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Chapter Six

WONDERFUL RADON

It is more prudent to worry about getting too little radon than too much.

Continental Surveys for Radon

In 2016 the American Lung Association (ALA) led a national work group to develop the National Radon Action Plan: A Strategy for Saving Lives. ALA was formed in the United States in 1904 in response to only one disease: tuberculosis (TB). At the time about 450 Americans died each day from TB, most between the ages of 15 and 44; few recovered by rest, diet and moderate outdoor exercise. In 1882 Robert Koch isolated the causative agent, *Mycobacterium tuberculosis*. Edward Trudeau (1848-1915) believed that rest, diet, exercise and cool fresh air of the mountains could cure TB. Trudeau had greater success in curing TB with his methods using mountain air. Herman Brehmer was cured of TB while living in the Himalayan Mountains and built the first TB sanatorium in the Adirondack Mountains of New York. Some springs of the Himalayas contain high radon levels ¹⁴⁷. Other American TB sanatoria were built in the mountains of Virginia and North Carolina and then at higher altitudes of western states. A significant association of radon exposure and TB cures in sanatoria has not been made, although radon levels and background radiation tend to be higher in mountain regions; as such the association is an intriguing possibility (Figure 1).

X-ray fluoroscopy examinations were given repeatedly in Canada and Massachusetts during the treatment of tuberculosis patients from the 1940s to 1960s. Cumulative doses to the lungs ranged up to 3 Gy. Cumulative doses up to about 1 Gy resulted in a benefit with decreased risk of breast cancer and lung cancer decades later than seen in unexposed control populations ^{21,194-196}. The sensitivity of the tubercular microorganism to X-rays was noted as early as 1896 (Chapter 7). X-rays were subsequently used to treat tuberculosis for the next few decades. Although not studied, it is possible that later tuberculosis patients receiving fractionated X-rays exposures benefited not just from visualization of treatment progress and radiation hormesis but also from direct effects of X-rays on mycobacterium.



Figure 1. The western third of the U.S. is largely mountainous. (U.S. Geological Survey, <http://ned.usgs.gov/images/nedus2.gif>)

In the early 20th century radon gas became popular in medical practice. ‘Radium emanations’ in the form of radon seeds were used in Canada by physicians to treat cancer ²³⁸. EL Harrington (1887-1956), a student of

RA Millikan, chair of Physics Department, University of Chicago from 1896-1921, was the chair of the Physics Department for the University of

Saskatchewan in Canada for about thirty years. Harrington setup a radon facility in the department for cancer therapy, as did several other universities in Canada in the 1930s. Radon was concentrated and encapsulated into tiny glass containers to treat skin lesions and tumors ²³⁹. By the end of World War I, radon seeds had been established in distinguished hospitals such as Memorial Hospital in New York City. Radon was also used for the treatment of benign conditions such as nevi, gingivitis and uterine fibrosis ²³⁸. During the early years of optimism in use of radium, there was an interest in the stimulatory and restorative effects of inhaled radon gas in large rooms called ‘emanatoriums’ ⁴⁸. However the radiation hormesis effects of radon were unexpected and overwhelmed by high dose use of radon seeds in treating tumors. There was a continuing debate as to whether radon was a poison or a cure ¹⁸⁷.

RA Millikan (1868-1953) received the Nobel Prize (1923) for his work on the photoelectric effect. He also obtained an accurate value for Planck’s constant and named radiation coming from outer space ‘cosmic rays’.

The World Health Organization (WHO) has called radon the second leading cause of lung cancer, second only to tobacco. About 7% of Canadians live in homes above the American guideline of

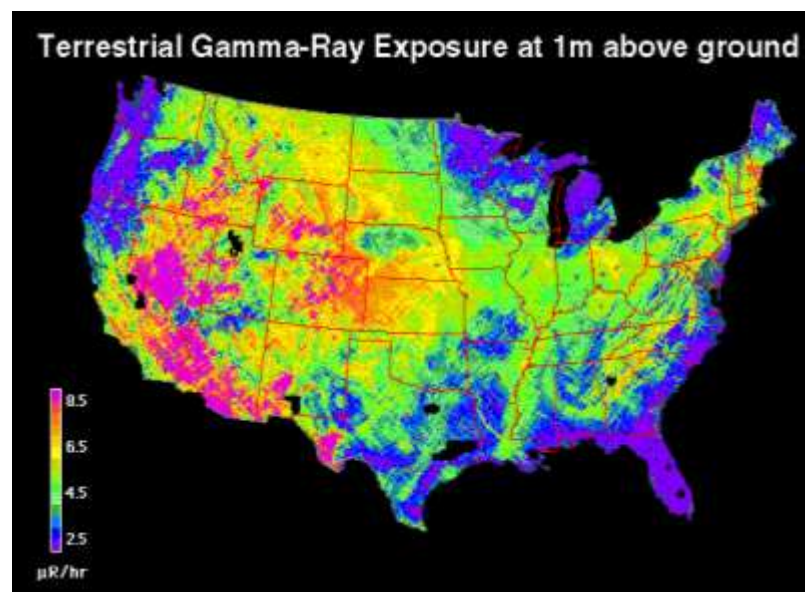


Figure 2. U.S. Geological Survey digital data series DDS-9, 1993, shows highest terrestrial gamma-ray exposures to be in the western U.S. ²²⁵.

