Radiation

by

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"People in the United States complain about our out-of-control medical costs. 30% or more of the medical costs are the result of fossil fuel air pollution." (http://nextbigfuture.com/2009/02/coal-power-and-waste-details.html.)

Radioactive Pollution

We periodically pass through a storm of fear regarding radioactivity. This is especially true whenever a nuclear energy plant experiences problems. Citizens in almost every country throughout all the nations of the world seem to be prodded into a form of hysteria because a small amount of radioactive particles might blow their way.

Let's look at some facts about radioactive elements, called radionuclides. There are over 60 of them found in nature. One group was formed before the creation of our sun. These are usually very long lived, such as Uranium 235, Uranium 238, Thorium 232, Radium 226, Radon 222, and Potassium 40.

Each of these long-lived elements has their own unique half lives, the time it takes for half of a given quantity of radioactivity to disappear. Uranium 235 half-life is 7.04 X 10^8 years, that's 7.04 with 6 zeros behind, or 704,000,000 years. Uranium 238 is 4.47 X 10^9 years (4,470,000,000 years). Thorium 232 is 1.41 X 10^{10} years (14,100,000,000). Radium 226 is 1.60 X 10^3 years (1,600 years). Radon 222 is 3.82 days. Postassium 40 is 1.28 X 10^9 years (1,280,000,000 years). Potassium 40 will be distributed in our bodies considerably more so than the Uranium, Thorium, Radium, or Radon. [There's between 1 and 30 pCi/g -- (pCi/g = a measure of the radioactivity) -- (1 to 30) of one gram of potassium radionuclide that decays at a rate of 3.7^{-2} disintegration per sec.]

Naturally occurring radioactive material is found almost everywhere. It is found in the air and in soil, and even as radioactive potassium in our own bodies -- and also in the potassium iodide pills given to us to protect us from radiation. Radiation -- alpha, beta, gamma rays, x-rays -- is found in public water supplies and foods such as brazil nuts, cereal, and peanut butter.

The average person in the United States is exposed to about 360 millirems of radiation from natural sources each year. A millirem, or one one-thousandth of a rem, is a measure of radiation exposure. More than 80% of this exposure level comes from background radiation sources. Consumer products contribute 10 millirem/year, while living or working in a brick building can add another 70 millirem/year. Granite, Sandstone, Cement, Limestone Concrete, Sandstone Concrete, Dry Wallboard, By-product gypsum, Natural gypsum, Wood, Clay Brick, each have their own degree of radioactive elements.

A person who smokes one and a half packs of cigarettes per day increases his or her exposure by 8000 millirem/year, while porcelain false teeth can add another 1600 millirem/year to a person's exposure level.

Another group of radioactive particles formed because of the interaction of some of earth's elements with cosmic rays. Cosmic radiation is everywhere streaming in from outside of our solar system. This radiation is in many forms including high speed heavy particles, high energy photons, and muons. When these particles hit our upper atmosphere some interact with particles in our atmosphere producing radioactive elements. Most have short half-lives, but some do not. Carbon 14 half-life is 5,730 years. Hydrogen 3 (Tritium) half-life is 12.3 years. Beryllium 7 half-life is 53.28 days. An average dose of 27 mrem per year is received from cosmic sources, both primary and secondary. This figure doubles for every 6,000 foot increase in elevation. Flying adds a few extra mrem to your annual dose depending upon how often you fly, how high the plane flies, and how long you're in the air. Obviously astronauts are exposed to radiation when they leave the protection of the earth's atmosphere and especially when they pass through the Van Allen radiation belt.

Then, of course, there's the group of radiation enhanced or created by humans, a very tiny amount compared to the naturally formed group. These consist of Tritium whose half-life is 12.3 years. Iodine 131 half-life is 8.04 days. Iodine 129 half-life is 1.57 X 10^7 days (about 43,000 years). Cesium 137 whose half-life is 30.17 years. Strontium 90 with a half-life of 28.78 years. Technetium 99 with half-life of 2.11 X 10^5 years (211,000 years). Plutonium 239 with half-life of 2.41 X 10^4 years (24,100 years).

