Radiation Information Network's

Radiation and Risk

How much radiation do we get?

The average person in the United States receives about 360 mrem every year whole body equivalent dose. This is mostly from natural sources of radiation, such as radon. (See Radiation and Us).

In 1992, the average dose received by nuclear power workers in the United States was 300 mrem whole body equivalent in addition to their background dose.

What is the effect of radiation?

Radiation causes ionizations in the molecules of living cells. These ionizations result in the removal of electrons from the atoms, forming ions or charged atoms. The ions formed then can go on to react with other atoms in the cell, causing damage. An example of this would be if a gamma ray passes through a cell, the water molecules near the DNA might be ionized and the ions might react with the DNA causing it to break.

At low doses, such as what we receive every day from background radiation, the cells repair the damage rapidly. At higher doses (up to 100 rem), the cells might not be able to repair the damage, and the cells may either be changed permanently or die. Most cells that die are of little consequence, the body can just replace them. Cells changed permanently may go on to produce abnormal cells when they divide. In the right circumstance, these cells may become cancerous. This is the origin of our increased risk in cancer, as a result of radiation exposure.

At even higher doses, the cells cannot be replaced fast enough and tissues fail to function. An example of this would be "radiation sickness." This is a condition that results after high doses to the whole body (>100 rem), where the intestinal lining is damaged to the point that it cannot perform its functions of intake of water and nutrients, and protecting the body against infection. This leads to nausea, diarrhea and general weakness. With higher whole body doses (>300 rem), the body's immune system is damaged and cannot fight off infection and disease. At whole body doses near 400 rem, if no medical attention is given, about 50% of the people are expected to die within 60 days of the exposure, due mostly from infections.

If someone receives a whole body dose more than 1,000 rem, they will suffer vascular damage of vital blood providing systems for nervous tissue, such as the brain. It is likely at doses this high, 100% of the people will die, from a combination of all the reasons associated with lower doses and the vascular damage.

There a large difference between whole body dose, and doses to only part of the body. Most cases we will consider will be for doses to the whole body.

For more information on Acute radiation doses and its effects, check here

What needs to be remembered is that very few people have **ever** received doses more than 200 rem by accident. With the current safety measures in place, it is not expected that anyone will receive greater than 5 rem in one year. Radiation risk estimates, therefore, are based on the increased rates of cancer, not on death directly from the radiation.

Non-Ionizing radiation does not cause damage the same way that ionizing radiation does. It tends to cause chemical changes (UV) or heating (Visible light, Microwaves) and other molecular changes. Further information can be found at:

- Living near Power lines (HPS)
- Info on risk of about Cell Phones (FDA)
- Non-ionizing radiation sources

Further information on the biological effects can be found in our FAQ.

Risk

How is risk determined?

Risk estimates for radiation were first evaluated by scientific committees in the starting in the 1950s. The most recent of these committees was the Biological Effects of Ionizing Radiation committee five (BEIR V). Like previous committees, this one was charged with estimating the risk associated with radiation exposure. They published their findings in 1990. The BEIR IV committee established risks exclusively for radon and other internally alpha emitting radiation, while BEIR V concentrated primarily on external radiation exposure data.

It is difficult to estimate risks from radiation, for most of the radiation exposures that humans receive are very close to background levels. In most cases, the effects from radiation are not distinguishable from normal levels of those same effects. With the beginning of radiation use in the early part of the century, the early researchers and users of radiation were not as careful as we are today though. The information from medical uses and from the survivors of the atomic bombs (ABS) in Japan, have given us most of what we know about radiation and its effects on humans. Risk estimates have their limitations,

1. The doses from which risk estimates are derived were much higher than the regulated dose levels of today;
2. The dose rates were much higher than normally received;
3. The actual doses received by the ABS group and some of the medical treatment cases have had to be estimated and are not known precisely;
4. Many other factors like ethnic origin, natural levels of cancers, diet, smoking, stress and bias effect the estimates.

What is the risk estimate?

According to the Biological Effects of Ionizing Radiation committee V (BEIR V), the risk of cancer death is 0.08% per rem for doses received rapidly (acute) and might be 2-4 times (0.04% per rem) less than that for doses received over a long period of time (chronic). These risk estimates are an average for all ages, males and females, and all forms of cancer. There is a great deal of uncertainty associated with the estimate.

BEIR VII risk estimates for fatal cancer are similar to the values from BEIR V, but they also estimated incidence rates, which were about 50% of the fatal cancer rate.

Risk from radiation exposure has been estimated by other scientific groups. The other estimates are not the exact same as the BEIR V estimates, due to differing methods of risk and assumptions used in the calculations, but all are close.

For more on risk, try:

- Principles for Evaluating Epidemiologic Data in Regulatory Risk Assessment
- Using Health Studies to Understand Your Risk from Radiation Exposure: A Guide to Risk Estimates and Statistics
- Understanding Health Studies
- BEIR V
- BEIR VII report

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 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%*10,000*1 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 a 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 Ave)	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 2 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)

Adapted from DOE Radiation Worker Training, based 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 x 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 x 10^{-8} deaths per mile driven
- **Radiation Induced Fatal Cancer** - 4% per Sv (100 rem) for exposure to low doses and dose rates

Procedure	Effective Dose (Sv)	Effective Dose (mrem)	Risk of Fatal Cancer	Equivalent to Number of Cigarettes Smoked	Equivalent to Number of Highway Miles Driven
Chest Radiograph	3.2 x 10^{-5}	3.2	1.3 x 10^{-6}	9	23
Skull Exam	1.5 x 10^{-4}	15	6 x 10^{-6}	44	104
Barium Enema	5.4 x 10^{-4}	54	2 x 10^{-5}	148	357
Bone Scan	4.4 x 10^{-3}	440	1.8 x 10^{-4}	1300	3200

Adapted from information in *Radiobiology for the Radiologist*, Forth Edition; Eric Hall 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 which 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.