4 pCi/L. The Canadian government takes a radiophobic position, estimating that 16% of all Canadian lung cancers are due to radon. The government claims that it has a way to clearly make a difference by waking up its population to the deep dark secret that is killing Canadians. For them, doing nothing about radon gas in Canada is unacceptable ¹⁴⁶. The Environmental Protection Agency (EPA) is projected to lead the plan and to address the radon problem in the U.S. The aim of the plan is to annually save 3200 lives by the year 2020. The Canadian government seems to take its lead from the Americans.

A number of homes in Lehigh County, Pennsylvania were found in 2016 to have radon levels over 1000 pCi/L ²⁰². The Watras family of a husband and wife and three young children lived in this area. The husband worked at a nearby nuclear plant. One day when being monitored before entering the facility he set off radiation alarms. The radioactivity was traced to his home where radon levels over a hundred times the EPA limit were found. The EPA predicted dire

consequences as a result. That was in 1984²⁵⁷. The EPA today continues indoor radon policy based on unsupported and biased opinion¹⁹³. Today the Waltras' family is alive and healthy¹⁸⁸. Ironically, Stanley Watras went on to start a radon abatement business. Not only will implementation of radon reduction be costly but it will not save lives. The actions of WHO, EPA and ALA will paradoxically and markedly increase, not decrease, lung cancer mortality¹⁴⁵.

The level of background radiation increases with increasing elevation¹²², and lower atmospheric pressure²⁵¹. An inverse association between radon and cancer was shown by Jagger when comparing Rocky Mountain States with Gulf Coast States¹¹⁹. Hart found a mean cancer mortality rate at low elevations in the U.S. to be 73.5 ± 18.4 versus 53.9 ± 13.8 at high elevations, which was highly significant at $p < 0.0001$ (Figure 2)¹²¹. High altitude was also protective for heart disease¹²⁰. Ecological epidemiological studies of U.S. cities, using GIS software from Google Earth, have also shown significantly decreased cancer rates with increased natural background radiation levels. The association was similar in both cities and counties¹²⁵. Living at a low altitude is the second greatest cause of lung cancer (not radon) just below cigarette smoking²¹⁸. Thus, land elevation is inversely related to cancer mortality¹¹⁸. The National Institutes of Health cancer map for 2006 also showed that cancer mortality rates, particularly for lung cancer (Figure 3), were lowest in the western mountainous states²¹⁹.