All air, water and soil contain radioactive elements. Indeed, they're even found inside of us, elements that make up our cells that make up our tissues, make up our organs and finally our body.

Let's put this in perspective. Suppose you have a garden that is 10 feet wide by 40 feet wide, and from time to time you must spade the garden 1/2 foot deep. Here's a table showing the approximate amount of radioactive substances you would encounter during each total turn over of the garden:

Uranium	0.00158 kilograms	1.58 grams
Thorium	0.0086 kilograms	0.86 grams
Potassium 40	0.00144 kilograms	1.44 grams
Radium	0.000002 grams	0.000002 grams
Radon	0.0000008 micrograms	0.0000008 micrograms

As you can see your vegetables will contain some radioactive elements. Silicon, iron, magnesium, potassium, phosphorus, and virtually the entire Periodic Table of elements are generally present in smaller or trace quantities.

It's clear that your crops will pick up some radioactive Potassium 40. Potassium is an element your body must have. The wind will blow some of all of the above elements about when the weather is dry. Rain will wash some out to the neighbor's land, to streams, to lakes or oceans.

Let's look at a truly large farm area growing corn, wheat, soy, or what have you. Assume the plowing is 1 square mile by 1 square mile, and 6" deep. During the plowing you would encounter:

Uranium	550 kilograms	550,000 grams	= 121 pounds (radioactive)
Thorium	6,000 kilograms	6,000,000 grams	= 13,200 pounds (radioactive)
Potassium 40	1,000 kilograms	1,000,000 grams	= 2,200 pounds (radioactive)
Radium	0.8 grams	= 0.8 grams	
Radon	5.5 micrograms	=.5 micrograms	

All foods have some small amount of radioactivity. The following table makes relative comparisons between Potassium 40 and Radium per kilogram of a few produce:

	Potassium 40	Radium 226
Banana	3,520	1
Brazil Nuts	5,600	1000 to 7,000
Carrot	3,400	0.62
White Potatoes	3,400	1 to 2.5
Beer	390	___
Lima Bean Raw	4,640	2 to 5
Drinking Water	__	0 to 0.17

The Pacific ocean contains about 6.549 X 10^{17} cubic meters of water. The Atlantic about 3.095 X 10^{17} cubic meters. Altogether there's more than 1.3 X 10^{18} cubic meters of water on our planet.

All water contains radioactive elements: Uranium, Potassium 40, Tritium, Carbon 14, Rubidium 87.

There's over 1,500 different radioactive nuclides. Virtually all elements have one or more isotopes, many that are radioactive. Sixty two radioactive elements were identified in premium coal ash in 1997. Some of these represented small trace elements and some larger. (http://pubs.usgs.gov/bul/bw144/determin_tables/table2.htm.)

The rem is a unit used to derive a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms of thousandths of a rem, or mrem. To determine equivalent dose (rem), you multiply absorbed dose (rad) by a quality factor (Q) that is unique to the type of incident radiation. Many units are broken down into smaller units or expressed as multiples, using standard metric prefixes. As examples, a kilobecquerel (kBq) is 1000 becquerels, a millirad (mrad) is 10^{-3} rad (1/1000), a microrem (µrem) is 10^{-6} rem (1/1,000,000), a nanogram is 10^{-9} grams (1/1,000,000,000), and a picocurie is a 10^{-12} curies (1/1,000,000 000,000). One Becquerel is that quantity of radioactive material that will have one transformation in one second.

According to Idaho State University's "Radioactivity in Nature," http://www.physics.isu.edu/radinf/natural.htm and their use of Merrill Eisenbud's and Tom Gesell's Environmental Radioactivity from Natural, Industrial and Military Sources (Academic Press, 4th Ed.) and other sources the average estimated human exposure or effective dose equivalent from radiation is 360 mrem (milirem: 1,000th of a rem) per adult in the United States, broken down as follows:

	µSv	mrem
Inhaled (Radon and Decay Products)	2000	200
Other Internally Deposited Radionuclides	390	39
Terrestial Radiation	280	28
Cosmic Radiation	270	27
Cosmogenic Radioactivity	10	1
Rounded total from natural sources	3000	300
Rounded total from artificial sources	600	60
Total from all sources	3600	360

It is not possible to escape from radiactivity on earth -- and much, much harder to do so above our atmosphere. Our bodies -- indeed all of earth's lifeforms -- evolved with exposure to radioactivity which might, to some small degree, also be a source of genetic mutations that lead to different species.

