

Safety Lines – The Basics

What are Safety Lines?

Helpful tips to answer questions in regards to radiation.

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Where Is It?

Radiation is part of our everyday lives. We are all exposed to radiation from the sun and in the atmosphere; naturally occurring radioactive materials are present in the earth, the houses we live in, and the foods we eat. Radioactive gases are mixed in the air we breathe; and even our own bodies contain naturally occurring elements that are radioactive. This inescapable radiation exposure is called "natural background".

In addition, we create and use sources of radiation for medical purposes in the diagnosis and treatment of injury and disease.

What Is It?

Radiation includes light, radio waves, and electric fields. These are examples of a lower energy radiation, called non-ionizing radiation. Non-ionizing and ionizing radiation does not affect matter in the same way.

Ionizing radiation changes the physical state of atoms it strikes causing them to become electrically charged or "ionized".

All matter is made up of atoms. The basic parts of atoms are neutrons, protons, and electrons. Neutrons and protons form the nucleus of the atom and electrons surround (orbit) the nucleus. An atom of a particular element has a unique number of protons in its nucleus. Certain combinations of protons and neutrons are stable (not radioactive). When an atom has an unstable combination of neutrons and protons, the atom will decay (emit radiation). These unstable atoms are called "radioisotopes."

Main Type of Ionizing Radiations

Alpha Particles consists of heavy, positively-charged particles emitted by atoms of heavy elements such as naturally occurring uranium and radium and some human-made sources. Alpha particles are completely absorbed by the outer dead layer of skin and is therefore not a hazard outside the body. If alpha particles are taken into the body

by inhalation or with food or water, they can directly expose internal tissues and can be a hazard.

Beta Particles (positively or negatively charged electrons) are emitted from the nucleus during decay. Beta particles are more penetrating than alpha particles and can sometimes penetrate the skin. Like alpha particles, they are generally more hazardous when inhaled or ingested. In air, beta particles may be stopped by plastic or wood. Carbon 14 (^{14}C), an example of a radioisotope that emits beta particles, is naturally produced in the atmosphere.

Gamma and X-rays are forms of electromagnetic radiation because they have both electric and magnetic properties. Gamma rays come from the nucleus when materials decay. X-rays are a result of electron removal or rearrangement in atoms. Gamma and x-ray radiation is used frequently in medicine because they can easily penetrate the human body.

Neutrons are heavy, uncharged particles that cause the atoms that they strike to become ionized.

From Radiation Exposure to Dose

Damage from radiation depends on several factors such as whether the exposure was from internal or external sources. The unit for measuring absorbed energy as radiation exposure to the human body is the rem (Roentgen Equivalent Man).

External Exposure comes from a source outside the body, such as a medical x-ray. To do harm, the radiation must have enough energy to penetrate the body. If it does, three factors affect the radiation dose that the individual will receive:

- The amount of **time** the individual was exposed;
- The **distance** from the source of radiation;
- and The amount of **shielding** between the individual and the source of radiation.

The longer a person is exposed to a source of radiation, the higher the radiation dose. The relationship between distance and exposure is not as simple because the intensity of radiation falls off very quickly. For example, if a source produces a radiation dose rate to an individual of 1 rem per hour at a distance of 1 foot, twice the distance (2 feet), the dose rate will be one-fourth of 1 rem per hour or 0.25 rem per hour. At three feet, the rate will be one-ninth of 1 rem per hour or 0.11 rem per hour.

The following shielding guidelines can be used:

- Alpha particles stopped by paper;

- Beta particles stopped by wood or plexiglass;
- Gamma and X-rays stopped by lead or concrete;
- Neutrons absorbed by hydrogen-rich materials.

Internal Exposure can occur when a radioisotope enters the body by inhalation, ingestion, or through an open wound. If this happens, any kind of radiation can directly harm living cells. The damage the radiation produces depends on the following factors:

- The amount of radioactive material deposited into the body;
- The type of radiation emitted;
- The physical characteristics of the element;
- The half-life of the radioisotope (how fast it decays away);
- The length of time in the body.

