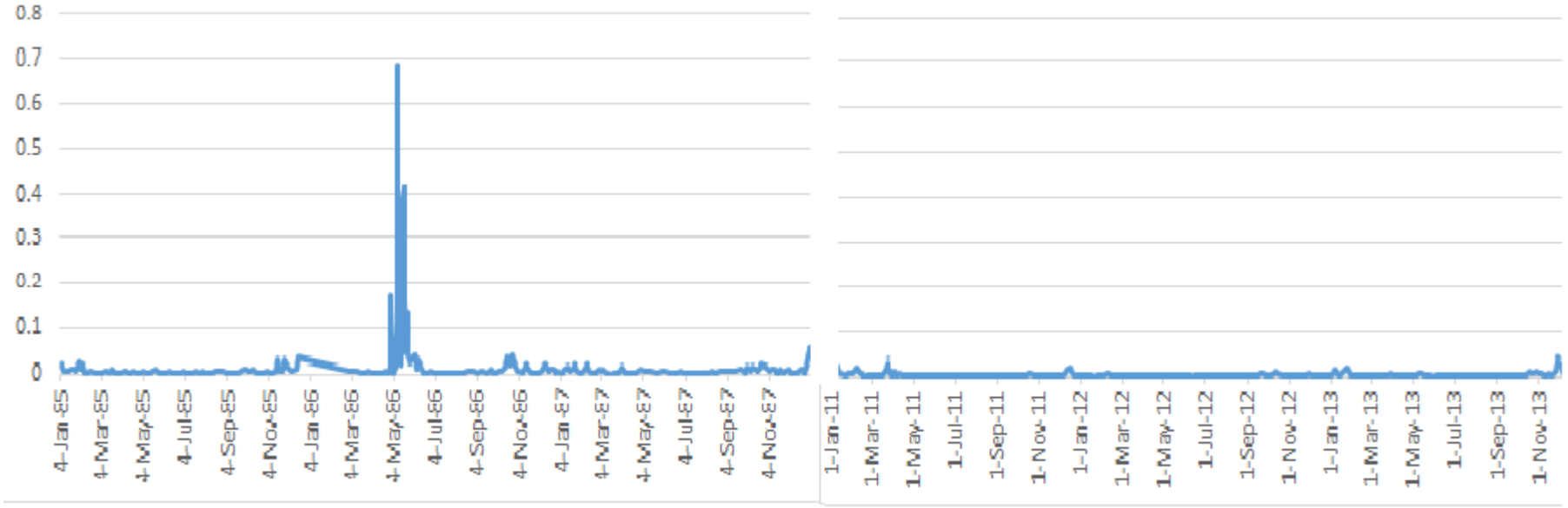
Portland Airborne Beta
1/1/85 to 12/30/87



Portland Airborne Beta

1/1/85 to 12/30/87
Chernobyl

1/1/11 to 12/30/13
Fukushima



Strontium-90 (^{90}Sr) and Iodine-131 (^{131}I)

- ^{90}Sr has a longer physical and biological half-life
- ^{90}Sr deposits and stays in the bone and lung
- ^{90}Sr has a large total dose to the bone or lung at a low dose-rate, causing an increase potential for leukemia as well as lung and bone cancer
- ^{131}I has a shorter physical and biological half-life
- ^{131}I concentrates in thyroid causing and increase potential for thyroid and other cancers

Cancer in US

Causes of Cancer

- Individual factors
  - Inherited mutations
  - Hormones
  - Immune conditions
  - Mutations that occur from metabolism
- Environmental factors
  - Tobacco
  - Infectious organisms
  - Chemicals
  - Radiation

