SAND2010-0482C

Biological Effects of Radiation Exposure

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

NNSA

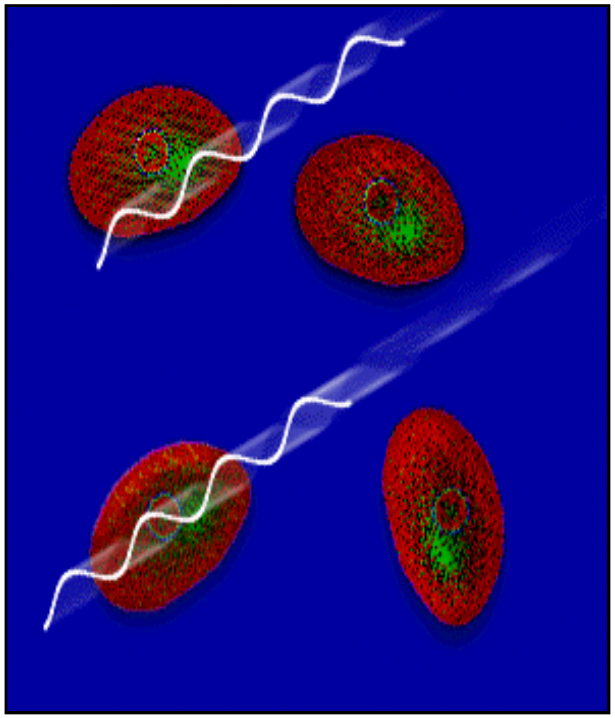
Sandia National Laboratories

Topics

- Biological Damage from Exposure to Radiation
- Radiation Damage Factors
- Potential Effects from Acute Exposure to Radiation
- Potential Effects from Chronic Exposure to Low-Level Radiation
- Hereditary Effects from Exposure to Radiation
- Prenatal Exposure
- Risks in Perspective

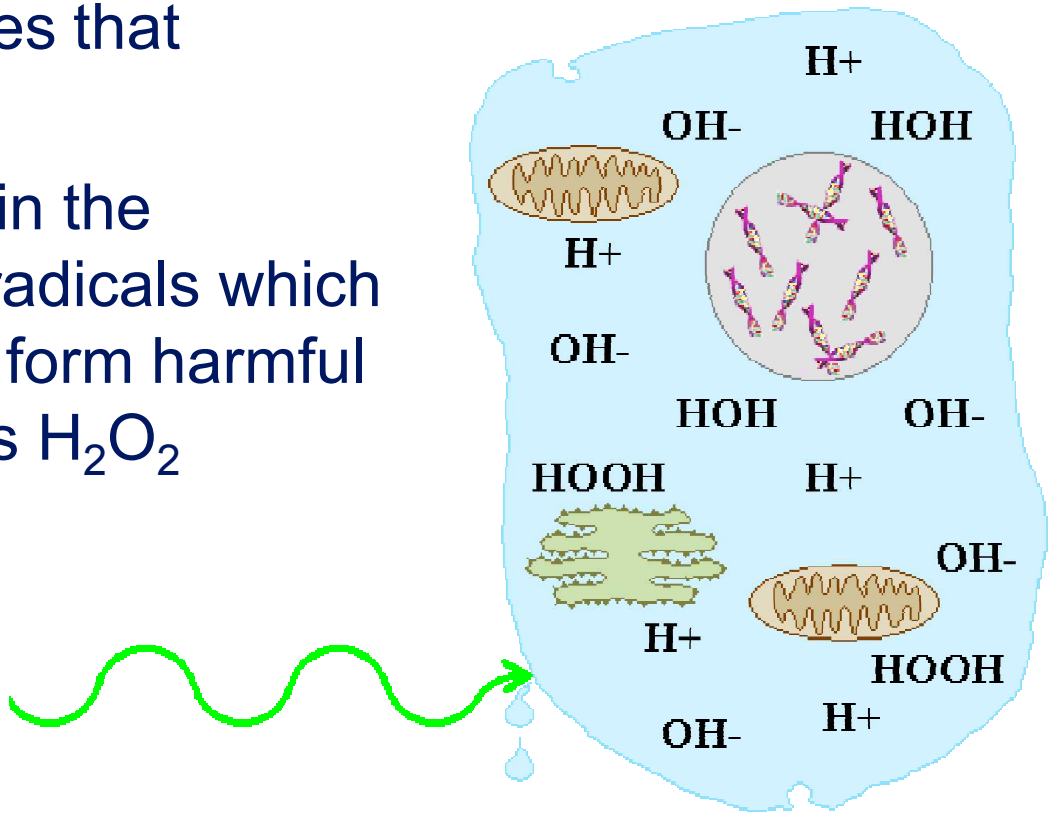
Radiation Risk

- Radiation exposure comes from a variety of natural and man-made sources
- The method by which radiation causes damage to human cells is by *ionization of atoms in the cells*
- Any potential radiation damage begins with damage to atoms