Our human bodies, therefore, have some capacity to handle radioactivity but, like drowning in water, the body can only handle so much radioactivtity and that amount depends upon genetics, age, type of radiation, length of exposure and health. Estimated natural radioactivity in our bodies follows:

	Total Mass	Daily Intake of Nuclides	
Uranium	90 µg	1.9 µg	(micrograms)
Thorium	30 µg	3 µg	(micrograms)
Potassium 40	17 µg	0.39 µg	(micrograms)
Radium	31 pg	2.3 pg	(picograms)
Carbon 14	22 ng	1.8 ng	(nanograms)
Tritium	0.06 pg	0.003 pg	(picograms)
Polonium	0.2 pg	approx.0.6 fg	(femtograms)

Our planet is not evenly populated with radioactive materials. High background sources occur in Brazil, India and China, primarily because of concentrations of certain minerals. Certain black beaches contain high concentrations of radioactive elements.

By now its easy to understand that those who remind us that it only takes one nuclear distintegration in one cell to began the formation of cancer are speaking from total ignorance. All terrestial life contains radioactive elements including ourselves!

Coal as a Major Source of Radioactivity

When I was in graduate school in Nashville, Tennesse back in the forties almost all homes and businesses used a soft coal for heating. I roomed on the 3rd floor of a dormitory. Room windows were left open for temperature control during winter time. When I wakened in the morning I could barely see detail in the walls across from me, such was the amount of coal smoke lingering everywhere. This common black apparition came about because Nashville, Tennessee lay in a kind of bowl which collected the heavy coal smoke unless a goodly wind was blowing. Eventually Nashville's city fathers solved this problem and now the city is clean both day and night. My point is this: coal smoke has long been considered the primary pollution from the burning of coal. As far back as the earliest industrial revolution beginning in England thick, black smoke from the burning of coal from steam engines, railroad engines and so on have been identified in the minds of most as the major unavoidable source of air pollution.

Next coal was blamed for the quickened warming of our planet. Coal contains among many other elements sulphur and produces sulphur dioxide and other sulphur products -- plus carbon dioxide (CO_2). The concentrations of CO_2 and methane have increased by 36% and 148% respectively since 1750. These levels are much higher than at any time during the last 800,000 years, the period for which reliable data has been extracted from ice cores. The last time CO_2values were higher than this was 20 million years ago. About three-quarters of the increase in CO_2 is caused by the burning of fossil fuels over the past 20 years. Most of the rest is due to land-use change, particularly deforestation.

The United States has an amount of coal reserves greater than any other nation on earth, 507.7 billion tons. Another 1,223.2 tons has been identified and also inferred to exist. Yet to be discovered, is an estimated 2,237.4 tons more. (http://www.clean-energy.us/facts/coal.htm) Coal is also the chief source for electricity.

Coal is mined in 100 countries. China, India and the United States were the top producers of coal in 2006, the United States accounting for 38%. Nine hundred and thirty tons of our recoverable coal is equivalent to 4,116 billion barrels of oil according to the Energy Information Administration. During 2007 the USA burned 7.075 billion tons of coal. This is equivalent in heat content to 57,000,000 barrels of oil per day or 365 X 57,000,000 = 21,375.000,000 barrels of oil per year.

The largest reserves of coal are in the United States, Russia, China, India, and Australia.

British Petroleum estimated in 2006 that there was an estimated 909,064 million tons of proven coal reserves worldwide. The proven reserves worldwide would last the world for an estimated 147 years. (When I was in grade school I was told that the US had enough coal to last for 1,000 years. Boy! Has our usage rate gone up? Or what? Oh, sure, increased population and industrialization! At a 5% growth per annum this would be reduced to 45 years, or until 2051.)

