Module 3
Biological Effects of Ionizing Radiation
TOPICS

• Exposure Limits,
• Biological Effects.
Exposure Limits
Regulatory Limits

• Occupational Dose Limits:
  • Adult – 5 rem a year,
  • Minor – 0.5 rem a year,
  • Embryo/Fetus – 0.5 rem for entire gestational period,
  • Eye – 15 rem a year,
  • Extremities – 50 rem.

• Public Dose Limits:
  • General Public – 0.1 rem a year.
LSU Radiation Protection Exposure Limits

• Each wear period (typically 3 months), the RSO will closely monitor exposure levels of each user and notify the user if their:
  • Whole body or collar badge has a reading of 200 mrem or more,
  • Extremity badge (ring) has a reading of 1,000 mrem or more.
Biological Effects
Terminology

• Acute Vs. Chronic Exposure,
• Direct Vs. Indirect Action,
• Prompt Vs. Delayed Effects,
• Stochastic Vs. Non-Stochastic Effects.
Acute Vs. Chronic Exposure
Acute Exposure

• Acute exposure is radiation exposure that occurs in a short period of time.

• It can be an exposure that occurs once in your lifetime or more than once such as dental X-rays or chest X-rays.

• Acute exposure can result in a small or large radiation exposure.
Chronic Exposure

- Chronic exposure is radiation exposure that occurs over a long period of time.
- It can be continuous exposure such as radiation exposure that occurs daily from natural background radiation.
- It can be off and on routinely over a long period of time in your life such as occupational exposure.
- Chronic exposure can result in small or large radiation doses.
Direct Vs. Indirect Action
Direct Action

- Direct actions are caused by radiation that interacts directly with atoms of DNA molecules or some other cellular components critical to the cell’s survival.

- The probability of the radiation interacting with the DNA molecule is very small since these critical components make up such a small part of the cell.
Chain of Events for Direct Action:

1. Incident particle or photon on a DNA molecule,
2. Excitation or Ionization of an atom of the DNA molecule,
3. Dissociation of a molecule of DNA due to the excitation or ionization on one of the atoms,
4. Possible biological effects depending on the molecule dissociated.
Indirect Action

• Indirect actions are caused by the interaction of radiation with molecules of water.
• Each cell, just as is the case for the human body, is mostly water.
• Ionizing radiation may break the bonds that hold the water molecules together, producing radicals such as hydroxyls OH, superoxide anions $O_2^-$ and others.
• These radicals can contribute to the destruction of the cell.
Chain of Events for Indirect Action:

1. Incident particle or photon on a molecule of water,
2. Ionization of a molecule of water,
3. Dissociation of a molecule of water,
4. Free radicals are produced,
5. Free radicals interact with DNA molecules,
6. Possible biological effects.

Examples include:

- $\text{H}_2\text{O} \rightarrow \text{H}_2\text{O}^+ + \text{e}^-$ Radiation ionizes water molecule.
- $\text{OH} + \text{OH} \rightarrow \text{H}_2\text{O}_2$ Hydrogen peroxide interacts with DNA.
Prompt Vs. Delayed Effects
Prompt Effects

• Effects, including radiation sickness and radiation burns, seen immediately after large doses of radiation delivered over short periods of time.

• High doses delivered to the whole body of healthy individuals within short periods of time can produce effects such as blood component changes, fatigue, diarrhea, nausea and death.

• These effects will develop within hours, days or weeks, depending on the amount of dose.
# Thresholds for Prompt Effects

<table>
<thead>
<tr>
<th>Effect</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Count Changes</td>
<td>50 rem</td>
</tr>
<tr>
<td>Vomiting (threshold)</td>
<td>100 rem</td>
</tr>
<tr>
<td>Mortality (threshold)</td>
<td>150 rem</td>
</tr>
<tr>
<td>LD 50/60 (with minimal supportive care)</td>
<td>320-360 rem</td>
</tr>
<tr>
<td>LD 50/60 (with supportive medical treatment)</td>
<td>480-540</td>
</tr>
<tr>
<td>100 % mortality (with best available treatment)</td>
<td>800 rem</td>
</tr>
</tbody>
</table>
Delayed Effects

