Health Effects of Exposure to Radiation

Followed by STEPs Dance
• Audio and video
  – Will be from the presenters only
  – Use computer or telephone (call in)
  – Computer seems to give the best sound quality
• Use the “Chat” feature to enter comments
• Use the “Questions” feature to ask questions
• Posted on webinar page
  – Video, Q&A answers, copy of the slides
• Follow up email will be sent
  – Topics covered, time of attendance
• It may be possible to change your Zoom view if the controls are hiding the closed captioning.
Outline

• What is Radiation?
• Ionizing Radiation
• Health Effects of Ionizing Radiation
• Non-Ionizing Radiation
• Health Effects of Non-Ionizing Radiation
• How Is This Determined?
• Regulators
• For More Information
Matter and Energy

- **Matter**
  - Has mass
  - Takes up space
- **Energy**
  - The ability to create change
• Radiation
  – Transfer of energy in a straight line
    • Beams of particles
    • Waves
• Radiation will interact differently with matter depending upon
  – Type
  – How much energy it has.
• Atom made up of
  – Protons (+)
  – Neutrons (0) and
  – Electrons (-)

• Nucleus
  – Protons and neutrons
  – At the center
  – Electrons orbit the nucleus
Ionizing Radiation

• When radiation strikes matter, it interacts with the atoms of the matter.

• Radiation with enough energy can knock electrons out of orbit from the atoms it strikes.
Ionizing Radiation

Ionization: the process of creating ions.

Neutral Atom  Electron  Ion Pair
Sources of Ionizing Radiation

Where does ionizing radiation come from?

Radioactive atoms

Man-made devices
Types of Ionizing Radiation

- Alpha
- Beta
- Neutron
- Gamma/X-Ray

Ionizing Radiation
Radiation Dose

• The effects of radiation depend on the amount of energy the radiation transfers to your body.

• This transfer of energy results in a radiation dose.
Radiation dose is typically measured in Sievert (Sv)

Sieverts take into account how biologically damaging different types of radiation are

1 Sv is a very large dose. Typically we use the miliSievert (mSv). 1 Sv = 1000 mSv
• Your body is made up of atoms, like any other material object.
• When radiation strikes it, it can interact.
• Radiation interacts with non-living and living material in the same ways.
A cell contains giant molecules called chromosomes.

Chromosomes contain information required to create another cell identical to the original cell.

The units of information in the chromosome are called the genes.

Each gene is a segment of a complex molecule called DNA (deoxyribonucleic acid).
• Interaction of radiation with a cell depends upon the energy and intensity of radiation and exposure time.
• Radiation may ionize the DNA molecule of the cell.
• This may produce alterations in the biological properties of the cell.
• When radiation strikes living tissue, there are a number of possible outcomes:
  – No damage at all
  – Damage to cells that is repaired
  – Damage to cells that leads to cell death
  – Damage to cell chromosomes that is incorrectly repaired ("mutated").
Cell mutations caused by radiation could lead to:

- **Hereditary (genetic) effects**

- **Somatic effects**
• Hereditary or genetic effects are potential health effects future generations might experience as a result of our exposure to radiation.
• Radiation alters the DNA molecule in the egg cells of a female or in the sperm cells of a male.
  – This may cause abnormalities in descendants, such as leukemia and developmental delays.
• Hereditary effects have been demonstrated on laboratory animals.
• Hereditary effects have not been proven on human beings yet.
Somatic effects are experienced by the person exposed to radiation.

A radiation dose has a certain probability of causing a mutation in a cell, which might cause cells to divide in an uncontrolled manner.

Uncontrolled cell division could lead to cancer, which could be fatal.
Stochastic Somatic Effects

- Radiation exposure increases the likelihood of developing cancer.
- The greater the exposures the greater the likelihood.
- But we cannot be certain that an effect will or will not occur.
**Stochastic Somatic Effects**

- We know that smoking causes lung cancer.
  - But, Joe smoked sixty a day and lived to be 95!
- Some people develop lung cancer in their life regardless.
  - Only some of these people are smokers.
- Smoking increases the likelihood of developing lung cancer.
  - This is a stochastic effect.
The risk of developing a fatal cancer as a result of exposure to radiation is approximately 4% per 1000 mSv.

