An Introduction to Space Radiation

Believe it or not, you are surrounded by radiation! As you are sitting here reading this article, electromagnetic radiation from sunlight, electric lights, power cables in the walls, and the local radio station are coursing through your body. Is it something to worry about? It all depends on how much you absorb, and in what forms.

There are two main types of radiation: electromagnetic radiation, and particle radiation. Both forms carry energy, which means that if you accumulate too much over time, either in the tissues of your body, or in sensitive electronic equipment, they can potentially do damage. A small amount of ultraviolet radiation can give you a nice tan. Too much can increase your risk for skin cancer. A small amount of radio radiation is enough to pick up a distant station on your radio, but too much in a microwave oven will cook you in ten seconds flat! A small amount of particle radiation in, say, the radium dial of a watch, is enough to make it glow in the dark harmlessly, but too much can destroy the DNA in your cells and lead to mutations…even death.

Scientists measure radiation dosages and exposure in terms of units called Rads and Rems (Grays and Seiverts are used in Europe). Rad means 'Radiation Equivalent Dose' and REM means 'Roentgen Equivalent Man'. One Rad is equal to 100 ergs of energy delivered to one gram of matter. The Rem compares the amount of absorbed energy to the amount of tissue damage it produces in a human.

$$\textbf{Rad} = \textbf{Rem} \times \textbf{Q}$$

Electromagnetic radiation, such as x-rays and gamma-rays, produce 'one unit' or tissue damage, so for this kind of radiation Q = 1, and so 1 Rad = 1 Rem. Most low-intensity forms of 'EM' radiation can be shielded by using clothing or skin creams. In high dosages, X-rays and gamma-rays require shielding to reduce their health effects, otherwise they can be lethal, or can even incinerate tissue. There are three different kinds of particle radiation, each produces its own level of tissue damage.

Alpha-particles are given-off by radioactive atoms. They are nuclei containing two protons and two neutrons: essentially helium nuclei. These particles, at high energy, can be very destructive to tissue as they leave tracks of ionization in cytoplasm and other cellular tissues. For these Q = 15-20.

Beta-particles are also given off by radioactive atoms. They consist of energetic electrons traveling at high-speed, and require several millimeters of aluminum or other shielding to stop most of them. For these, Q = 1.

Neutron particles are produced in nuclear reactions including fission and fusion. Because they carry no charge, they easily penetrate many substances. Q = 10.

Because of the differences in Q, different forms of radiation produce different levels of tissue damage. Beyond this, radiation also has different effects depending on how much you absorb over different amounts of time. Let's consider two extreme examples where your entire body is 'irradiated': A small dose over a long time, and a big does over a short time.

Weak and Long! On the ground, you receive about 0.4 Rem (e.g. 400 milliRem) of natural backround radiation and radiation from all forms of medical testing, what you eat, and where you live. Over the course of your lifetime, say 80 years, this adds up to 80 x 0.4 = 32 Rem of radiation. By far, the biggest contribution comes from radioactive radon gas in your home, which can amount to as much as 0.1 Rem, which yields a lifetime dose of 8 Rem. Some portion of this radiation exposure invariably contributes to the average cancer risk that each and every one of us experiences.

Medical Diagnostic Radiation:

0.002 Rems	Dental x-ray
0.010 Rems	Diagnostic chest X-ray
0.065 Rems	Pelvis/Hip x-ray
0.150 Rems	Barium enema for colonoscopy
0.300 Rems	Mammogram
0.440 Rems	Bone scan
2 to 10 Rem	CT scan of whole body

Strong and Intense! In cancer therapy, small parts of your body are irradiated to kill cancerous cells. This works because radiation transports energy into cellular tissue where it is absorbed, and cancerous cells are very sensitive to heat. Although patients report nausea and loss of hair, the benefits to destroying cancerous cells far outweighs the collateral effects. Typical dosages are about 200 Rems over a few square centimeters, or even 5,000 Rem over a single tumor area! For whole-body dosages, the effects are far worse!

50 - 100 Rems	No significant illness
100 - 200 Rems	Nausia ,vomiting. 10% fatal in 30 days.
200 - 300 Rems	Vomiting. 35% fatal in 30 days.
300 - 400 Rems	Vomiting, diarrhea. 50% fatal in 30 days.
400 - 500 Rems	Hair loss, fever, hemorrhaging in 3wks.
500 - 600 Rems	Internal bleeding. 60% die in 30 days.
600- 1,000 Rems	Intestinal damage. 100% lethal in 14 days.
5,000 Rems	Delerium, Coma: 100% fatal in 7 days.
8,000 Rems	Coma in seconds. Death in an hour.
10,000 Rems	Instant death.