Cell Damage

- Ionizing radiation can directly rupture membranes that surround the cells
- Ionizations result in the formation of free radicals which can recombine to form harmful chemicals such as H_2O_2



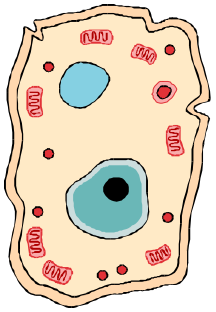
Sandia National Laboratories

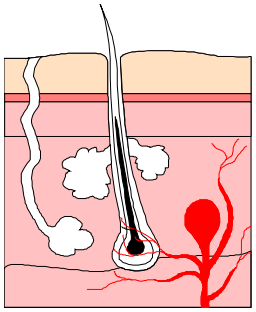
Cell Sensitivity

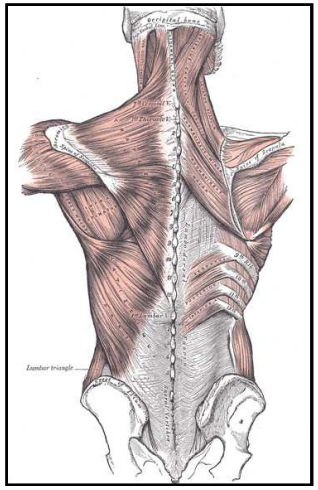
Some cells are more sensitive than others to environmental factors (viruses, toxins, ionizing radiation).

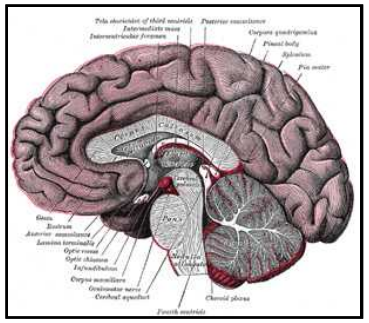
Highest Sensitivity:

- Actively dividing cells
- Non-specialized cells
- Examples: blood forming cells, hair follicles, cells that form sperm





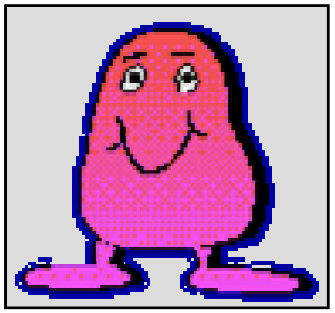




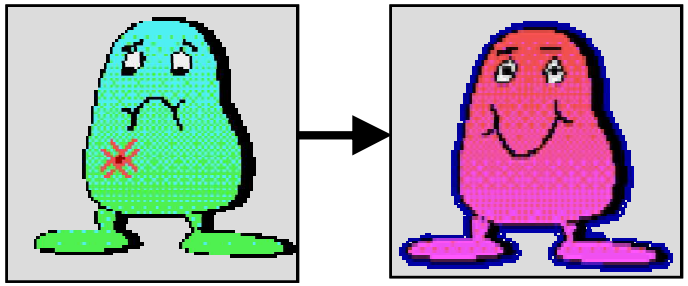
Lowest Sensitivity:

- Less actively dividing cells
- More specialized cells
- Examples: brain and muscle cells

