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Radiation and Nuclear Health Hazards

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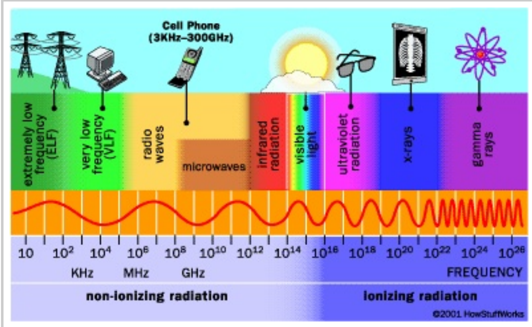
This case study is part of a collection of pages developed by students in the 2012 introductory-level Geology and Human Health course in the Department of Earth Sciences, Montana State University. [Learn more about this project](#).

When we think of radiation we may immediately think of only dangerous and harmful things. In reality, the word radiation refers to any transfer of energy through space from a source. Some examples of radiation include sunlight, radio waves, x-rays, heat, alpha, beta, gamma ionizing radiation, and infrared, just to name a few. Not all of these types of radiation are harmful, in fact, in moderation, most radiation will not pose a health risk. Certain types of radiation, however, can be dangerous, even in small doses.

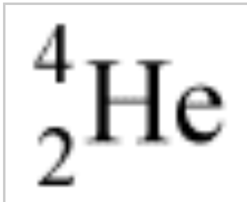


Radiation types image credit: http://www.nucellcanada.ca/store/media/cell-phone-radiation-spectru.gif

So What is Radiation?

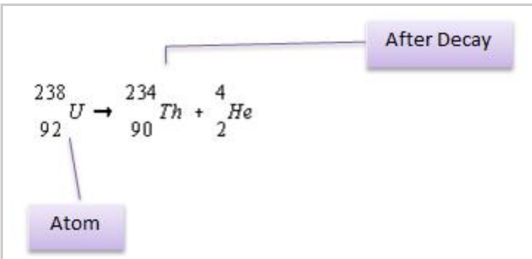
Radiation is a fairly general term that can be used to describe the transfer of energy through space away from a source. There are many types of radiation. When we talk about radiation as a danger to humans through the rest of this site, we will primarily be talking about '*Ionizing radiation*'. Ionizing radiation is generated through nuclear reactions and can be very harmful to human health. Nuclear reactions can be naturally occurring, or artificial. There are three basic types of radiation. These include alpha, beta, and gamma radiation. Each radiation source is unique in the type of radiation it emits, and its risk to humans.

Alpha Decay:



alpha particle

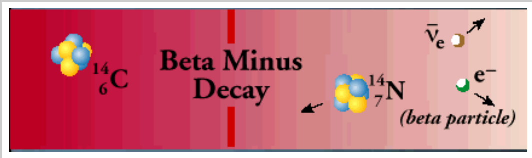
An alpha particle has two protons and two neutrons, so it has a positive charge. An alpha particle is a helium nucleus. The '2' on the bottom left of the He refers to the number of protons. The '4' represents the combined number of protons and neutrons. As an atom 'decays' it can emit protons, neutrons, or electrons. The number and type of particles it emits gives rise to the type of radiation being emitted. In the case of alpha decay, a helium nucleus (two protons, and two neutrons) are emitted. This is the lowest energy radiation type, but it is none the less dangerous to human health. Here is an example of the alpha decay process. Here, Uranium is decaying to Thorium. The number of protons in Uranium (92) is reduced to 90, making a new element- Thorium. The two protons do not simply disappear however, the protons that are emitted are what alpha radiation consists of.



Alpha Decay- image credit http://www.lbl.gov/abc/wallchart/chapters/03/1.html

Beta Decay:

Beta decay is the emission of a positron or electron from an atom, allowing the atom to obtain an optimal (more stable) number of protons and neutrons. When an atom has too many protons or neutrons such that it is unstable, it can transform a neutron into a proton or a proton into a neutron. There are two types of beta decay, (-) beta decay in which a neutron decays into a proton, and (+) beta decay in which a proton decays into a neutron. The particles emitted for these reactions to take place (electrons, positrons) are what accounts for the radiation.



