Health Effects

Health effects are the central focus of EPA's Radiation Protection Programs. Below is information that explains the topics that we consider as we prepare regulations and guidance on protective limits.

Health Effects

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Radiation and Health

How does radiation cause health effects?

Radioactive materials that decay spontaneously produce ionizing radiation, which has sufficient energy to strip away electrons from atoms (creating two charged ions) or to break some chemical bonds. Any living tissue in the human body can be damaged by ionizing radiation in a unique manner. The body attempts to repair the damage, but sometimes the damage is of a nature that cannot be repaired or it is too severe or widespread to be repaired. Also mistakes made in the natural repair process can lead to cancerous cells. The most common forms of ionizing radiation are alpha and beta particles, or gamma and X-rays.

What kinds of health effects does exposure to radiation cause?

In general, the amount and duration of radiation exposure affects the severity or type of health effect. There are two broad categories of health effects: stochastic and non-stochastic.

Stochastic Health Effects

Stochastic effects are associated with long-term, low-level (chronic) exposure to radiation. ("Stochastic" refers to the likelihood that something will happen.) Increased levels of exposure make these health effects more likely to occur, but do not influence the type or severity of the effect.

Cancer is considered by most people the primary health effect from radiation exposure. Simply put, cancer is the uncontrolled growth of cells. Ordinarily, natural processes control the rate at which cells grow and replace themselves. They also control the body's processes for repairing or replacing damaged tissue. Damage occurring at the cellular or molecular level, can disrupt the control processes, permitting the uncontrolled growth of cells--cancer. This is why ionizing radiation's ability to break chemical bonds in atoms and molecules makes it such a potent carcinogen.

Other stochastic effects also occur. Radiation can cause changes in DNA, the "blueprints" that ensure cell repair and replacement produces a perfect copy of the original cell. Changes in DNA are called mutations.

Sometimes the body fails to repair these mutations or even creates mutations during repair. The mutations can be teratogenic or genetic. Teratogenic mutations are caused by exposure of the fetus in the uterus and affect only the individual who was exposed. Genetic mutations are passed on to offspring.

Non-Stochastic Health Effects

Non-stochastic effects appear in cases of exposure to high levels of radiation, and become more severe as the exposure increases. Short-term, high-level exposure is referred to as 'acute' exposure.

Many non-cancerous health effects of radiation are non-stochastic. Unlike cancer, health effects from 'acute' exposure to radiation usually appear quickly. Acute health effects include burns and radiation sickness. Radiation sickness is also called 'radiation poisoning.' It can cause premature aging or even death. If the dose is fatal, death usually occurs within two months. The symptoms of radiation sickness include: nausea, weakness, hair loss, skin burns or diminished organ function.

Medical patients receiving radiation treatments often experience acute effects, because they are receiving relatively high "bursts" of radiation during treatment.

Is any amount of radiation safe?

There is no firm basis for setting a "safe" level of exposure above background for stochastic effects. Many sources emit radiation that is well below natural background levels. This makes it extremely difficult to isolate its stochastic effects. In setting limits, EPA makes the conservative (cautious) assumption that any increase in radiation exposure is accompanied by an increased risk of stochastic effects.

Some scientists assert that low levels of radiation are beneficial to health (this idea is known as hormesis).

However, there do appear to be threshold exposures for the various non-stochastic effects. (Please note that the acute affects in the following table are cumulative. For example, a dose that produces damage to bone marrow will have produced changes in blood chemistry and be accompanied by nausea.)

Exposure (rem)	Health Effect	Time to Onset (without treatment)
5-10	changes in blood chemistry	
50	nausea	hours
55	fatigue	
70	vomiting	
75	hair loss	2-3 weeks
90	diarrhea	
100	hemorrhage	
400	possible death	within 2 months
1,000	destruction of intestinal lining	
	internal bleeding	
	and death	1-2 weeks
2,000	damage to central nervous system	
	loss of consciousness;	minutes
	and death	hours to days

Estimating Risk
This page describes how scientists estimate cancer and other health risks from radiation exposures.

How do we know radiation causes cancer?

Basically, we have learned through observation. When people first began working with radioactive materials, scientists didn't understand radioactive decay, and reports of illness were scattered.

As the use of radioactive materials and reports of illness became more frequent, scientists began to notice patterns in the illnesses. People working with radioactive materials and x-rays developed particular types of uncommon medical conditions. For example, scientists recognized as early at 1910 that radiation caused skin cancer. Scientists began to keep track of the health effects, and soon set up careful scientific studies of groups of people who had been exposed.

Among the best known long-term studies are those of Japanese atomic bomb blast survivors, other populations exposed to nuclear testing fallout (for example, natives of the Marshall Islands), and uranium miners.

Decay Chains: Uranium Miners
This page contains information on the risks of radon in mines to miners.

Aren't children more sensitive to radiation than adults?

Yes, because children are growing more rapidly, there are more cells dividing and a greater opportunity for radiation to disrupt the process. EPA's radiation protection standards take into account the differences in the sensitivity due to age and gender.

Fetuses are also highly sensitive to radiation. The resulting effects depend on which systems are developing at the time of exposure.

Effects of Radiation Type and Exposure Pathway

Both the type of radiation to which the person is exposed and the pathway by which they are exposed influence health effects. Different types of radiation vary in their ability to damage different kinds of tissue. Radiation and radiation emitters (radionuclides) can expose the whole body (direct exposure) or expose tissues inside the body when inhaled or ingested.