Radiation Risk Comparison

The real question is: how much will radiation exposure increase my chances of cancer death over my lifetime.

To answer this, we need to make a few general statements of understanding. One is that in the US, the current death rate from cancer is approximately 20 percent, so out of any group of 10,000 United States citizens, about 2,000 of them will die of cancer. Second, that contracting cancer is a random process, where given a set of population, we can estimate that about 20 percent will die from cancer, but we cannot say which individuals will die. Finally, that a conservative estimate of risk from low doses of radiation is thought to be one in which the risk is linear with dose. That is, that the risk increases with a subsequent increase in dose. Most scientists believe that this is a conservative model of the risk.

So, now the risk estimates. If you were to take a large population, such as 10,000 people and expose them to one rem (to their whole body), you would expect approximately eight additional deaths ($0.08\% \times 10,000 \times 1 \text{ rem}$). So, instead of the 2,000 people expected to die from cancer naturally, you would now have 2,008. This small increase in the expected number of deaths would not be seen in this group, due to natural fluctuations in the rate of cancer.

What needs to be remembered it is not known that 8 people will die, but that there is a risk of 8 additional deaths in a group of 10,000 people if they would all receive one rem instantaneously.

If they would receive the 1 rem over a long period of time, such as a year, the risk would be less than half this (<4 expected fatal cancers).

Risks can be looked at in many ways, here are a few ways to help visualize risk.

One way often used is to look at the number of "days lost" out of population due to early death from separate causes, then dividing those days lost between the population to get an Average Life expectancy lost" due to those causes. The following is a table of life expectancy lost for several causes:

Health Risk	Est. life expectancy lost
Smoking 20 cigs a day	6 years
Overweight (15%)	2 years
Alcohol (US Average)	1 year
All Accidents	207 days
All Natural Hazards	7 days
Occupational dose (300 mrem/yr)	15 days
Occupational dose (1 rem/yr)	51 days

You can also use the same approach to looking at risks on the job:

Industry type	Est. life expectancy lost
All Industries	60 days
Agriculture	320 days
Construction	227 days
Mining and quarrying	167 days
Manufacturing	40 days
Occupational dose (300 mrem/yr)	15 days
Occupational dose (1 rem/yr)	51 days

These are estimates taken from the NRC Draft guide DG-8012 and were adapted from B.L. Cohen and I.S. Lee, "Catalogue of Risks Extended and Updates", *Health Physics*, Vol. 61, September 1991.

Another way of looking at risk, is to look at the Relative Risk of 1 in a million chances of dying of activities common to our society.

- Smoking 1.4 cigarettes (lung cancer)

- Eating 40 tablespoons of peanut butter
- Spending 20 days in New York City (air pollution)
- Driving 40 miles in a car (accident)
- Flying 2500 miles in a jet (accident)
- Canoeing for 6 minutes
- Receiving 10 mrem of radiation (cancer)

Procedure	Effective Dose (mrem)	Risk of Fatal Cancer	Equivalent to Number of Cigarettes Smoked	Equivalent to Number of Highway Miles Driven
Chest Radiograph	3.2	1.3E-6	9	23
Skull Exam	15	6E-6	44	104
Barium Enema	54	2E-5	148	357
Bone Scan	440	1.8E-4	1300	3200

Adapted from DOE Radiation Worker Training, bases on work by B.L. Cohen, Sc.D.