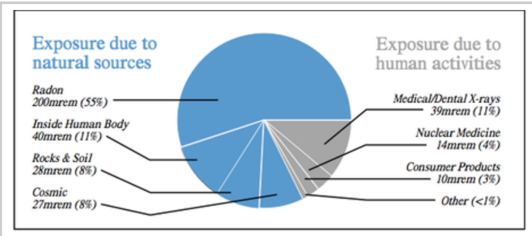
Beta Decay image credit: http://www.nucellcanada.ca/store/media/cell-phone-radiation-spectru.gif

Gamma Radiation:

Gamma rays are electromagnetic radiation, as opposed to alpha and beta radiation which are in the form of particles. (electrons, positrons, neutrons, protons). Gamma radiation is the highest energy radiation of the three types. Gamma rays are emitted from radioactive elements, but differ from alpha and beta decay in that it does not alter the number of protons or neutrons in the nucleus but instead has the effect of moving the nucleus from a higher to a lower energy state.

Where Does Radiation Come From?

I'm glad you asked, radiation can come from many sources. Some of these sources are artificial, and some are natural. Let's go over a few of these sources.



Radiation Sources image credit: http://www.umich.edu/~radinfo/introduction/popdose.htm

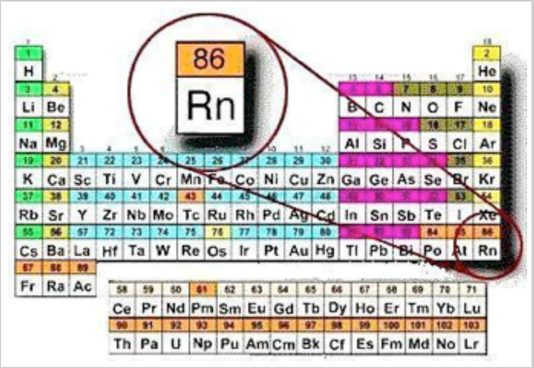
The image above gives a breakdown of the many sources that can expose humans to radiation. Four major groups from which humans recieve doses of radiation include Radon, sources inside the human body, rocks and soil, and the sun. These are all natural sources. Other sources of radiation include medical diagnostic tools, nuclear medicine, and consumer products.

Let's go over each source in a little more detail.

Natural Sources

Source one: Radon

Radon is a chemical element. Its atomic number is 86. It lies within the noble gas column on the periodic table, which means it is inert and nonreactive. Radium is, however, radioactive. Radon occurs as an intermediate decay product from uranium or thorium as they decay to lead. The half life of radon is about 3.8 days. This means that it takes about 3.8 days for half of the radon available to decay. 3.8 days after this, 1/4 will be left, another half life and an 1/8 will be left and so on. Radon emits alpha particles, and is therefore ionizing radiation, and dangerous to human health.



Radon
http://www.neradonsolutions.com/site/Welcome.html

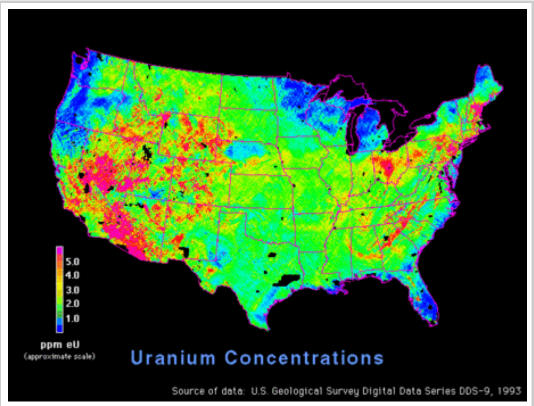
Source two: Inside the human body

Some of the elements that make up the human body have radioactive isotopes that can add to the amount of radiation you are exposed to while decaying inside your body. Carbon and potassium are two of these elements. C14 has a half life of over 5,000 years while potassium has a half life of about 1.25 billion years. Potassium accounts for the majority of the radiation inside your body. There are three naturally occurring isotopes of potassium. K39, K40, and K41. K40 decays to Ar40 by electron capture or positron emission (Beta decay)