Would you like to check your annual exposure? Visit the American Nuclear Society webpage and take their test at
http://www.ans.org/pi/resources/dosechart/

or use the one at the US Environmental Protection Agency
http://www.epa.gov/radiation/students/calculate.html

or the one at the Livermore National Radiation Laboratory
http://newnet.lanl.gov/main.htm

Questions to ponder, based on the text.

1- During an accident, a 70 kg person absorbed 1,000 Rem of x-ray radiation.

A) How much energy, in ergs, did the person gain?

B) If 41,600,000 ergs is needed to raise the temperature of 1 gram of water by 1 degree C, how many degrees did the radiation raise the person's body temperature if the human body is mostly water?

2 - Your probability of contracting cancer from the natural background radiation (0.3 Rem/year) depends on your lifetime exposure. From detailed statistics, a sudden 1 Rem increase in dosage causes an 0.08% increase in deaths during your lifetime, but the same dosage spread over a lifetime causes about 1/2 this cancer increase. By comparison, cancer studies show that a typical person has an 20% lifetime mortality rate from all sources of cancer. (see "Radiation and Risk", Ohio State University, http://www.physics.isu.edu/radinf/risk.htm).

A) Consider 10,000 people exposed to radiation. How many natural cancer deaths would you expect to find in such a sample?

B) How much does the natural background radiation contribute to this cancer death rate?

C) Whenever you take a survey of people, there is a built-in statistical uncertainty in how precisely you can make the measurement, which is found by comparing the sample size to the square-root of the number of samples. In polls, this is referred to as the 'margin of error'. For your answer to Problem 2a, what is the range of people that may die from cancer in this population?

D) Compared to your answer to Problem 2B, do you think you would be able to measure the lifetime deaths from natural background radiation exposure compared to the variation in cancer mortality in this population?

Answer Key

1- During an accident, a 70 kg person absorbed 1,000 Rem of x-ray radiation.

A) How much energy, in ergs, did the person gain?
Answer: For X-rays, which are electromagnetic radiation, Q = 1 so 1 Rem = 1 Rad.
Then, 1000 Rem x 100 ergs/gram x 170 kg x 1000 gm/kg = **170,000,000,000 ergs.**

B) If 41,600,000 ergs is needed to raise the temperature of 1 gram of water by 1 degree C, how many degrees did the radiation raise the person's body if the human body is mostly water?

Answer: 1000 Rem x 100 ergs/Rem = 100,000 ergs
So, 100,000 ergs/ (41,600,000 ergs/degree C) = **0.002 degrees C.**

2 - Your probability of contracting cancer from the natural background radiation (0.3 Rem/year) depends on your lifetime exposure. From detailed statistics, a sudden 1 Rem increase in dosage causes an 0.08% increase in deaths during your lifetime, but the same dosage spread over a lifetime causes about 1/2 this cancer increase. By comparison, cancer studies show that a typical person has an 20% lifetime mortality rate from all sources of cancer. (see "Radiation and Risk", Ohio State University, http://www.physics.isu.edu/radinf/risk.htm).

A) Consider 10,000 people exposed to radiation. How many natural cancer deaths would you expect to find in such a sample?
Answer: 10,000 x 0.2 = **2,000 deaths over a lifetime.**

B) How much does the natural background radiation contribute to this cancer death rate?
Answer: 0.3 Rem/yr x 75 years x 0.04% = 0.9% x 10,000 people = **90 people.**

C) Whenever you take a survey of people, there is a built-in statistical uncertainty in how precisely you can make the measurement, which is found by comparing the sample size to the square-root of the number of samples. In polls, this is referred to as the 'margin of error'. For your answer to Problem 2a, what is the range of people that may die from cancer in this population?
Answer: $(10000)^{1/2}$ = 100 so the range is from (2000 - 100) to (2000 + 100)
or **1900 to 2100 people.**

D) Compared to your answer to Problem 2B, do you think you would be able to measure the lifetime deaths from natural background radiation exposure compared to the variation in cancer mortality in this population?
Answer: Comparing the 90 deaths to the statistical uncertainty of 100 deaths in a sample of 10,000 people, you would not be able to detect the 90 deaths assigned to the natural background, against the variation of deaths you statistically expect from all other causes of cancer.