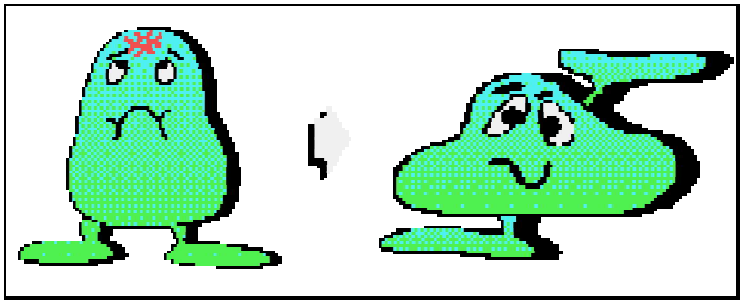
Possible Radiation Effects On Cells



There is no damage



Cells repair the damage and operate normally



Cells are damaged and operate abnormally

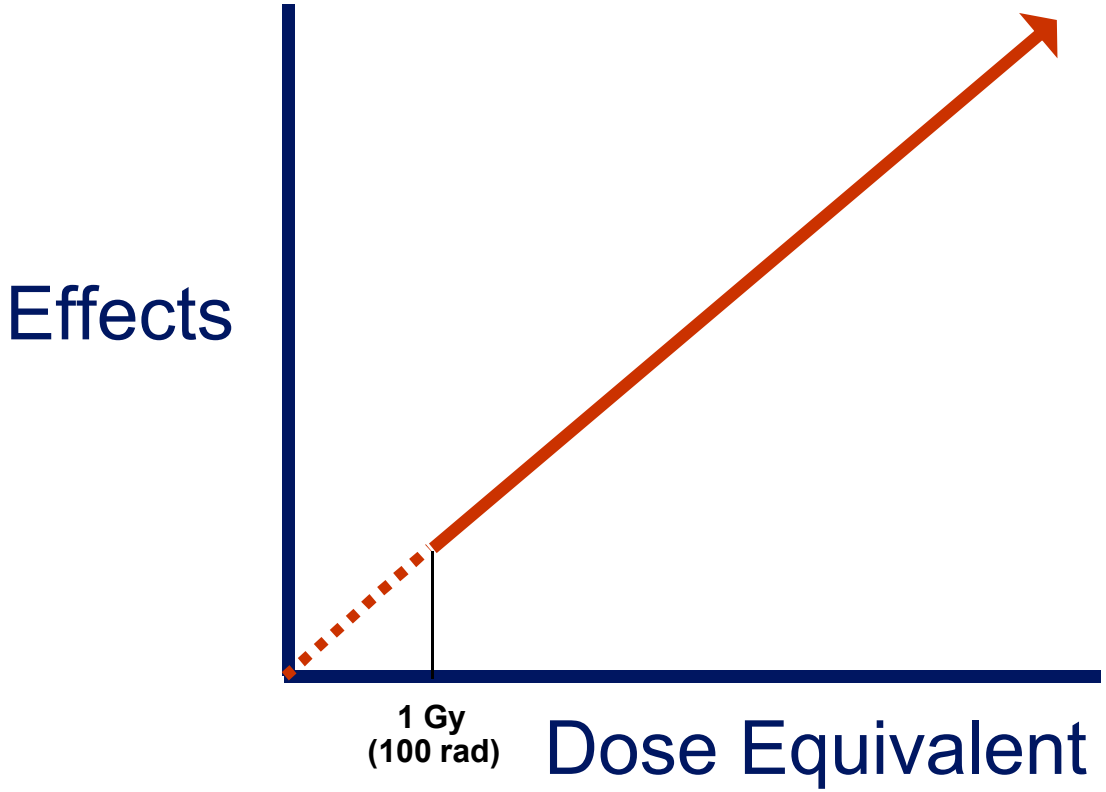
Cells die

Radiation Damage Factors

- Total Dose
- Dose Rate
- Type of Radiation
- Area of Body Exposed
- Individual Sensitivity

Total Dose

In general, the greater the dose, the greater the potential for biological effects.



Dose Rate

The faster the dose is delivered, the less time the body has to repair itself.

$$\frac{3.6\ \text{Sv}}{50\ \text{y}} = \frac{72\ \text{mSv}}{\cancel{\text{y}}} \times \frac{1\ \cancel{\text{y}}}{50\ \cancel{\text{w}}} \times \frac{\cancel{\text{w}}}{40\ \text{h}} = \frac{36\ \mu\text{Sv}}{\text{h}} \rightarrow$$