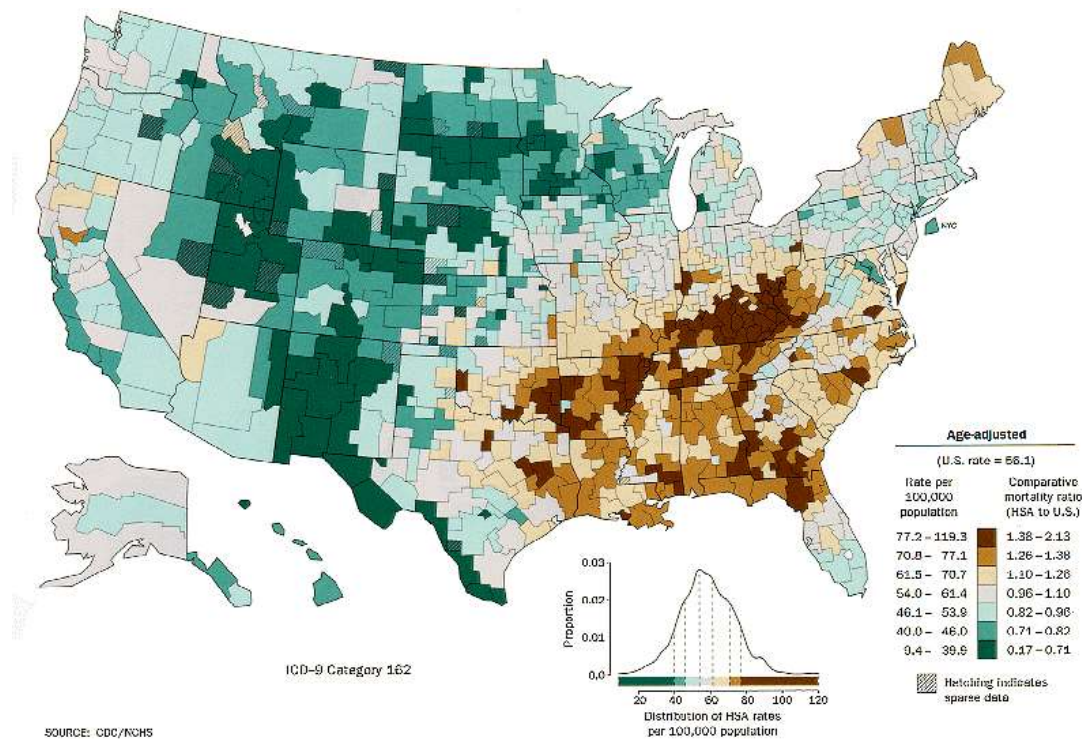
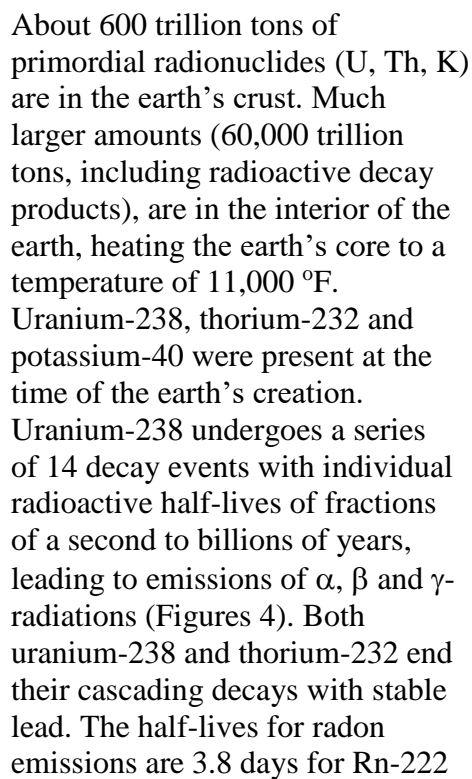


Figure 3. Lung cancer mortality rates for white males in counties of the United States. Centers for Disease Control and Prevention and National Center for Health Statistics (CDC/NCHS). Last updated 2010.
(<https://www.cdc.gov/nchs/products/other/atlas/lcwm.htm>)

Dosimetry



Over half of background radiation exposure in the world is due to radon and radon daughter exposures from radioactive decay of uranium and thorium (Figure 5). Radon has an atomic number 86, and naturally occurs from the decay of radium. Radon is 7.6 times heavier than air

A 70 kg adult, human body has 90 microgram uranium isotopes, 30 microgram thorium isotopes, 17 microgram potassium-40, 31 picogram radium isotopes, 22 nanogram carbon-14, 60 nanogram tritium, and 0.2 picogram polonium isotopes¹⁹².

and readily dissolves in water. Radon-222 emits 5.5 MeV alpha particles with a range in soft tissue of about 50 μm .

Radon and radon daughters are ubiquitous in our environment due to the dispersal of U-238 and Th-232 in soils and rocks up to several parts per million concentrations, except for much higher levels in areas of uranium concentration. Radon is an inert, colorless, odorless, heavy, radioactive gas. Surface air radon in the world averages about $1 \times 10^{-10} \mu\text{Ci}/\text{cm}^3$ (100 pCi/m³). The molecular, cellular and pathogenic mechanisms from the effects of radon are different at low doses than at high doses; beneficial at low doses and harmful at high doses ²¹.

About 30% of the dose from radon and daughter products is low LET (Linear Energy Transfer) radiation, primarily β -particles and γ -ray emissions. The biological half-life for Rn-222 in the human body is about 45 minutes. About 80% of inhaled radon is expelled from the body during the first two hours after the end of exposure. The 1993 report of UNSCEAR (the United Nations Scientific Committee on the Effects of Atomic Radiation), Sources and Effects of Ionizing Radiation, uses a radon conversion factor of 25 $\mu\text{Gy y}^{-1}$ per Bq m⁻³ with an indoor occupancy factor of 0.8 or about 7,000 h/y; a thoron conversion factor of 22 $\mu\text{Gy y}^{-1}$ per Bq/m³ was inferred for the same occupancy conditions (Table 1).

