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Ionizing Radiation

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Health Effects

This section provides information about health effects associated with ionizing radiation. It focuses on health effects associated with the radiation doses that workers may receive on a routine basis. See the [Overview](#) page for examples of ionizing radiation in occupational settings.

Workers may be exposed to ionizing radiation in several ways, depending on their job tasks. The health effects of radiation dose depend on the type of radiation emitted, the radiation dose received by a worker, and the parts of the body that are exposed, among other factors. Radiation dose depends on the duration of exposure, the amount of radiation generated from the radiation source, the distance from the radiation source, and the amount and type of shielding in place. In general, radiation dose is received when a worker is:

- In close proximity to an unshielded or partially shielded radiation source.
- Unprotected when near unshielded radiation-generating machines (e.g., X-ray machine, accelerator, etc.) in operation.
- Unprotected when handling radioactive materials (e.g., radionuclides).
- In close proximity to surfaces or areas contaminated with radioactive materials (e.g., from small spills or leaks).
- Contaminated with radioactive materials.

Information about chronic and acute radiation doses is provided on the [Background](#) page. More information about external dose and internal dose is provided on the [Hazard Recognition](#) page.

Types of Health Effects

When ionizing radiation interacts with cells, it can cause damage to the cells and genetic material (i.e., deoxyribonucleic acid, or DNA). If not properly repaired, this damage can result in the death of the cell or potentially harmful changes in the DNA (i.e., mutations).

Health effects from radiation doses can be grouped into two categories: **deterministic** and **stochastic**. **Deterministic effects** occur after a threshold dose is reached, meaning at dose below the threshold are not expected to cause the particular effect. The severity of the effect increases with the dose. Skin reddening (erythema) is an example of a deterministic effect with a threshold dose of approximately 300 rad (3 Gy). Although it may not accurately describe all deterministic health effects, they are sometimes described as "short-term" health effects.

Stochastic effects occur by statistical chance. The probability of the effect occurring in a population increases with the dose received, and the severity of the effect does not depend on the dose. Cancer is the main stochastic effect that can result from radiation dose, often many years following the exposure. Stochastic health effects are assumed not to have a threshold dose below which they do not occur. This is the reason that no level of radiation dose is considered to be completely "safe" and why doses should always be kept as low as reasonably achievable (ALARA). Although it may not accurately describe all stochastic health effects, they are sometimes described as "long-term" health effects.

The table below summarizes the differences between deterministic and stochastic effects.

Comparison of Deterministic and Stochastic Health Effects

	Deterministic	Stochastic
Threshold dose	Deterministic effects generally have a threshold dose below which the effect does not occur.	Stochastic effects are assumed to have no threshold dose. A single DNA mutation can lead to the effect.
Probability of developing health	Effect occurs when dose is above threshold.	The greater the dose, the greater the probability of the effect occurring.

effects		
Severity of health effects	The greater the dose, the greater the severity of the effect.	Severity of the effect does not depend on the dose. All-or-none response; an individual either develops the health effect or does not develop the effect.
Alpha particles (α)	Deterministic health effects develop after a threshold dose is reached. Examples of deterministic health effects: <ul style="list-style-type: none"> ▪ Temporary or permanent sterility (<i>for men, temporary sterility can occur at doses at or above 15 rad (0.15 Gy) to testes in brief single exposure</i>)¹ ▪ Cataracts, detectable lens opacities (<i>for detectable eye lens opacities, the threshold dose is 50 rad (0.5 Gy) to lens of eye</i>)² ▪ Skin reddening (erythema) (<i>threshold dose for erythema is <300 - 600 rad (<3 - 6 Gy) to skin</i>)¹ 	Stochastic health effects can develop from radiation doses over a short period of time or long period of time (such as a working lifetime). Note that the health effect may not be observed for many years (i.e., latency period). Examples of stochastic health effects: <ul style="list-style-type: none"> ▪ Cancer (e.g., leukemia or solid tumors) ▪ Genetic effects (e.g., mutations that can be transmitted to offspring)

The U.S. Department of Health and Human Services (HHS), Centers for Disease Control and Prevention (CDC) webpage on Health Effects of Radiation: Health Effects Depend on the Dose lists factors influencing possible health effects from a radiation dose, including:

- How fast the dose was received (a dose received over a long period of time is less harmful than the same dose received all at once)
- Where the dose was received (e.g., tissue, organ)
- How sensitive each individual is to radiation (e.g., age, other medical conditions).

The CDC provides more information on Health Effects of Radiation. The U.S. Environmental Protection Agency (EPA) also provides information on Radiation Health Effects.

Control measures, including shielding and personal protective equipment (PPE), function to protect workers by reducing the radiation dose and preventing contamination, respectively. See the Control and Prevention page for more information.