- Consider a person who worked for 50 years and received 20 mSv per year.
- This person’s total lifetime radiation dose is 1000 mSv.
- This person will have an extra 4% chance of developing a fatal cancer.
• Approximately 25% of people develop a fatal cancer in their life.
• So, this person’s risk of developing a fatal cancer becomes 29% instead of 25%.
• Other professions carry risks too.
## Risk of Death for Various Professions

<table>
<thead>
<tr>
<th>Profession</th>
<th>Risk of Death per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finance</td>
<td>1 in 60,000</td>
</tr>
<tr>
<td>Service</td>
<td>1 in 40,000</td>
</tr>
<tr>
<td>Trade</td>
<td>1 in 20,000</td>
</tr>
<tr>
<td>2 mSv of radiation per year</td>
<td>1 in 12,000</td>
</tr>
<tr>
<td>Government (includes police and fire)</td>
<td>1 in 11,000</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1 in 11,000</td>
</tr>
<tr>
<td>Transportation</td>
<td>1 in 4,000</td>
</tr>
<tr>
<td>Construction</td>
<td>1 in 3,000</td>
</tr>
<tr>
<td>20 mSv of radiation per year</td>
<td>1 in 1,200</td>
</tr>
<tr>
<td>Mining</td>
<td>1 in 1,100</td>
</tr>
<tr>
<td>Forestry</td>
<td>1 in 900</td>
</tr>
<tr>
<td>Fishing and Hunting</td>
<td>1 in 500</td>
</tr>
</tbody>
</table>

Occupational Exposures to Ionizing Radiation

The mean dose of ionizing radiation received by Canadian workers has been decreasing for the past 5 years and is at its lowest level since the first report was published in 1978.

Risk of Death From Accidents

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Risk of Death per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents on the road</td>
<td>1 in 5,000</td>
</tr>
<tr>
<td>Accidents at home</td>
<td>1 in 11,000</td>
</tr>
<tr>
<td>Accidents at work</td>
<td>1 in 24,000</td>
</tr>
<tr>
<td>1 mSv per year (annual dose limit for members of the general public)</td>
<td>1 in 20,000</td>
</tr>
<tr>
<td>0.05 mSv per year (maximum emission from nuclear facilities in Canada)</td>
<td>1 in 400,000</td>
</tr>
<tr>
<td>0.001 mSv per year (average emission from nuclear facilities in Canada)</td>
<td>1 in 20,000,000</td>
</tr>
</tbody>
</table>

• A deterministic effect is one which will certainly result from exposure
• There will be a minimum exposure (threshold) above which the effect will occur
• The severity of the effect will depend on the exposure
  – Example: cataract formation, radiation sickness
• Exposure to low doses of radiation over months or years
• Deterministic effects
  – Cataracts
  – Nonspecific life shortening
• Stochastic effects
  – Cancer
  – Genetic effects
• Exposure to a high dose delivered within seconds, minutes or days
• Possible deterministic effects
  – Blood changes
  – Nausea
  – Diarrhea
  – Hair-loss
  – Malaise
  – Death

Image by LK Wagner, PhD; Vlietstra et a, CC BY-SA 3.0 via Wikimedia Commons
<table>
<thead>
<tr>
<th>Acute Dose (mGy)</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 250</td>
<td>No detectable effects</td>
</tr>
<tr>
<td>&gt; 3,000</td>
<td>Chance of death 50% and above</td>
</tr>
<tr>
<td>&gt; 6,000</td>
<td>Death an almost certainty, time between exposure and death depends on amount of dose</td>
</tr>
</tbody>
</table>
We are all exposed to radiation:

- Cosmic radiation
  - sun, space
- Terrestrial radiation
  - soil, rocks
- Internally
  - Food, air (radon gas)
- Medical treatment

On average, we receive about 2 – 4 mSv per year from background radiation.
### Public exposures and threshold effects:

<table>
<thead>
<tr>
<th>Source or Effect</th>
<th>Effective Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Dose limit</td>
<td>20 mSv (NEW)</td>
</tr>
<tr>
<td></td>
<td>1 mSv (public)</td>
</tr>
<tr>
<td>Background Radiation</td>
<td>2-4 mSv/year</td>
</tr>
<tr>
<td></td>
<td>0.01 mSv/day</td>
</tr>
<tr>
<td>Acute dose which affects the blood</td>
<td>&gt; 250 mSv</td>
</tr>
<tr>
<td>4% increased risk of fatal cancer</td>
<td>1000 mSv</td>
</tr>
<tr>
<td>Cross country plane ride</td>
<td>0.03 mSv</td>
</tr>
</tbody>
</table>