- Effects such as cataract formation and cancer induction that may appear months or years after a radiation exposure.
- Depending upon the effect, they can be produced by acute or chronic exposures.
- One type of delayed effect is considered possible even with the smallest of exposures. The other types only occur if the dose exceeded a threshold value.
Stochastic Vs. Non-Stochastic Effects
Stochastic (Random) Effects

• Occur by chance,
• Occur in both exposed and unexposed individuals,
• Are not unequivocally related to radiation exposure,
• Become more likely as dose increases,
• Severity is independent of the dose.
Linear No Threshold Model

- Assumes that any amount of radiation has a detrimental effect,
- Is not a predictive model,
- Is used to establish regulatory dose limits (NRC).
Examples of Stochastic Effects

- Cancer,
- Mental Retardation,
- Genetic Effects.
Cancer

- Radiation induced tumors are most frequent in the hemopoietic system, thyroid, and skin.
- Cancer induction is well documented at doses of 100 rad or more.
- Induction at lower doses is inconclusive (possible exceptions are leukemia and thyroid cancer).
- Tumor induction has a latent time of 5-20 years.
Cancer (Cont.)

• Radiation induced leukemia in atomic bomb survivors has been documented at doses above 40 rad.

• Bone Cancer induction has been documented in laboratory animals for large injection of “bone seeking” radionuclide.

• Radiation induced lung cancer is seen mainly in underground miners exposed to high Radon concentrations.
Mental Retardation

• Most pronounced in those exposed between the 8th and 17th week of pregnancy.
  • Brain cells divide rapidly during this period.
• Has been observed in children exposed in-utero to radiation from the atomic bombs in Japan.
Genetic Effects

• No radiation induced genetic effects have been observed in humans.
• Genetic effects have been observed in animal studies.
Non-Stochastic (Deterministic) Effects

- A certain minimum dose must be exceeded before the effect occurs.
- The severity of the effect increases as dose increase.
- There is a clear relationship between exposure and occurrence.
Nonlinear Threshold Response

• No response is seen until the threshold dose is exceeded,
• At some dose, all individuals experience the effect,
• Applies to non-stochastic effects.
Examples of Non-Stochastic Effects

• Sterility,
• Cataracts,
• Skin Erythema,
• Hemopoietic Syndrome,
• Gastrointestinal (GI) Syndrome,
• Central Nervous System Syndrome.
Sterility

• Temporary sterility had been observed:
  • In men at doses as low as 30 rads,
  • In women at doses as low as 300 rads.
• The higher the dose the longer the period of sterility.
Cataracts

• Cataracts:
  • Threshold eye dose of about 200 rads of beta or gamma radiation,
  • Threshold may be as low as 60 rads for neutron radiation,
  • Long latent period.
Erythema & Other Skin Effects

• Reddening of the skin (erythema) occurs at photon or beta doses of about 300 rads.

• Higher dose may cause epilation, blistering, necrosis, and ulceration.
Hemopoietic Syndrome

• Blood changes may be seen at doses as low as 14 rads.
• Blood changes are almost certain at doses above 50 rads.
• Hemopoietic Syndrome appears at about 200 rads.
  • Characterized by depression or ablation of the bone marrow,
  • May be accompanied by nausea, vomiting, fatigue, and increased temperature,
  • Death occurs within 1-2 months unless medical treatment is successful.
Gastrointestinal Syndrome

- Occurs at a whole-body dose of 1,000 rads or greater.
- Characterized by the destruction of the intestinal epithelium and complete destruction of the bone marrow.
- Accompanied by severe nausea, vomiting, and diarrhea soon after exposure.
- Death occurs within a few weeks.
Central Nervous System Syndrome

• Occurs at whole-body doses of 2,000 rads or more.
• Damages the central nervous system as well as all other organs and systems.
• Unconsciousness occurs within minutes.
• Death follows in a matter of a few hours to a few days.
Summary

• Biological effects of concern, in the occupational setting, do not appear for several years after radiation exposure, if affects appear at all.

• The probability of these effects increases with dose.

• In any individual case, it can never be determined with 100% confidence that radiation exposure was the cause.