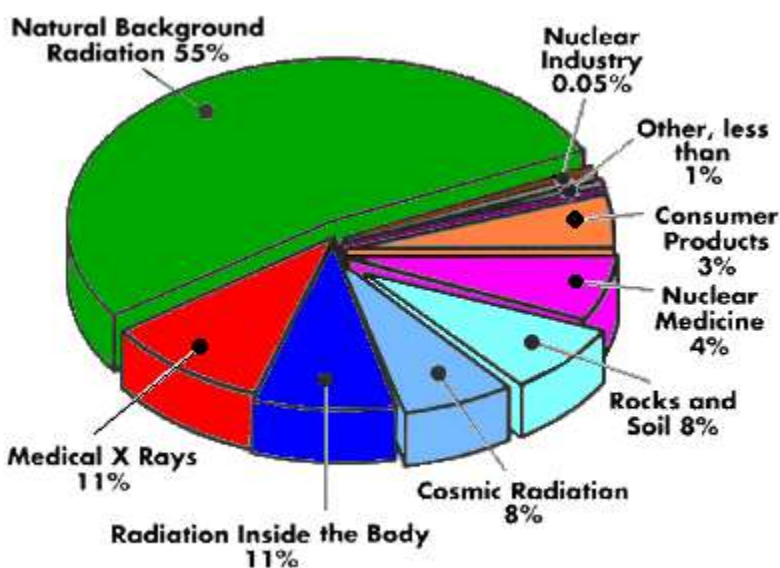


Figure 5. Human sources of radiation dose (National Council on Radiation Protection and Measurements, NCRP Report 93).

Because of the complex chain decay of uranium, radon radioactivity concentration is sometimes expressed in units of the working level (WL), particularly to measure lung dose for uranium miners. The working level is defined as the concentration of short lived radon daughters that emit 1.3×10^5 MeV of alpha energy in one liter of air; 1 WL = 100 pCi/L or 3700 Bq/m³ for radon in equilibrium with its daughter products. Exposure to 1 WL for 170 hours is equivalent to one working level month (WLM) ⁷².

One WLM delivers a dose to the bronchial epithelium of from 5-20 mGy; 500 WLM gives a lung dose of 1000 mGy which is the approximated threshold dose for alpha-radiation induced lung tumors. ICRP estimates the bronchial epithelial dose from inhaled radon to be 12 mGy per WLM for uranium workers and 9 mGy per WLM for residential radon exposure. A radon level of 300 Bq m⁻³ in homes corresponds to an annual dose to the lung of ~10 mGy ²⁰⁴.

The EPA estimates the average indoor radon level in American homes to be 1.3 pCi/L. The EPA residential action level is 4 pCi/L for air exposure and 4,000 pCi/L for drinking water exposure. A 1000 WLM dose accumulation is equivalent to a dose of ~1 Gy to the lung. Dose to the lung from residential radon should be typically expressed in Gy ²²⁰.

CONVERSION FACTORS FOR RADON UNITS

INTRODUCTION

The following conversion factors are useful for converting between units commonly used for the measurement of radon and radon decay products. For some conversion factors the following assumptions have been made and are indicated in parentheses beside the units.

- (a) the equilibrium ratio between radon progeny and the parent radon is 0.5
 - (b) the dwelling occupancy factor is 100%
 - (c) the dose conversion coefficient is 1×10^{-5} mSv per Bq.h.m.⁻³ EER (equilibrium equivalent radon concentration - ICRP-50, sec. 3.3.)
 - (d) 1 WLM is 1 WL for 170 h
- 1 WLM = 6.3×10^6 Bq.h.m.⁻³ EER
 1 Bq.h.m.⁻³ EER = 1.60×10^{-4} WLM
 (ICRP-50, section A.5)

ACTIVITY

1 becquerel (Bq) = 1 disintegration per second (s⁻¹)
 1 curie (Ci) = 3.7×10^{10} Bq
 1 picocurie (pCi) = 0.037 Bq
 1 becquerel (Bq) = 27 pCi

RADON CONCENTRATION

becquerel per cubic metre
 1 Bq.m⁻³ = 2.7×10^{-2} pCi.L⁻¹
 = 1.35×10^{-4} WL (a)
 = 0.5 Bq.m⁻³ EER (a)

picocurie per litre
 1 pCi.L⁻¹ = 37 Bq.m⁻³
 = 5×10^{-3} WL (a)
 = 18.5 Bq.m⁻³ EER (a)

RADON PROGENY CONCENTRATION

Working Level
 1 WL = 7.4×10^2 Bq.m⁻³ (a)
 = 3.7×10^3 Bq.m⁻³ EER (a)
 = 2.0×10^2 pCi.L⁻¹ (a)
 0.02 WL = 1.48×10^2 Bq.m⁻³ EER (a)
 = 4 pCi.L⁻¹ (a)

becquerel per cubic metre, EER
 1 Bq.m⁻³ EER = 2 Bq.m⁻³
 = 5.4×10^{-2} pCi.L⁻¹
 = 2.7×10^{-4} WL

POTENTIAL ALPHA ENERGY CONCENTRATION

1 Working Level (WL) = 1.3×10^6 MeV.L⁻¹
 = 2.08×10^5 J.m⁻³
 1 WL corresponds to radon progeny concentration in equilibrium with 100 pCi.L⁻¹ radon (3700 Bq.m⁻³)

