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) = $10^{-12} = 0.0000000000001$
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
Radioactivity Measurement

- **Becquerel (Bq) (SI Units)**
  - 1 Bq = one decay (disintegration) per second
  - 1 Bq = 27 pCi = \(2.7 \times 10^{-11}\) Ci

- **Curie (Ci)**
  - 1 Ci = \(3.7 \times 10^{10}\) disintegrations per second (\(\sim\) # disintegrations per second in a gram of radium)

- **Disintegrations per minute (dpm)**
  - 60 dpm = 1 Bq
  - 1 dpm = \(\sim\) 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/m³)
  - Microcurie/milliliter (µCi/ml)
  - DAC (Derived Air Concentrations)

- **Solid**
  - Microcurie/gram (µCi/g)
  - Picocurie per cubic meter (pCi/m³)

- **Water**
  - Picocurie/liter (pCi/l)

- **Surface contamination/swipe**
  - Disintegrations per minute per 100 cm²
Air Measurements

Gross Beta in Air (Bi Weekly Filter) at C Farm, 2009

- DOH
- MSA
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

- Rain washing radioactive materials out of the air
- External radiation direct from cloud
- Internal dose from radioactive materials in the air
- External dose direct from radioactive materials deposited on the ground
- Internal dose from eating and drinking radioactive materials in food
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
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

- Radon and Thoron - 37%
- Medical Procedures - 36%
- Nuclear Medicine - 12%
- Consumer Products - 2%
- Industrial and Occupational - .1%
- Internal - 5%
- Terrestrial (Soil) - 3%
- Cosmic (Space) - 5%

Natural Sources - 50%
~310 millirem (0.31 rem)

Manmade Sources - 50%
~310 millirem (0.31 rem)

Full report is available on the NCRP Web site at www.NCRPpublications.org.
Example of How Cancer Risks are Expressed by Medical Organization

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Approximate additional risk of fatal cancer for an adult from examination:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible:</td>
<td>less than 1 in 1,000,000</td>
</tr>
<tr>
<td>Minimal:</td>
<td>1 in 1,000,000 to 1 in 100,000</td>
</tr>
<tr>
<td>Very Low:</td>
<td>1 in 100,000 to 1 in 10,000</td>
</tr>
<tr>
<td>Low:</td>
<td>1 in 10,000 to 1 in 1000</td>
</tr>
<tr>
<td>Moderate:</td>
<td>1 in 1000 to 1 in 500</td>
</tr>
</tbody>
</table>

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

Source: 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.