≈26% increased risk of being diagnosed with cancer*

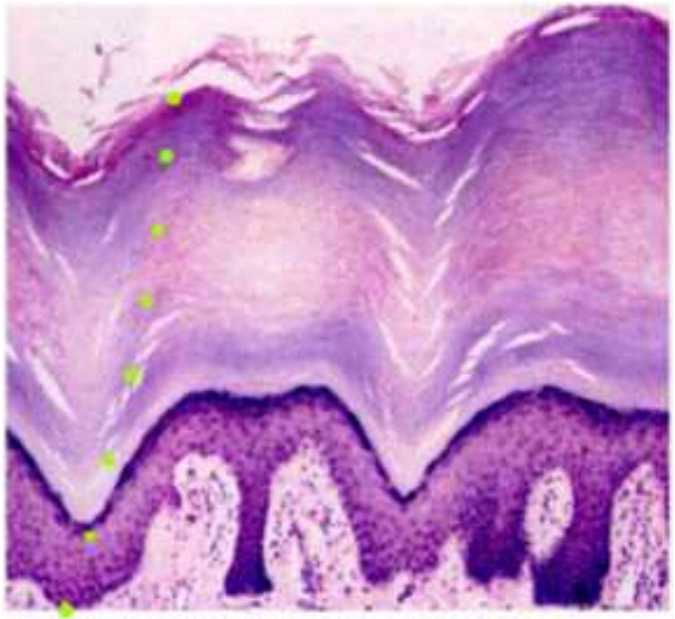
versus

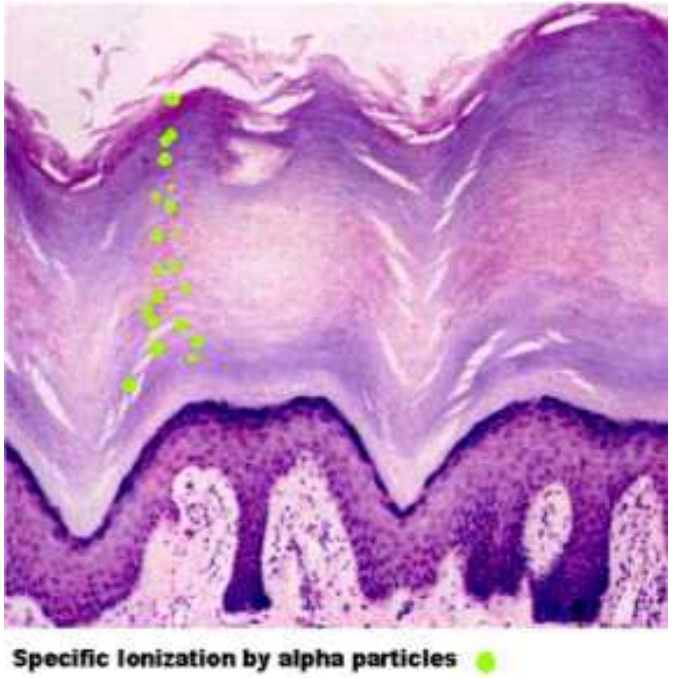
$$\frac{3.6\ \text{Sv}}{1\text{h}} \longrightarrow$$

50% chance of dying in 60 days <u>without</u> medical intervention

*BIER VII Phase 2

Type of Radiation





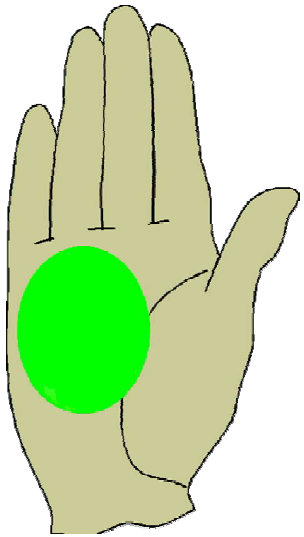
The specific ionization of x and gamma rays does not create ion pairs as close together as particle radiation

The specific ionization of particle radiation is higher as ionization occurs more frequently and at closer intervals along the path.

Area of Body Exposed

- In general, the larger the area of the body that receives a dose, the greater the biological effect
- Extremities are less sensitive than blood forming and other critical organs

vs.



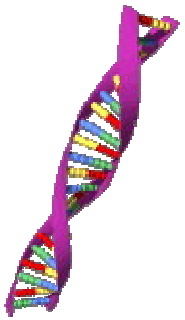
Individual Sensitivity

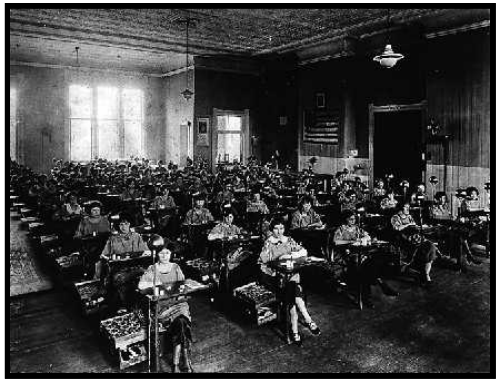
Age

- The human body becomes less sensitive to ionizing radiation with increasing age; however, elderly people are more sensitive than middle-aged adults

Genetic make-up

- Some individuals are more sensitive to environmental factors





Acute vs. Chronic Dose

Potential biological effects depend on how much and how fast a radiation dose is received.