You may be thinking- potassium... we get that from bananas, does that mean that bananas are radioactive? The answer is yes. Like all organic material, bananas contain some radioactive isotopes of potassium. In fact, in order to come up with a unit that could easily be used to understand the severity of a radiation dose, the 'banana equivalent dose was introduced. Now, it is important to recognize that eating one banana... or even 2 or 3 or 7 for that matter is not going to kill you, however, like all organic materials, bananas do contain some radioactive isotopes. For every 1 grams of potassium, about 31 atoms will decay per second. Each banana contains about .5 grams of potassium,a dn therefore the radiation dose form eating one banana is about 15bq.

Source three: Rocks and Soils

We already discussed that radon, a dense gas that is radioactive naturally occurs in soils. This is due to the fact that Uranium and thorium, (other radioactive elements) also occur naturally in soils. Some parts of the world naturally have higher concentrations of these elements in soils than others. It is important to remember that this is not from any kind of human contamination. Just like oxygen, nitrogen, carbon or hydrogen, Uranium and thorium are elements that were present in the nebular cloud that eventually formed the solar system and our earth. They were present in trace amounts compared to other elements, but none the less present. Below is a map of uranium concentrations in soils in the United States.



Uranium in soils
http://www.neradonsolutions.com/site/Welcome_files/Radon%20on%20Periodic%20Table.png

Source Four: The sun

We already know that the sun emits visible light. This part is easy because our eyes are adapted to see light that falls within the visible spectrum. You may have also noticed that even on a cold day if you stand out in the sun you feel warmer. This is because your skin is absorbing radiation from the sun that passes through the air. This is because in addition to visible light the sun is also emitting radiation from all areas of the electromagnetic spectrum from radio waves to gamma rays. The higher end of this spectrum (X-ray to gamma) is dangerous radiation to human health. (This is why you can get a sunburn, UV light is a form of ionizing radiation, and can burn your skin!). Most of the harmful radiation sent our way by the sun is reflected back into space by our protective atmosphere, but some of this radiation gets through and accounts for a large amount of the radiation you experience every day.

The sun as seen by Trace
http://www.neradonsolutions.com/site/Welcome_files/Radon%20on%20Periodic%20Table.png

Human Created Sources

Source five: Medical diagnostic tools and procedures

Diagnostic radiation is a term used to describe the non-invasive procedures used to diagnose disease that rely upon radiation to produce images of internal structures. Some of the procedures that use diagnostic radiation include CT scans, MRI, mammography, radiography, and ultrasound.

While the radiation involved in these scans can cause cancer, it is important to weight the benefits and risks to make an informed decision. When the risk of cancer s small compared to the condition potentially being diagnosed, the procedure is very worth the risk.

Certain treatments of disease also use radiation

The treatment of cancer using certain types of radiation can be highly effective. Radiation can be targeted to mostly effect cancer cells while only delivering a small dose of radiation to other tissues that the radiation must pass through to get to the cancer tissue.

Source six: Consumer Products

Antiques, building products, smoke detectors, fertilizers, tobacco products and many other products that we use and are exposed to every day may contain small amounts of radioactive materials. This does not account for a large radiation dose compared to the other sources that we have talked about, but it is significant enough to mention.

Transport. The good the bad and the ugly. How radiation infiltrates your body

The functions of living tissue are carried out by molecules, that is, combinations of different types of atoms united by *chemical bonds*. The proper functioning of these molecules depends upon their *composition* and also their *structure*. Altering chemical bonds may change composition or structure. Ionizing radiation is powerful enough to do this. There are several ways that radiation physically interacts with your body.

#1: Inhalation of radon

As radon itself decays, it produces new radioactive elements called radon daughters or decay products. Unlike the gaseous radon itself, radon daughters are solids and stick to surfaces, such as dust particles in the air. If such contaminated dust is inhaled, these particles can stick to the airways of the lung and increase the risk of developing lung cancer.