### Medical Exposures:

<table>
<thead>
<tr>
<th>Source</th>
<th>Effective Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest X-ray</td>
<td>0.1 mSv</td>
</tr>
<tr>
<td>Chest CT</td>
<td>6 mSv</td>
</tr>
<tr>
<td>PET/CT scan</td>
<td>25 mSv</td>
</tr>
<tr>
<td>SPECT w/ Tc-99m</td>
<td>10 mSv</td>
</tr>
<tr>
<td>Mammography (x4)</td>
<td>2-3 mSv</td>
</tr>
<tr>
<td>Dental X-rays (x4)</td>
<td>0.04 mSv</td>
</tr>
<tr>
<td>Radiation Therapy</td>
<td>Up to 60 Gy (equivalent dose)</td>
</tr>
</tbody>
</table>
Types of Non-Ionizing Radiation

- Radio waves
- Infrared light
- Visible light
- Microwaves
• Temperature is a measure of the average kinetic energy of the atoms and molecules in a system, or thermal energy
• Heat is the transfer of thermal energy from one area to another
• If you heat an object, you cause its atoms or molecules to move around more
• Living things are sensitive to temperature changes
  – Change of state
  – Burns
  – Denaturing of proteins
  – Metabolic rates
• Chemical reaction
• Initiated by absorbing electromagnetic radiation
  – Infrared
  – Visible
  – Ultraviolet
• Examples:
  – Photosynthesis
  – Formation of vitamin D
  – Creating long molecules called polymers
  – Degradation
  – Photoreception in the eye
• Generate electric fields and currents
  – Can interfere with body’s fields
  – Low energy levels, unnoticed
  – Over threshold
    • Peripheral vision: faint light flicker
    • Effects similar to static buildup
    • Tingling sensation
    • Very high levels: cardiovascular effects or tissue burns

• Research has not shown chronic exposure has detrimental health effects.
Radiofrequency

- Electromagnetic spectrum in the 100 kHz to 300 GHz in frequency
- Used in
  - telecommunications
    - Mobile phones, base stations, Wi-Fi, 5G, radio, television
  - MRI equipment
  - Microwave ovens
- Research shows effects
  - Heating of exposed tissue
  - Above a threshold: heatstroke, burns

Microwave Oven: Consumer Reports, CC BY-SA 4.0 via Wikimedia Commons
• Lasers produce a beam of light
  – Same frequency (monochromatic)
  – Same phase (coherent)
  – Travel in the same direction
• Cannot see the beams
• Easily reflected
• Dangers: burns to tissue
  – Eye particularly vulnerable
• Non-beam hazards
  – Fire
  – Generating airborne hazards
• Eye/skin protection
• More energetic than visible light
• Divided into 3 categories
  – Increasing energy
  – UVA, UVB, UVC
• Sunlight
  – UVC and some UVB filtered by atmosphere
• Health effects
  – Heating
  – Photoelectric
  – Ionizing
• Manifest as
  – Acute: Sunburns, Increased melanin production, vitamin D production, local immunosuppression, eye inflammation and retinal damage
  – Chronic: skin wrinkling, skin aging, skin cancer, cataract, retinal degeneration, eye cancer
• Global scientific research
• International agencies compile and make recommendations
  – Low frequency: keep induced currents below normal body
  – Radio/microwave/infrared: prevent effects due to heating
  – Visible, UV: prevent thermal, negative photochemical
  – Ionizing: prevent acute exposure and keep chronic exposure ALARA
• Recommendations include additional safety factors
• International Commission on Non-Ionizing Radiation Protection (ICNIRP)
• Behavioral changes observed
• Threshold determined
• Safety factors:
  – /10 for occupational
  – /50 for public
• The Canadian Nuclear Safety Commission (CNSC) regulates the possession and use of all radioactive substances and radiation devices in Canada
  – Owners of radiation sources and devices must have a license from the CNSC
• Equipment which produces non-ionizing radiation are generally under provincial jurisdiction, if they are regulated
  – Most x-ray equipment is provincially regulated
  – Very high energy x-ray units are regulated by the CNSC
• The Radiation Safety Institute of Canada is an independent, not-for-profit organization specializing in radiation safety.

• For further information on all types of radiation contact us at:
  1-800-263-5803
  info@radiationsafety.ca
  www.radiationsafety.ca