RADON, RADON PROGENY EXPOSURE

Average of 1 becquerel per cubic metre Rn for a year
 1 Bq.m.⁻³y = 4.38×10^{-2} mSv (a,b,c,d)
 = 7.0×10^{-3} WLM (a,b,d)
 = 8.76×10^6 Bq.h.m.⁻³

Average of 1 picocurie per litre radon for a year
 1 pCi.L⁻¹y = 1.62 mSv (a,b,c,d)
 = 0.26 WLM (a,b,d)
 = 3.24×10^6 Bq.h.m.⁻³

Average of one Working Level for a year
 1 WLy = 51.53 WLM
 = 6.48×10^6 Bq.h.m.⁻³ (a,b,d)
 = 3.24×10^7 Bq.h.m.⁻³ EER (a,b,d)
 = 1.75×10^6 pCi.h.L⁻¹ (a,b,d)
 = 324 mSv (a,b,c,d)

Average of 1 becquerel per cubic metre, equilibrium equivalent Rn concentration for a year
 1 Bq.m.⁻³EER.y = 8.76×10^{-2} mSv (a,b,c,d)
 = 1.4×10^{-2} WLM (a,b,d)
 = 1.75×10^6 Bq.h.m.⁻³ (a,b,d)
 = 8.76×10^6 Bq.h.m.⁻³ EER (a,b,d)

Table 1. EPA Radon inhalation dose conversion factors (https://www.epa.gov/sites/production/files/2014-08/documents/conversion_factors_rn.pdf)

High Background Radiation Areas

The normal background radiation areas (NBRAs) of the world provide an average dose of about 2.5 mGy per year. However, there are many HBRAs (High Background Radiation Areas) in the world ²¹. One is comprised of thorium-enriched beach sand along the southern coast of India where the absorbed gamma dose-rate is about ten times above other areas of India (Figure 6) ⁴⁰. Other HBRA sites occur in Iran, China and Brazil ⁶³⁻⁶⁴. Beneficial effects result from a prolonged exposure to high levels of natural radiation for inhabitants of HBRAs, which are inconsistent with LNT projections ²¹⁵. The cancer risk from low-dose radiation has been highly politicized. This has led to a frequently exaggerated perception of the potential health risks from radiation to the public which is not seen in HBRA areas of the world ⁴⁶.

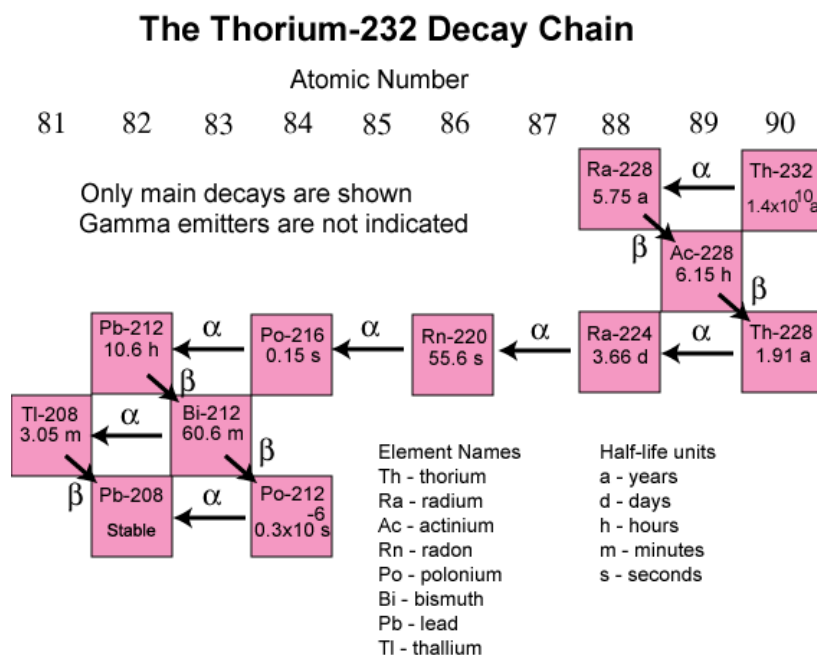


Figure 6. <https://pubs.usgs.gov/of/2004/1050/Th-232-Decay-Chain.gif>

The world's highest dose HBRA is found in Ramsar, Iran, a small city of 35,000 people. High natural levels of radon and radium, are typical of Ramsar^{66, 109}. In Ramsar, natural radiation levels are 55-130 times greater than the average global dose-rate. The annual radiation absorbed dose reaches as high as 260 mGy, which is thirteen times higher than the current annual dose limit of 20 mGy suggested by the ICRP for radiation workers. The indoor radon concentration in one region of Ramsar, comprising 2000 individuals, was up to 31 kBq/m³, a concentration that is over 200 times higher than the action

level recommended by the EPA of 148 Bq/m³ or 4 pCi/L⁶¹⁻⁶².