All kinds of ionizing radiation can cause cancer and other health effects. The main difference in the ability of alpha and beta particles and gamma and x-rays to cause health effects is the amount of energy they can deposit in a given space. Their energy determines how far they can penetrate into tissue. It also determines how much energy they are able to transmit directly or indirectly to tissues and the resulting damage.

Although an alpha particle and a gamma ray may have the same amount of energy, inside the body the alpha particle will deposit all of its energy in a very small volume of tissue. The gamma radiation will spread energy over a much larger volume. This occurs because alpha particles have a mass that carries the energy, while gamma rays do not.

Non-Radiation Health Effects of Radionuclides

Radioactive elements and compounds behave chemically exactly like their non-radioactive forms. For example, radioactive lead has the same chemical properties as non-radioactive lead. The public health protection question that EPA's scientists must answer is, "How do we best manage all the hazards a pollutant presents?" (See Protecting Against Exposure)

Do chemical properties of radionuclides contribute to radiation health effects?

The chemical properties of a radionuclide can determine where health effects occur. To function properly many organs require certain elements. They cannot distinguish between radioactive and non-radioactive forms of the element and accumulate one as quickly as the other.

> Radioactive iodine concentrates in the thyroid. The thyroid needs iodine to function normally, and cannot tell the difference between stable and radioactive isotopes. As a result, radioactive iodine contributes to thyroid cancer more than other types of cancer.
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> Calcium, strontium-90 and radium-226 have similar chemical properties. The result is that strontium and radium in the body tend to collect in calcium rich areas, such as bones and teeth. They contribute to bone cancer.

Estimating Health Effects

What is the cancer risk from radiation? How does it compare to the risk of cancer from other sources?

Each radionuclide represents a somewhat different health risk. However, health physicists currently estimate that overall, if each person in a group of 10,000 people exposed to 1 rem of ionizing radiation, in small doses over a life time, we would expect 5 or 6 more people to die of cancer than would otherwise.

In this group of 10,000 people, we can expect about 2,000 to die of cancer from all non-radiation causes. The accumulated exposure to 1 rem of radiation, would increase that number to about 2005 or 2006.

To give you an idea of the usual rate of exposure, most people receive about 3 tenths of a rem (300 mrem) every year from natural background sources of radiation (mostly radon).

What are the risks of other long-term health effects?

Other than cancer, the most prominent long-term health effects are teratogenic and genetic mutations.

Teratogenic mutations result from the exposure of fetuses (unborn children) to radiation. They can include smaller head or brain size, poorly formed eyes, abnormally slow growth, and mental retardation. Studies indicate that fetuses are most sensitive between about eight to fifteen weeks after conception. They remain somewhat less sensitive between six and twenty-five weeks old.

The relationship between dose and mental retardation is not known exactly. However, scientists estimate that if 1,000 fetuses that were between eight and fifteen weeks old were exposed to one rem, four fetuses would become mentally retarded. If the fetuses were between sixteen and twenty-five weeks old, it is estimated that one of them would be mentally retarded.

Genetic effects are those that can be passed from parent to child. Health physicists estimate that about fifty severe hereditary effects will occur in a group of one million live-born children whose parents were both exposed to one rem. About one hundred twenty severe hereditary effects would occur in all descendants.

In comparison, all other causes of genetic effects result in as many as 100,000 severe hereditary effects in one million live-born children. These genetic effects include those that occur spontaneously ("just happen") as well as those that have non-radioactive causes.

Protecting Against Exposure

What limits does EPA set on exposure to radiation?

Health physicists generally agree on limiting a person's exposure beyond background radiation to about 100 mrem per year from all sources. Exceptions are occupational, medical or accidental exposures. (Medical X-rays generally deliver less than 10 mrem). EPA and other regulatory agencies generally limit exposures from specific source to the public to levels well under 100 mrem. This is far below the exposure levels that cause acute health effects.

How does EPA protect against radionuclides that are also toxic?

In most cases, the radiation hazard is much greater than the chemical (toxic) hazard. Radiation protection limits are lower than the chemical hazard protection limits would be. By issuing radiation protection regulations, EPA can protect people from both the radiation and the chemical hazard. However, deciding which hazard is greater is not always straightforward. Several factors can tip the balance:

- toxicity of the radionuclide
- strength of the ionizing radiation
- how quickly the radionuclide emits radiation (half-life)
- relative abundance of the radioactive and non-radioactive forms

For example:

> Uranium-238 is both radioactive and very toxic. Its half-life of 4.5 billion years means that only a few atoms emit radiation at a time. A sample containing enough atoms to pose a radiation hazard contains enough atoms to pose a chemical hazard. As a result, EPA regulates uranium-238 as both a chemical and a radiation hazard.
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> Radioactive isotopes of lead are both radioactive and toxic. In spite of the severe effects of lead on the brain and the nervous system, the radiation hazard is greater. However, the radioactive forms of lead are so uncommon that paint or other lead containing products do not contain enough radioactive lead to present a radiation hazard. As a result, EPA regulates lead as a chemical hazard.

Resources

Possible Health Effects of Radiation Exposure on Unborn Babies
Centers for Disease Control and Prevention (CDC)
This fact sheet was developed to help you understand the possible health effects to your unborn baby from exposure to radiation.

http://www.epa.gov/radiation/understand/health_effects.html
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