The primary composition of coal is carbon, sulfur, hydrogen, oxygen and nitrogen. We've already mentioned 62 radioactive elements found in coal ash and smokestacks.

Coal began millions of years ago as fallen plant matter that piled up beneath acidic water in wide shallow seas of the Carboniferous period. Huge peat bogs were eventually buried by sediments and these layers of plant materials metamorphosed into coal, a solid material. Peat, a precursor to hard coal, is used in Ireland and Finland. It's a good heat source when dried from the moisture of the bogs from which it's mined. Lignite is a "stony" coal, hard to get started (I remember) but once it is started burns and produces considerable heat. Bituminous coal is a dense black mineral. It's heat value (BTUs) is usually higher than peat or lignite which is why it's railroaded in by the thousands of box car loads to every coal burning electric generation plant. Anthracite, usually glossy and black, is most often used for commercial space heating ad residential heating. One should mention slate which is very hard to ignite but can be processed to burn and even to obtain oil.

Naturally all classifications are subject to differences found in geographical regions and to the past history of each deposit.

Most everyone knows that coal is dug from the ground either in seams that run beneath the surface or the surface, itself, is stripped off until the coal seams are reached. Coal can also be used to make coke where the volitile constituents are driven off by baking in an oven without oxygen at temperatures as high as 1000^{0}C ($1,832^{00}$F). The reaction of coal and natural gas produces ethanol. Syngas, a mixture of carbon monoxide and hydrogen gas, can be manufactured from coal, and this can also be converted to gasolene by a liquefaction process. Coal can also be refined to remove moisture and certain pollutants.

It's clear that the use of coal is a necessary part of our environment. But, most discussion of its harmful effects center around CO_2 emissions and, to some extent, the products of sulphur. Here are some of the downsides to our generous use of coal:

1. Burning coal generates hundreds of millions of tons of waste products, including fly ash, bottom ash, flue gas desulfurization sludge that contain mercury, uranium, thorium, arsenic and other heavy metals. Some of this sludge is used for landfill and even for farmland, nevermind the arsenic poisons.

2. High sulfur coal produces acid rain. Acid rain acidifies our oceans and lakes and has other deleterious consequences.

3. Mining coal disturbs groundwater and pollutes our water tables and also affects the flow of rivers and other land uses.

4. Coal-fired power plants shorten nearly 24,000 lives a year in the United States, including 2,800 from lung cancer. How does this compare against cigarette smoking which causes 443,000 deaths according to http://www.cancer.gov/

cancertopics/tobacco/smoking. Apparently only 0.6% of the total lung cancer deaths are caused by coal emmissions, but 5% of deaths overall are attributed to coal-fired plants.

5. Coal-fired power plants emit mercury, selenium, and arsenic which are harmful to human health and the environment. The Environmental Protection Department says there's no lower limit to the amount of mercury that humans can tolerate. And radioactive effects are not yet factored in!

6. Burning coal is the largest release of CO_2 in the air. There are hundreds of coal fires burning throughout the world. Underground they're not only difficult to locate but almost impossible to extinguish. Coal fires in China, for example. burn 109 million tons per year emitting 360 metric tons of CO_2. It's been estimated that 2-3% of annual worldwide production of CO_2 comes from uncontrolled coal burning. This is equivalent to coal that has been burned in coal-fired plants from that carried by all of the trucks and trains in the United States. These underground fires are often started by surface grass fires, trash fires, lightning or even spontaneous combustion. The Australian Burning Mountain, originally believed to be a volcano, has been burning coal for 5,000 years! 200 million tons per year of coal has burned underground naturally for millions of years! (http://www.climateimc.org/en/breaking-news/2005/12/03/200-million-tons-year-coal-has-burned-underground-naturally-million-years)

OK! So you know all of this.

But, to replace coal, the world would need to build annually 1,150 nuclear plants and tap 70 trillion cubic feet of gas annually!