Many homes in Ramsar are constructed from limestone containing RaCO₃ giving in-home radon levels of 100 pCi/L or 3700 Bq/m³; some residential radiation levels were >100 µGy/h. Some want to 'protect' inhabitants of Ramsar by making it into the Ramsar Research Natural Radioactive Park¹²⁸ and evacuating it's citizens. Myron Pollycove addressed the question, "What is safe?" In visiting Ramsar, Iran—Pollycove was impressed by the fact that public health and longevity is better in the high-radiation parts of the city. He pointed out that the DNA in our cells is constantly being destroyed and reconstituted, and it is becoming apparent that low doses stimulate the reconstitution process. Pollycove's conclusion based on observations in Ramsar: We don't have to worry about chronic radiation¹²⁷

There are at least nine hot springs in Ramsar that are used by tourists and residents as spas. The people and their ancestors have been exposed to these high radiation levels over many generations. Yet, adverse health effects attributable to radiation have not been seen.

Up until 1991, over a thousand students had attended Saeid Nafisi primary school in Ramsar. The background radiation dose was 28 µGy/h giving an annual dose of ~250 mGy/y. Students who are now a mean of 27 years old, who studied at the school for at least five years, were examined for health problems. No significant differences were noted between matched controls. In fact, there was a small positive beneficial difference in students from Saeid⁴¹.

Ramsar is divided into eight health districts with a health center that provides primary health services in each health district. Indoor radon concentration levels were previously measured in each dwelling by the Iranian Nuclear Regulatory Authority. The overall cancer mortality, lung cancer mortality and neonatal death rate of different districts were collected. The highest radon level residences were located in Ramak. The highest lung cancer mortality rate was in Galesh Mahaleeh, where the radon levels were normal. On the other hand, the lowest lung cancer

mortality rate was in Ramak, where the highest concentrations of radon in the dwellings were found⁴³; overall, there was no increase in total cancer risk¹⁸⁹.

Cytogenetic, immunological and hematological studies on the residents of high background radiation areas of Ramsar demonstrate similar adaptive responses. Lymphocytes of Ramsar residents when subjected to 1.5 Gy of gamma rays showed fewer induced chromosome aberrations compared to residents in a nearby low-background dose control area⁴².

Thirty five individuals from a HBRA and 35 individuals from a normal background radiation area (NBRA) were randomly selected from districts of Ramsar. Among the eight biomarkers investigated, the mean concentration of PSA, CA15.3, CA125, CA19.9 and AFP between the HBRA and NBRA were not significantly different. However, Cyfra21, CEA and Tag72 in the HBRA group revealed statistically significant increases compared to those of NBRA group ($P < 0.05$)⁴⁴. Cancer mortality rates in Ramsar from 2007 to 2012 for GI, breast, leukemia, bone, gynecological, skin and urinary tract cancers in the residents of HBRA were lower than those of the nearby normal background radiation areas (NBRA) ⁴⁵.

Uranium Mines

The Paracelsus paradigm, “the dose is everything,” is ageless. The concept that small doses of poisons are stimulatory was verified experimentally by a Greifswald pharmacist, Dr. H. Schulz, in 1888 for mercury, chromium, arsenic and iodine with studies using yeast cultures. This established the Arndt-Shultz law, which generalized, said that sufficiently diluted toxicants should have a beneficial effect on the organism.

Sixty miles from Prague, Czech Republic, are the 16th century silver mines of Joachimsthal. Silver coins from the mine were called ‘thalers’ which became dollars in English. The mines produced a black, pitchy, heavy nodular mineral called pitchblende. Martin Klaproth (1743-1817) named the most prominent element in pitchblende, uranium. It was from pitchblende that Pierre and Marie Curie laboriously separated and named the first samples of new elements, radium and polonium⁶⁷. In 1898 Marie and Pierre Curie also found a radioactive gas emanating from radium purified from pitchblende uranium ore⁵⁹. Radon-222, a daughter product of radium, was characterized in 1900 by Dorn.

The world’s land-based uranium resources will suffice for the next 470,000 years at present usage rate according to the IAEA (2008). There are 4 billion tons uranium dissolved in seawater (3 parts per billion) that is continuously replaced from 100 trillion tons of uranium in rocks on land. Polyethylene fibers coated with amidoxime (which binds with uranium) placed in seawater for 50 days yields 6 grams U per kg fiber at a cost today that is only double the current price for mined uranium¹⁹⁷.