Stochastic Health Effects from Chronic Doses

Some workers, such as radiology department workers, may be repeatedly exposed to low levels of ionizing radiation over the course of their careers. The resulting dose levels are almost always below the threshold doses needed for deterministic health effects to occur. Stochastic health effects, such as cancer, may occur years following the radiation dose. The probability of an adverse health effect occurring is proportional to the radiation dose received.³

Scientific studies have shown significant associations between cancer and radiation dose levels of about 10 rem (0.1 Sv) or greater, with the cancer risk increasing as the radiation dose increases. For low-level radiation exposure (i.e., whole body doses less than about 10 rem (0.1 Sv)), statistical limitations in studies have made cancer risk assessment more difficult.⁴

In 2006, for the Biological Effects of Ionizing Radiation (BEIR) VII report, the National Research Council's Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation reviewed the available data and concluded that the cancer risk would continue linearly at low doses. This conclusion assumes that there is likely no safe dose level (i.e., threshold), and that even low radiation doses have the potential to cause a small increase in cancer risk.⁴

Radiation protection standards are based on the premise that any radiation dose carries some risk, and that risk increases with dose.

Deterministic Health Effects from Acute Doses

Deterministic health effects can occur when a part of the body receives a radiation dose that exceeds the threshold for that health effect. Some of these health effects (e.g., skin reddening/burns) can occur after a short delay of 1-4 weeks after an acute radiation dose is received. In most controlled occupational settings, workers are not likely to receive radiation doses that would result in such effects.

At lower doses, particularly below 50 rad (0.5 Gy), radiation may cause short-term changes in blood chemistry, including the count, structure, and function of various types of blood cells. Other deterministic effects at lower radiation doses include:

- Birth defects at doses at or above about 10–20 rad (0.1–0.2 Gy) to the embryo/fetus.⁵
- Temporary sterility at doses at or above 15 rad (0.15 Gy) to the testes in a brief single exposure.⁶
- Detectable lens opacities (which, when they cause vision problems, are known as cataracts) at acute doses at or above 50 rad (0.5 Gy) to the lens of the eye.⁷

Cutaneous Radiation Injury

Cutaneous radiation injury (CRI) occurs when a high radiation dose of 200 rad (2 Gy) or higher causes injury to the skin.⁸ Symptoms of CRI can appear within a few hours or several days or weeks after exposure and may include itchiness, tingling, abnormal skin redness (erythema), and swelling caused by a buildup of fluid (edema). Depending on the radiation dose, symptoms of acute radiation syndrome (see section below) may also occur.

CDC provides additional information about radiation doses and symptoms of CRI, including CRI fact sheets for the general public and clinicians.

Acute Radiation Syndrome

Acute radiation syndrome (ARS) occurs when all or most of the body receives a very high dose—around 70 rad (0.7 Gy) or higher—of penetrating radiation in a short period of time.⁹ ARS is a collection of symptoms attributable to damage to the bone marrow and the gastrointestinal, cardiovascular, and central nervous systems resulting from such a dose.

CDC provides additional information about the stages of ARS and the radiation doses associated with the different ARS syndromes (bone marrow, gastrointestinal, cardiovascular, central nervous system), including ARS fact sheets for the general public and clinicians.

Because ionizing radiation is strictly regulated, it is unlikely that workers would receive very high doses of penetrating radiation (able to reach internal organs) to the whole body. Doses sufficient to produce ARS and potentially cause death are associated with catastrophic radiation emergencies, and not the types of radiation doses that workers receive on a day-to-day basis. Visit OSHA's Radiation Emergency Preparedness and Response page for information on protecting workers during radiological emergencies. For example, the Chernobyl Nuclear Power Plant accident in Ukraine resulted in acute doses following a release of massive amounts of radioactive material. Approximately 134 plant workers and firefighters battling the fire during this radiation emergency at the Chernobyl plant received high radiation doses and suffered from ARS.¹⁰

¹ International Commission on Radiological Protection (ICRP). (2007). Publication No. 103, The 2007 Recommendations of the ICRP. Ottawa, Ontario, Canada: ICRP.

² International Commission on Radiological Protection (ICRP). (2011). "2011 Statement on Tissue Reactions." Ottawa, Ontario, Canada: ICRP.

³ World Health Organization (WHO), Ionizing Radiation, Health Effects and Protective Measures.

⁴ National Research Council. (2006). Health Risks from Exposure to Low Levels of Ionizing Radiation. Washington, DC: National Academies Press.

⁵ U.S. Department of Health and Human Services (HHS), Centers for Disease Control and Prevention (CDC), "Radiation and Pregnancy: A Fact Sheet for Clinicians."

⁶ International Commission on Radiological Protection (ICRP). (2007). Publication No. 103, The 2007 Recommendations of the ICRP. Ottawa, Ontario, Canada: ICRP.

⁷ International Commission on Radiological Protection (ICRP), "Statement on Tissue Reactions."

⁸ U.S. Department of Health and Human Services (HHS), Centers for Disease Control and Prevention (CDC), "Cutaneous Radiation Injury: Fact Sheet for Physicians."

⁹ U.S. Department of Health and Human Services (HHS), Centers for Disease Control and Prevention (CDC), "Acute Radiation Syndrome: A Fact Sheet for Physicians."

¹⁰ U.S. Nuclear Regulatory Commission (NRC), "Backgrounder on Chernobyl Nuclear Power Plant Accident"; NRC, "High Radiation Doses."

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