Doses

The following is a comparison of limits, doses and dose rates from many different sources. Most of this data came from Radiobiology for the Radiologist, by Eric Hall or BEIR V, National Academy of Science. Ranges have been given if known. All doses are TEDE (whole body total) unless otherwise noted. Upon revision, SI units will be added. Units are defined on our Terms Page. The doses for x-rays are for the years 1980-1985 and could be lower today. Any correction or comments can be sent to us at: RIN Webmaster

Also, see Calculator for Medical Radiation Exposure.

Doses from various sources

Limits for Exposures	Exposure	Range
Occupational Dose limit (US - NRC)	5,000 mrem/year	

Occupational Exposure Limits for Minors	500 mrem/year	
Occupational Exposure Limits for Fetus	500 mrem	
Public dose limits due to licensed activities (NRC)	100 mrem/year	
Occupational Limits (eye)	15,000 mrem/year	
Occupational Limits (skin)	50,000 mrem/year	
Occupational Limits (extremities)	50,000 mrem/year	
Source of Exposure		
Average Dose to US public from All sources	360 mrem/year	
Average Dose to US Public From Natural Sources	300 mrem/year	
Average Dose to US Public From Medical Sources	53 mrem/year	
Average dose to US Public from Weapons Fallout	< 1 mrem/year	
Average Dose to US Public From Nuclear Power	< 0.1 mrem/year	
Coal Burning Power Plant	0.165 mrem/year	
X-rays from TV set (1 inch)	0.500 mrem/hour	
Airplane ride (39,000 ft.)	0.500 mrem/hour	
Nuclear Power Plant (normal operation at plant boundary)	0.600 mrem/year	
Natural gas in home	9 mrem/year	
Average Natural Background	0.008 mR/hour	0.006-0.015 mR/hour
Average US Cosmic Radiation	27 mrem/year	
Average US Terrestrial Radiation	28 mrem/year	
Terrestrial background (Atlantic coast)	16 mrem/year	
Terrestrial background (Rocky Mountains)	40 mrem/year	
Cosmic Radiation (Sea level)	26 mrem/year	
Cosmic Radiation (Denver)	50 mrem/year	
Background Radiation Total (East, West, Central US)	46 mrem/year	35-75 mrem/year
Background Radiation Total (Colorado Plateau)	90 mrem/year	75-140 mrem/year
Background Radiation Total (Atlantic and Gulf in US)	23 mrem/year	15-35 mrem/year
Radionuclides in the body (i.e., potassium)	39 mrem/year	
Building materials (concrete)	3 mrem/year	
Drinking Water	5 mrem/year	

Pocket watch (radium dial)	6 mrem/year	
Eyeglasses (containing thorium)	6 - 11 mrem/year	
Coast to coast Airplane roundtrip	5 mrem	
Chest x-ray	8 mrem	5 - 20 mrem
Extemities x-ray	1 mrem	
Dental x-ray	10 mrem	
Head/neck x-ray	20 mrem	
Cervical Spine x-ray	22 mrem	
Lumbar spinal x-rays	130 mrem	
Pelvis x-ray	44 mrem	
Hip x-ray	83 mrem	
Shoe Fitting Fluroscope (not in use now)	170 mrem	
Upper GI series	245 mrem	
Lower GI series	405 mrem	
Diagnostic thyroid exam (to the thyroid)		
Diagnostic thyroid exam (to the Whole Body)		
CT (head and body)	1,100 mrem	
Therapeutic thyroid treatment (dose to the thyroid)	10,000,000 mrad	
Therapeutic thyroid treatment (dose to the whole body)	7,000 mrem	5,000-15,000 mrad
Earliest Onset of Radiation Sickness	75,000 mrad	
Onset of hematopoietic syndrome	300,000 mrad	100,000 to 800,000 mrad
Onset of gastrointestinal syndrome	1,000,000 mrad	500,000 to 1,200,000 mrad
Onset of cerebrovacular syndrome	10,000,000 mrad	>5,000,000 mrad
Thershold for cataracts (dose to the eye)	200,000 mrad	
Expected 50% death without medical attention	400,000 mrad	300,000 to 500,000 mrem
Doubling dose for genetic effects	100,000 mrad	
Doubling dose for cancer	500,000 mrad	(8% per Sv, natural level at 20%)
Dose for increase cancer risk of 1 in a 1,000	1,250 mrem	(8% per Sv)
Consideration of theraputic abortion threshold (dose in utero)	10,000 mrem	
SL1 Reactor Accident highest dose to survivor	27,000 mrem	
Three Mile Island (dose at plant duration of the accident)	80 mrem	

For additional information on risk and low level radiation:

Radiation Effects Study (Diane LaMacchia)

Health Physics Society Position Statement on Risk from Ionizing Radiation

BEIR V

BEIR VII report

EPA risk publications

Radiation in Every Day Life

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