The following is a comparison of the risks of some medical exams and is based on the following information:

- Cigarette Smoking – 50,000 lung cancer deaths each year per 50 million smokers consuming 20 cigarettes a day, or one death per 7.3 million cigarettes smoked or 1.37×10^{-7} deaths per cigarette
- Highway Driving – 56,000 deaths each year per 100 million drivers, each covering 10,000 miles or one death per 18 million miles driving, or 5.6×10^{-8} deaths per mile driven
- Radiation Induced Fatal Cancer – 4% per Sv (100 rem) for exposure to low doses and dose rates

Adapted from information in *Radiobiology for the Radiologist*, Fourth Edition; Eric all 1994, J. B. Lippincott Company.

So, in summary, we must balance the risks with the benefit. It is something we do often. We want to go somewhere in a hurry, we accept the risks of driving for that benefit. We

want to eat fat foods, we accept the risks of heart disease. Radiation is another risk that we must balance with the benefit. The benefit is that we can have a source of power, or we can do scientific research, or receive medical treatments. The risks are a small increase in cancer risk comparisons show that radiation is a small risk, when compared to risks we take every day. We have studied radiation for nearly 100 years now. It is not a mysterious source of disease, but a well-understood phenomenon, better understood than almost any other cancer causing agent to which we are exposed.

Radiation Dose Perspective

1 millirem dose:	One one-thousandth of a rem.
2.5 millirem dose:	Cosmic Radiation dose to a person on a one-way flight from New York to Los Angeles
10 millirem dose:	One chest x-ray using modern equipment
25 millirem dose:	Yearly exposure limit set by the Environmental Protection Agency for people who live near nuclear power plants.
60-80 millirem dose:	Average yearly radiation dose from cosmic radiation to people who live in the Rocky Mountain States
100 millirem dose:	Yearly limit from all sources of human-made radiation (non-radiation worker) set by the Nuclear Regulatory Commission.
160 millirem dose:	Yearly dose to the average flight crew members from cosmic radiation.
300 millirem dose:	Average yearly dose to people in the U.S.(background radiation).
5 rem dose:	Yearly limit for radiation workers set by the North Carolina Administrative code, Title 15A, Department of Environment and Natural Resources (NCDENR) Division of Radiation Protection Chapter 11- <i>Radiation Protection</i> (external and internal).
25 rem dose:	15 A NCAC II (North Carolina Administrative Code Title 15 A Chapter 11 – Radiation Protection) regulation for voluntary maximum radiation dose to emergency workers for non-lifesaving work during a reactor emergency. Assumed to be a once-in-lifetime event.
75 rem dose:	Environmental Protection Agency guideline for maximum radiation dose to emergency workers volunteering for lifesaving work.

Radiation Dose Effects

Low Exposure

Biological effects of radiation exposure can be classified as either stochastic (random) or deterministic. A stochastic effect is one in which the probability of the effect, rather

than its severity, increases with radiation dose. Radiation-induced cancer and genetic effects are stochastic; the probability of occurrence is substantially higher after an exposure to 100 rem than for 1 rem, but there will be no difference in the severity of the disease if it occurs.

Deterministic effects occur when the radiation exposure is very high and the predominant biological effect is cell killing that results in degenerative changes in the exposed tissue. Deterministic effects are discussed below and are not likely to occur from diagnostic procedures or routine occupational exposure.

High Exposure

This information is based on known cases of high exposure delivered quickly over the whole body.

50-200 rem:	At the lower end of this range, the symptoms of acute radiation syndrome: anorexia, nausea, vomiting, and the diarrhea can be delayed as much as a few weeks. A slight decrease in blood cell count can be noted. Survival with or without treatment is almost certain. At the upper end of this range, symptoms are more severe and early symptoms of bone marrow damage are noted. Survival without treatment is probable, and almost certain if treatment is given.
200-500 rem:	Anorexia, nausea, vomiting, and diarrhea occur sooner and are more severe. Moderate to severe bone marrow damage and slight intestinal damage occurs. Without treatment, death is likely; survival with treatment is possible.
500-600 rem:	Severe anorexia, nausea, vomiting, and diarrhea occur. Moderate to severe bone marrow and intestinal damage and hypotension. Death is likely.