LSU | Radiation Safety Office

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:

- $H_2O \rightarrow H_2O^+ + e^-$ Radiation ionizes water molecule.
- $OH + OH \rightarrow H_2O_2$ 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

Effect	Dose
Blood Count Changes	50 rem
Vomiting (threshold)	100 rem
Mortality (threshold)	150 rem
LD 50/60 (with minimal supportive care)	320-360 rem
LD 50/60 (with supportive medical treatment)	480-540
100 % mortality (with best available treatment)	800 rem

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 occurs if the dose exceeded a threshold value.

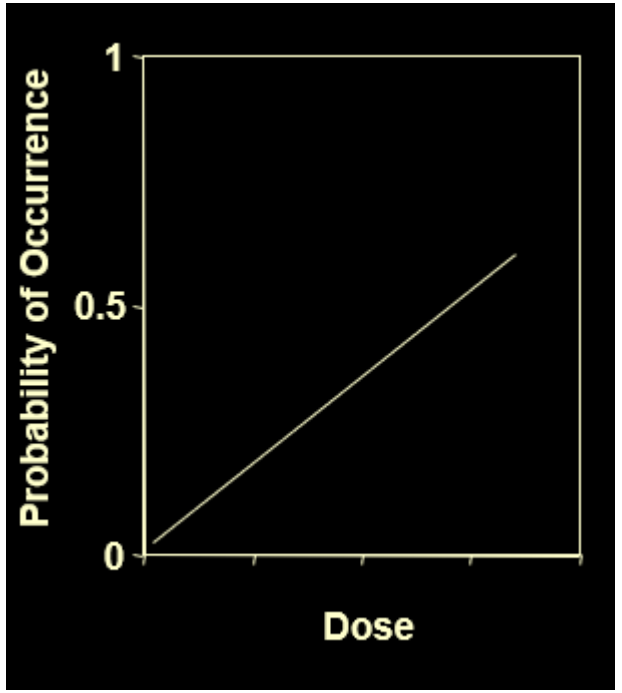
Stochastic Vs. Non-Stochastic Effects

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

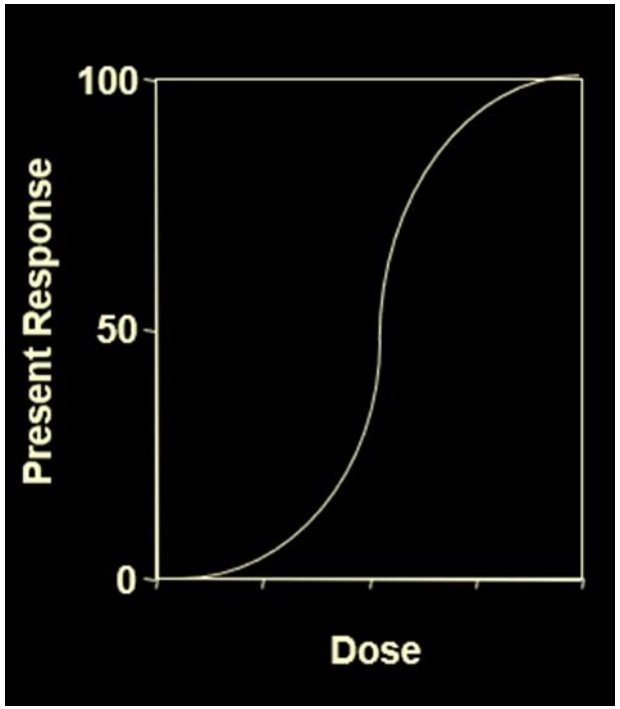
- No radiation induced genetic effects have been observed in humans.
- Genetic effects have been observed in animal studies.

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.