Here and there some coal-fired electric plants are scrubbing some of their emissions. That's a good thing. However, the persistent and large radioactive fallout from the burning of coal is seldom mentioned. Let's look at some further facts. According to U.S. Geological Survey Bulletin 1823 (http://pubs.usgs.gov/bul/b1823/append.htm) Potassium found in fly ash samples taken in 1985 represented a concentration of 0.0748 %. This is not surprising as Potassium is the eighth most abundant element in the earth's crust estimated to be between 2.0 and 2.5 percent, just slightly less abundant than its alkali cousin, Sodium.

There are three naturally occurring isotopes of Potassium: Potassium 39, Potassium 40 and Potassium 41. It's radioactive Potassium 40 we're interested in.

In any quantity of Potassium there will be 0.0118% of Potassium 40 with a half-life of 1,260,000,000 years.

It follows, therefore, that a given unit of coal will contain 0.00078 X 0.000188 = 0.00000014664 units of radioactive potassium. That's 1.4664 X 10^{-7} units of Potassium, or, say 1.4664 X 10^{-5} percent.

Nothing to worry over, is there? The human body consists of 0.012 percent, considerably more radioactive Potassium 40. The average human who weighs 70 kilograms (150 pounds) has 140 grams (5 ounces) of potassium in his or her body. Normal daily intake of potassium is about 3.3 grams (0.1 ounce). Since potassium occurs in all plants, humans normally do not have any problems getting enough of the element in their daily diet. Multiply 5 ounces by 0.012% and find that the human body contains about six ten thousandths of an ounce of radioactive potassium and takes in about 0.000012 ounces of Potassium each day. Some estimate that the human body averages Potassium intake of about 2.5 grams per day. This, they say, amounts to 80 Becquerels producing 80 radioactive decays each second. 140 grams of Potassium in a normal male contains about 4,400 Becquerels or about 4,400 disintegrations per second. Considering that Potassium decays near the interstitial fluids, about 98% is in the body within the cells. Thus at least 98% of the disintigrations take place within the body cells and are potentially able to alter our DNA. (http://rerowland.com/K40.html)

According to Wikipedia there was 6,743,786,000 tons of coal consumed in 2006. Consumption is expected to increase 48% to 9.98 billion tons by 2030.

6,743,786,000 tons X 2000 = 1,348,757,000,000 pounds of coal consumed per year worldwide (2006).

0.00000014664 of radioactive potassium per pound of coal times 1,348,757,000,000 pounds of coal consumed worldwide annually = 19,780 pounds of radioactive Potassium spread into our environment annually -- and growing! (Don't forget it's half-life is 1,260,000,000 years. Compounded accumulation with this disintigration rate becomes significant.)

Potassium is but one isotope that might affect us from the burning of coal. Most of the elements from the periodic table of elements have isotopes. The following are additional elements that are released from coal plants listed as milligrams/gram of coal ash, according to the U.S. Geological Survey Bulletin 1823 (http://pubs.usgs.gov/bul/b1823/append.htm): (These figures vary according to type and location of coal measured.)

Element	Concentration in mg/g
Al(%)	0.855
As	3.72
Ba	67.5
C(%)	78.11
Ca	0.204
Cd	0.0573
Co	2.29
Cu	6.28
Fe(%)	0.759
H(%)	5.07
Mg(%)	0.0383
Mn	12.4
N(%)	1.56
Na(%)	0.0515
Ni	6.10
Pb	3.67
Rb	5.05
S(%)	1.89
Th	1.34
Ti(%)	0.0454
U	0.436
Zn	11.9

The radionuclides of all of these emissions significantly add to our worldwide radioactive exposure.

Are you interested in the contribution of radioactivity by all of the isotopes of all of these elements?

Simply find the percentage of the radioactive isotope in each pound of coal of a given element above and add all them up along with my figure of 19,780 pounds of Potassium 40.

When you're done with this afternoon exercise, consider that we have yet to figure radioactive contributions of oil and gas!!

You'll also agree, I believe, that Homo sapiens is saturated with radioactivity and that daily we're thickening the brew!!