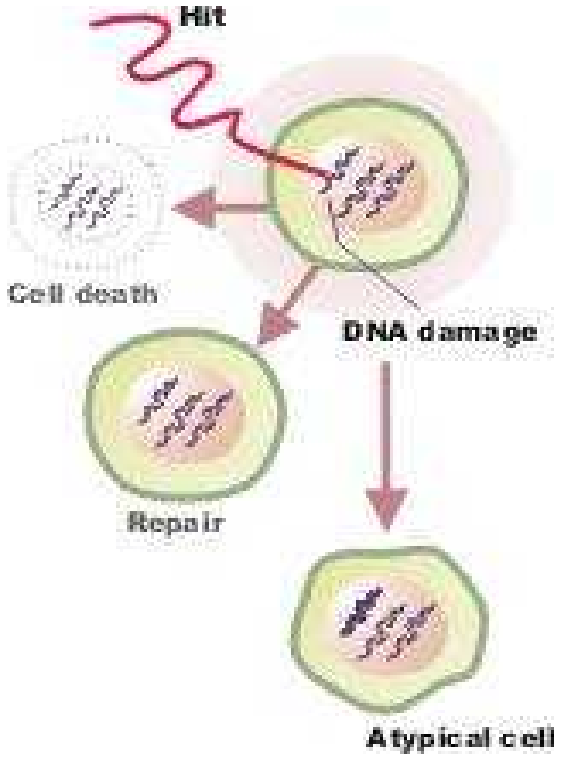
Radiation doses are grouped into:

- Acute - high dose of radiation received in a short period of time (seconds to days)
- Chronic - a small dose of radiation received over a long period of time (months to years)

Acute Dose

The body's cell repair mechanisms are not as effective for repairing damage caused by an acute dose.

- Damaged cells will be replaced by new cells and the body will repair itself, although this may take a number of months
- In extreme cases the dose may be high enough that recovery would be unlikely



Acute Exposure Effects

AVG DOSE	DAMAGE
> 50,000 mSv (> 5000 rem)	Death Within 2-3 Days
> 5000 mSv (>500 rem)	Gastrointestinal Damage
3,200 - 3,600 mSv (320 -360 rem)	LD_{50}
2,000 - 5,000 mSv (200 – 500 rem)	Blood System Damaged
1,000 - 2,000 mSv (100 – 200 rem)	Radiation Sickness
250 - 500 mSv (25 – 50 rem)	Slight Blood Changes
20 mSv (2 rem)	Annual Limit

Chronic Dose

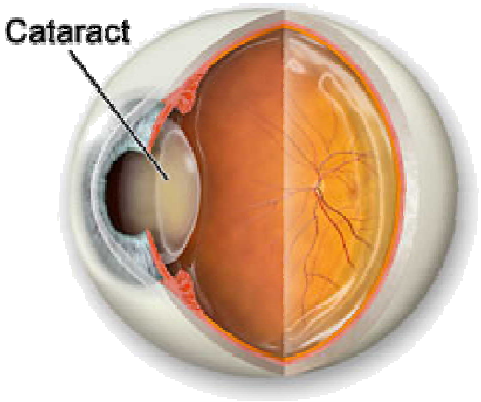
Body is better equipped to tolerate chronic doses.