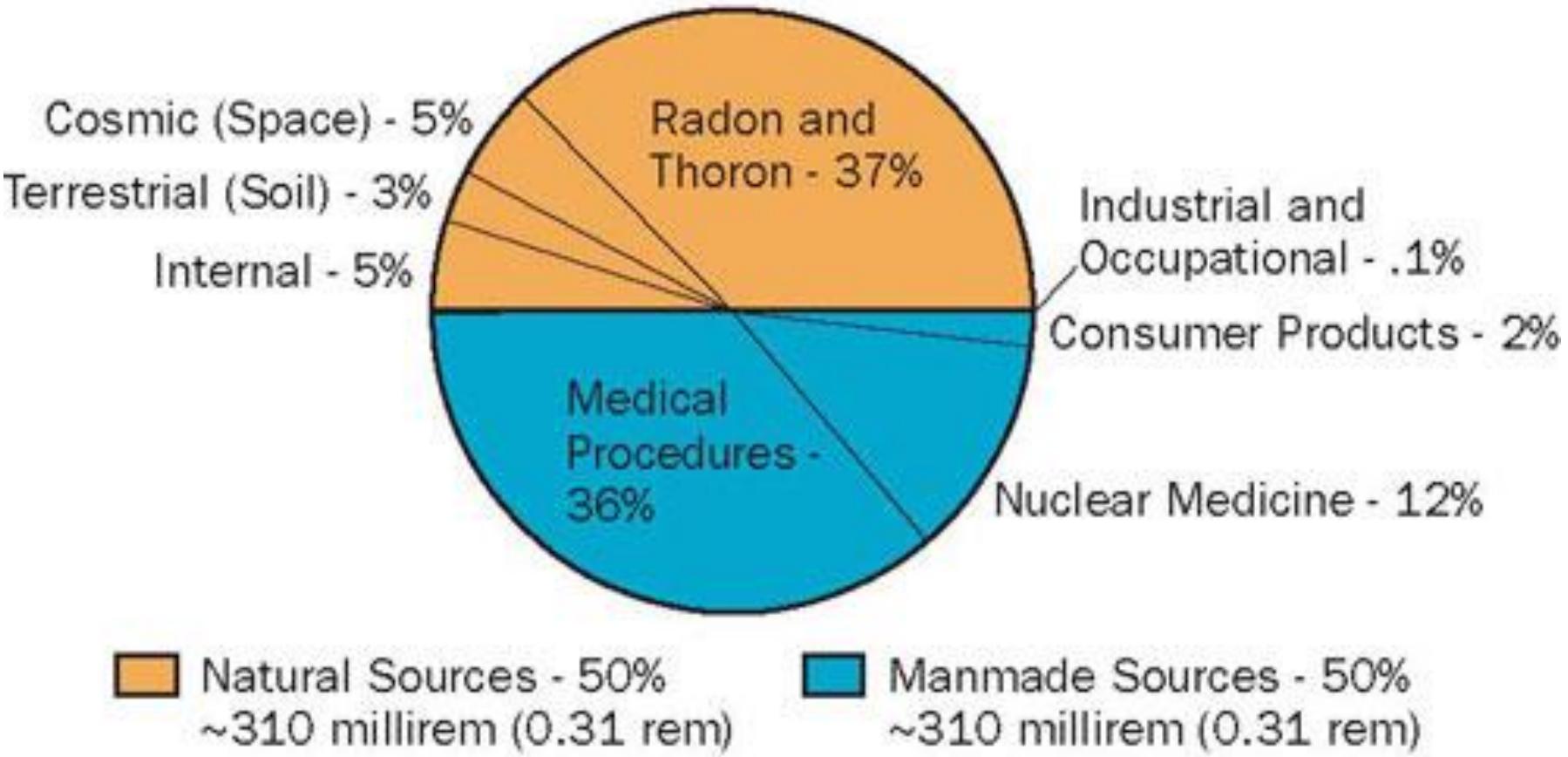
Lifetime Risk = Men 1 in 2 (43.9%)
= Women 1 in 3 (38%)
Cause of death – 1 in 4 (25%)

Source: American Cancer Society
www.cancer.org/acs/groups/content/@epidemiologysurveilance/documents/document/acspc-036845.pdf

Linear Dose Response

- A linear dose-response predicts that cancer risk is present at even extremely low doses
- Extensive research on biological effects of low dose radiation resulted in many new observations

Sources of Radiation Exposure in the United States



Source: NCRP Report No.160(2009)
Full report is available on the NCRP Web site at www.NCRPpublications.org.

Example of How Cancer Risks are Expressed by Medical Organization

Risk Level	**Approximate additional risk of fatal cancer for an adult from examination:**
Negligible:	less than 1 in 1,000,000
Minimal:	1 in 1,000,000 to 1 in 100,000
Very Low:	1 in 100,000 to 1 in 10,000
Low:	1 in 10,000 to 1 in 1000
Moderate:	1 in 1000 to 1 in 500
Note: These risk levels represent very small additions to the 1 in 5 chance we all have of dying from cancer.	

Source: www.radiologyinfo.org

Medical Radiation Exposures

- 200 million medical x-rays/year
  - X-ray (~0.1 Rad each)
- 100 million dental x-rays/year
  - Dental (~0.07 Rad)
- 10 million doses of radiopharmaceuticals/yr
- 75 million CT scans/year
  - Head scan 30-50 Rad/scan
  - Body scan 50-100 Rad/scan
- 8 million radiation cancer therapy/yr
  - 100-8000 Rad total/treatment

Soursce: DOE Dose Chart.

Increased Risk of Cancer in Adult Example

Increased cancer risk per 1 rem* = 0.055%

Population impact of 1 rem –

1 earlier death due to cancer in 1,800

Risk of Cancer Death = 25%

Procedure Dose – 1,000 mrem (10mSv)

= 0.055%

New Individual Risk = 25.055%

* Source = ICRP (International Commission on Radiation Safety

Differing Views on Radiation Risk

- There is no safe level of radionuclide exposure whether from food, water or other sources
- Elevated radiological exposure above average background is beneficial (e.g. Live in Denver)
- The risk associated with low radiation doses needs to be weighed against the benefit of the exposure but should always be maintained ALARA

Conclusion

- The cancer risk is proportional to the exposure
- Occupational limits are set at levels (< 5 rem/year) such that cancer risk is minimal when compared to other risk factors but ALARA principles and risk vs. benefit is applied
- Effect of total radiation exposures below 1 rem per year (1,000 mrem/year) are below a level where disease rate effects are masked by the relatively high overall rate of cancer
- Lifetime risk for cancer remains relatively high regardless of added radiation exposure. Lifestyle plays a critical roll in cancer risk