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 3 mSv 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 1 Sv), 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 acute doses to the whole body (>2 Gy), the body's immune system is damaged and cannot fight off infection and disease. Several hours after exposure nausea and vomiting occur. This leads to nausea, diarrhea and general weakness. With higher whole body doses (>10 Gy), 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. At whole body doses near 7 Gy, 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 20 Gy, 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 2 Gy. With the current safety measures in place, it is not expected that anyone will receive greater than 0.05 Gy in one year where these sicknesses are for sudden doses delivered all at once. 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 (EMF). Further information on EMF that may be of interest.

- FAQ on Power lines and Cancer (John Moulder)
- FAQs about Cell Phone Base Antennas and Human Health (John Moulder)
- Static fields and Cancer FAQ (John Moulder)

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.

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.

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. 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 the University of Michigan using our comment form.

Doses from various sources

Limits for Exposures	Exposure	Range
Occupational Dose limit (US - NRC)	50 mSv/year	
Occupational Exposure Limits for Minors	5 mSv/year	
Occupational Exposure Limits for Fetus	5 mSv	
Public dose limits due to licensed activities (NRC)	1 mSv/year	
Occupational Limits (eye)	150 mSv/year	
Occupational Limits (skin)	500 mSv/year	
Occupational Limits (extremities)	500 mSv/year	
Source of Exposure		
Average Dose to US public from All sources	3.6 mSv/year	
Average Dose to US Public From Natural Sources	3.0 mSv/year	
Average Dose to US Public From Medical Sources	530 microSv/year	
Average dose to US Public from Weapons Fallout	< 10 microSv/year	
Average Dose to US Public From Nuclear Power	< 1 microSv/year	
Coal Burning Power Plant	1.65 microSv/year	
X-rays from old TV set (1 inch)	5 microSv/hour	
Airplane ride (39,000 ft.)	5 microSv/hour	
Nuclear Power Plant (normal operation at plant boundary)	6 microSv/year	
Natural gas in home	90 microSv/year	
Average Natural Background	0.008 mR/hour	0.006-0.015 mR/hour
Average US Cosmic Radiation	270 microSv/year	
Average US Terrestrial Radiation	280 microSv/year	
Terrestrial background (Atlantic coast)	160 microSv/year	
Terrestrial background (Rocky Mountains)	400 microSv/year	
Cosmic Radiation (Sea level)	260 microSv/year	
Cosmic Radiation (Denver)	500 microSv/year	
Background Radiation Total (East, West, Central US)	460 microSv/year	350-750 microSv/year
Background Radiation Total (Colorado Plateau)	900 microSv/year	750-1400 microSv/year
Background Radiation Total (Atlantic and Gulf in US)	230 microSv/year	150-350 microSv/year

Radionuclides in the body (i.e., potassium)	390 microSv/year	
Building materials (concrete)	30 microSv/year	
Drinking Water	50 microSv/year	
Pocket watch (radium dial)	60 microSv/year	
Eyeglasses (containing thorium)	60 - 110 microSv/year	
Coast to coast Airplane roundtrip	50 microSv	
Chest x-ray	80 microSv	50 - 200 microSv
Extemities x-ray	10 microSv	
Dental x-ray	100 microSv	
Head/neck x-ray	200 microSv	
Cervical Spine x-ray	220 microSv	
Lumbar spinal x-rays	1.30 mSv	
Pelvis x-ray	440 microSv	
Hip x-ray	830 microSv	
Shoe Fitting Fluroscope (not in use now)	1.70 mSv	
Upper GI series	2.45 mSv	
Lower GI series	4.05 mSv	
Diagnostic thyroid exam (to the thyroid)	0.5 Gy	
Diagnostic thyroid exam (to the Whole Body)	0.35 mGy	
CT (head and body)	11 mSv	
Therapeutic thyroid treatment (dose to the thyroid)		50-100 Gy
Therapeutic thyroid treatment (dose to the whole body)	7 cSv	5-15 cGy
Earliest Onset of Radiation Sickness	0.75 Gy	
Onset of hematopoietic syndrome	3 Gy	1 to 8 Gy
Onset of gastrointestinal syndrome	10 Gy	5 - 12 Gy
Onset of cerebrovacular syndrome	100 Gy	>500 Gy
Thershold for cataracts (dose to the eye)	2 Gy	
Expected 50% death without medical attention	4 Gy	3 to 5 Gy
Doubling dose for genetic effects	1 Gy	
Doubling dose for cancer	5 Gy	(8% per Sv, natural level at 20%)
Dose for increase cancer risk of 1 in a 1,000	1.250 cSv	(8% per Sv)
Consideration of theraputic abortion threshold (dose in utero)	10 cSv	
SL1 Reactor Accident highest dose to survivor	27 cSv	
Three Mile Island (dose at plant duration of the accident)	0.80 mSv	

For additional information on risk and low level radiation:

Radiation Effects Study (Diane LaMacchia)

Health Physics Society Position Statement on Risk from Ionizing Radiation (PDF Version, html)