Typical examples include:

- The doses commonly received from natural background
- The doses commonly received from occupational exposure

Effects of Chronic Doses

- Increased risk of cataract formation (eye doses > 4,500 mSv)
- Increased risk of developing cancer



Somatic vs. Heritable

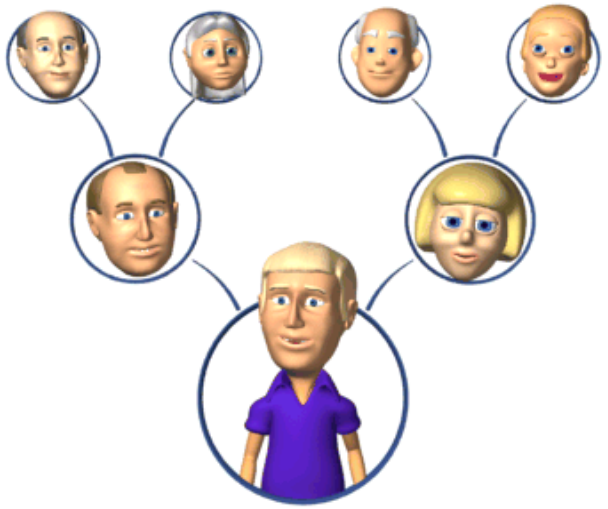
Somatic effects appear in the exposed individual.

Examples:

- Cells may become cancerous
- Increased risk of cataract formation
- Possible life-shortening

Heritable (genetic) effects appear in future generations

- Not yet observed in human populations

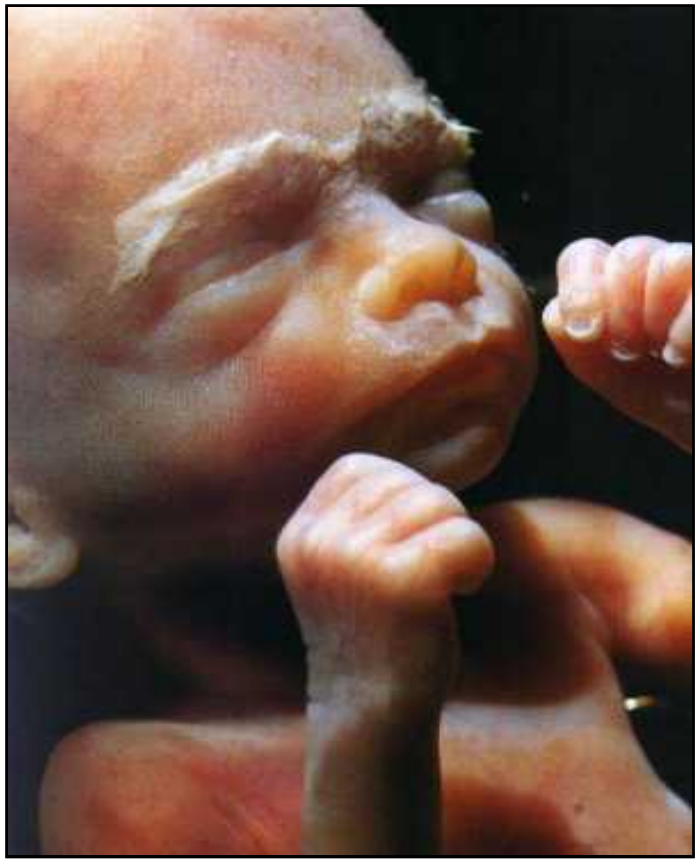


Prenatal Exposure

- Prenatal Sensitivity
- Potential Prenatal Effects

Prenatal Sensitivity

Embryo/fetus cells are rapidly dividing, which makes them sensitive to many environmental factors including ionizing radiation.



Potential Prenatal Effects for Entire Pregnancy

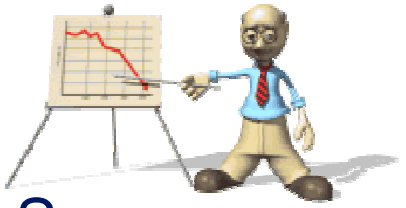
Although no effects were seen in Japanese children conceived after the atomic bomb, there were effects seen in some children who were in the womb when exposed to radiation

- Slightly Smaller Head Size
- Lower Birth Weight
- Increased Incidence of Mental Retardation
- Increased Risk of Childhood Cancer

Risks in Perspective

- Cancer Risk Information
- Comparison of Health Risks
- Occupational Risk Comparison

Cancer Risk Information



- Health effects have been observed in humans at acute doses in excess of 250 mSv
- No increase in cancer has been observed in individuals who receive a dose of ionizing radiation at occupational levels
- The possibility of cancer induction can not be dismissed even though an increase has not been observed
- Current rate of cancer death is about 10%*
- An individual who receives 250 mSv over a working life increases his/her risk of cancer to about 19%

*World Cumulative risk average (age 0-64)