#2: Direct action

Keep in mind that ionizing radiation emits small particles that can pass right through your body, and occasionally collide with one of the particles around an atom in your body. Ionizing radiation, by definition, "ionizes," that is, it pushes an electron out of its orbit around an atomic nucleus, causing the formation of electrical charges on atoms or molecules. If this electron comes from the DNA itself or from a neighboring molecule and directly strikes and disrupts the DNA molecule, the effect is called *direct action.*

#3: Indirect action

It is currently thought that most damage from radiation comes from indirect action. That is, instead of string your DNA itself, a particle hits a water molecule and ionizes it producing what is known as a *free radical*. A free radical reacts very strongly with other molecules as it seeks to restore a stable configuration of electrons. This in turn can damage DNA and lead to mutations and cell death. Mutations in a cell's DNA and reproductive mechanisms are what can eventually lead to cancer.

Bioavailability

Radioactivity or the strength of radioactive source is measured in units of becquerel (Bq).

1 Bq = 1 event of radiation emission per second.

Radiation is all around us and it comes from so many sources that there really is no escaping it. We can define how much a particular radioactive source is exposing us to radiation by examining its 'absorbed dose. Absorbed dose describes the amount of radiation absorbed by an object or person (that is, the amount of energy that radioactive sources deposit in materials through which they pass). The units for absorbed dose are the radiation absorbed dose (rad) and gray (Gy). 1 Gy = 100 rads. Equal doses of all types of ionizing radiation are not equally harmful. Alpha particles produce greater harm than do beta particles, gamma rays and x rays for a given absorbed dose. To account for this difference, radiation dose is expressed as equivalent dose in units of sievert (Sv). The dose in Sv is equal to "absorbed dose" multiplied by a "radiation weighting factor" (W_R - see Table 2 below). Prior to 1990, this weighting factor was referred to as Quality Factor (QF).

Table 2
Recommended Radiation Weighting Factors

Type and energy range	Radiation weighting factor, WR
Gamma rays and x rays	1
Beta particles	1
Neutrons, energy	
< 10 keV	5
> 10 keV to 100 keV	10
> 100 keV to 2 MeV	20
> 2 MeV to 20 MeV	10
> 20 MeV	5
Alpha particles	20

One sievert is a large dose. The recommended TLV is average annual dose of 0.05 Sv (50 mSv).

The effects of being exposed to large doses of radiation at one time (acute exposure) vary with the dose. Here are some examples:

10 Sv - Risk of death within days or weeks

1 Sv - Risk of cancer later in life (5 in 100)

100 mSv - Risk of cancer later in life (5 in 1000)

50 mSv - TLV for annual dose for radiation workers in any one year

20 mSv - TLV for annual average dose, averaged over five years

Impacts on Human Health

Radiation is a mutagen, which eventually can lead to cancer. Radiation can either kill cells or damage the DNA within them, which damages their ability to reproduce and can eventually lead to cancer. When radiation is present, high energy particles pass through your body. These can collide with atoms in your body and disrupt atomic structure. Atoms make up your DNA, so over time, your

DNA can be damaged. Often, it is the replication mechanisms of cells that is damaged, so uncontrolled cell division occurs- which is the definition of cancer.

Prevention or Mitigation

One thing that can be done to protect from radiation is reducing radon exposure. Radon enters homes through basement areas exposed to underground soils. If a house is tightly sealed, this can cause radon to build up. Ventilation in homes is important if radon is detected. Radon detectors can be purchased to determine if radon is a concern in your home.

Solar radiation exposure can be reduced simply by wearing sunscreen- even on cloudy days. UV radiation can penetrate clouds, and is made even worse by spending time near reflective surfaces such as snow or sand. These can reflect UV radiation which increases the amount you receive.

Flying often also increases how much solar radiation you are exposed to, and adds a significant amount to your background radiation dose. Avoid flying when possible. For a full list of things that add to your radiation exposure, see the link to calculate your annual radiation dose.

Related Links

You can calculate your radiation dose per year **HERE**

Another cool tool is a real time radiation map of the US, showing where radiation levels are high right now at Interactive realtime radiation map http://radiationnetwork.com/

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