Radon levels in the Joachimsthaler mine reached as high as 1,000,000 Bq/m³. Paracelsus (1530) described a wasting disease in Czech miners and Agricola recommended ventilation in mines to avoid this sickness. The sickness was identified as pulmonary fibrosis and lung cancer in 1879. Up to 1926, as many as 75% of miners working in these mines had died from lung fibrosis and cancer. Miners at Joachimsthal and nearby mines at Schneeberg, Germany also showed a remarkable increase in lung cancer mortality rates soon after cigarette smoking became popular. The first cigarette manufacturing facility was built in 1862 in Saxony. After this smoking and not radon became the greatest contributor to lung cancer in miners in men. Female lung cancer rates were inversely proportional to indoor radon levels¹³⁷.

The Czech miners worked under very difficult and generally unhealthy conditions and frequently suffering (and dying early) from lung diseases. However, they had less problems with arthritis and other inflammatory diseases than did non-miners. Miners with lower doses from the mine experienced these health benefits¹³⁸. Their family members and town people drank water which originated in the mines and used pitchblende- packages for the external treatment of inflammatory diseases. A ‘clinic’ or spa was opened up in Joachimsthaler. The residents knew of the healing properties for painful inflammatory conditions, such as arthritis, from the mine air at its entrance for centuries before⁶. Bruschiu wrote in 1548 in a description of the high-radon Fichtelgebirge/Germany: Here people get very old, have few diseases, and recover quickly if they have any. Werner Schuttmann, and Klaus Becker of Germany, both showed that women in the very high radon uranium mining areas of Saxony, Germany, had significantly lower lung cancer rates than women in lower radon areas, irrespective of smoking habits. In spite of the evidence, the Health Physics Journal denied publication of a Schuttmann and Becker article documenting these historical findings^{6-7,72}.

Po-210 is an alpha emitter and radionuclide formed by the decay of U-238 that accumulates on the tri-chromes found on the underside of the tobacco leaf. A two-pack-a-day smoker receives ~100 mGy) per year to bronchial bifurcations in the upper respiratory tract from Po-210.

Uranium Mine Location	Threshold, mSv
Yunnan, China	1000
Colorado Plateau, US	3000
Newfoundland, Canada	2000
Malmberget, Sweden	250
Grants, New Mexico, US	1000
Eastern Germany	4000

Table 2. Threshold dose for lung cancer in non-smoker underground miners²¹

Smoking is the greatest contributor to lung cancer in uranium miners and other nuclear workers^{22, 200}. Radon is not the second greatest cause of lung cancer. It is high levels of radon combined with cigarette smoking. Few lung cancers are seen in never smokers that can be attributed to radon²⁵³. A study of eleven underground uranium miner cohorts showed a variable dose-response relationship between WLM and lung cancer based upon how well each study controlled for the confounding factor of cigarette smoking. Several studies showed a

lung cancer threshold >1000 mSv to the lung (Table 2). In U.S. uranium mines, the radon levels averaged 1800-2900 pCi/L, with levels as high as 50,000 pCi/L measured in certain parts of the mines. The relative risk of lung cancer was 29 for miners with lung doses > 1,450 WLM compared to those exposed to < 80 WLM. A threshold of about 500 WLM was seen for lung cancer formation in non-smoking uranium miners²¹⁻²². For Chinese tin miners and German uranium miners, the threshold was 600-800 WLM. The German miner study emphasized the role of smoking status in its analysis. Smoking status was not carefully evaluated in U.S. uranium miner epidemiological studies²². Where it was considered, as in the German study, the lung cancer threshold dose in smokers appeared similar to that in non-smoking U.S. uranium miners.

A fascinating lifespan study in rats exposed to sequences of radon and tobacco smoke was carried out by French radiobiologists in the 1990s²⁴. Heavy tobacco smoke given alone failed to induce any lung tumors. Heavy radon exposure given by itself induced an incidence of 22% lung tumors. When radon was given prior to exposure to tobacco smoke the lung tumor incidence soared to 78%. However, when the tobacco smoke was given before radon exposure the lung tumor incidence was only 16%. This corresponds to the idea that heavy smokers should get one or more of the older whole-body CT scans a year to prevent lung cancer formation²². An

increase in pulmonary health issues, including lung cancer, has not been found in pets living in homes with high radon levels ¹¹⁵.

Dr. Geno Saccomanno (1915-1999) carried out research on the relationship of radon daughters and cigarette smoking in the development of lung cancer in uranium miners of the Colorado Plateau, starting in the 1950s. He found that few non-smoking uranium miners developed lung tumors even at high exposures of radon. The majority of lung tumors seen in uranium miners were of the oat cell or small cell undifferentiated carcinoma type (57%) as compared to a much lower incidence distribution in non-mining smokers (18%) or in non-mining nonsmokers (6%).

Dr. Saccomanno pioneered the use of sputum cytology for lung cancer screening. Exfoliative sputum cytology was used to document the progression of early metaplastic lesions to early carcinoma *in situ* and malignant invasive tumors in the tracheobronchial tree. Abnormal cytology findings were up to 10 times more frequent in smoking uranium miners than in nonsmoking uranium miners. In addition he observed a clear threshold in radon mine exposure for lung cancer in uranium miners ²⁵⁻²⁶. In uranium miners with documented radon exposure levels, he found 35 lung cancer cases in smokers at <300 WLM and no lung cancer cases in non-smoking miners at <300 WLM ⁶⁵. He recommended a maximum allowable level of radon in homes at 20 pCi/L (0.10 WL) ²⁵.

In a letter written on May 14, 1998 by Dr. Geno Saccomanno of St. Mary's Hospital, Grand Junction, Colorado, concerning the role of cigarette smoking and radon threshold in lung cancer, he wrote: Please note that the miner with the lowest exposure was diagnosed with lung cancer sustained 250 WLM. We have 44 miners who developed lung cancer and were non-smokers. Since none were found to have less than 250 WLM that would indicate that radon exposure is not linear and that all the talk about radon in the homes at 4 pCi is not justified. We agree that 20 pCi is a conservative level. All of the research by the EPA has not found any cases of lung cancer in homes of non-smokers, but they still insist on ventilation of homes with radon levels higher than 4 pCi. I hope that my testimony at the congressional hearings help stay the development of a law forcing the EPA recommendations.

Residential Radon

The risk of lung cancer from residential radon is largely derived from exposure of bronchiolar epithelial cells exposed to high LET α -particles. Currently this risk estimate is extrapolated from uranium miner data, which are delivered at much higher doses and dose-rates. Annual worldwide cancer mortality is 7.6 million. There are about 1.5 million new cases of lung cancer diagnosed in the world every year accounting for 1.2 million deaths or 18% of global cancer deaths. Lung cancer is the most prevalent cause of cancer mortality in the U.S. accounting for nearly 30% of all cancer deaths. About 90% of worldwide and U.S. lung cancer deaths are due to cigarette smoking. All cancer incidence and lung cancer incidence are not increased in populations living in proximity to uranium mines, mills or processing operations ²¹.

In 1988 the maximum Canadian indoor radon level was set at 800 Bq/m³ (21 pCi/L); the U.S. guideline was set at 148 Bq/m³ (4 pCi/L) ²⁸. The government in Ontario, Canada, is currently debating a bill, Radon Awareness and Prevention Act that would regulate radon in homes to a level similar to the U.S.. This law will create unwarranted anxieties, stress and radiophobia as well as influence the value and sale of homes. This has already happened in the U.S. due to over-regulation by the EPA. It is not feasible to completely eliminate radon from indoor air. Typical

radon mitigation systems are available to homeowners that currently cost between \$1,000 and \$5000.

The linear extrapolation of lung cancer at high radon levels as found in underground uranium mines to very low levels of radon found in residences is well proven to be false in epidemiological and in animal studies²¹. The EPA radon gas action levels for lung cancer risk prediction in homes is taken mostly from data associated with lung cancer in high radon containing uranium mines as applied by the National Academy of Sciences in 1999¹¹⁴. The EPA has failed to find increased lung cancer due to radon in non-smokers at radon levels <100 pCi/L. Increased lung cancer has not been found in U.S. non-smoking uranium miners at <60 pCi/L²³.

The EPA has established radon exposure limits in homes and other dwellings in the U.S. based on the LNT assumption that there are 21,600 deaths from lung cancer each year from residential radon (Figure 7); this is more than deaths due to falls in the home, drownings and house fires combined²⁰⁵. The EPA estimate of indoor radon lung cancer deaths was obtained by the use of collective dose which has been disproven by radiation protection organizations.

$$\begin{array}{lcl}
 240,000,000 \text{ persons} & \times & \frac{0.25 \text{ WLM}}{y} \\
 (\text{approximate size of} & & \\
 \text{U.S. population}) & & \\
 \hline
 60,000,000 & \times & \frac{360 \text{ deaths}}{1,000,000 \text{ person-WLM}} \\
 \text{person-WLM} & & (\text{age-averaged rate of} \\
 & & \text{radon-induced lung-cancer deaths}). \\
 \hline
 & = & 21,600 \text{ deaths due to} \\
 & & \text{radon each year}
 \end{array}$$

Figure 7. Calculation of radon related lung cancer deaths from determination of collective dose.

There is a large number of constituencies that would prefer the status quo of the LNT as they have financially benefited over the past 50 years by the fear of radon. This includes regulatory agencies and advisory bodies, universities, individual scientists, particularly epidemiologists, and their 'research' dollars, journals and publishers and manufacturies of radiation security and service products used for radon abatement and tens of thousands of local

EPA thinks all radiation can potentially kill you with cancer, and recommends radon testing and remediation if radioactivity exceeds 4 pico-curies per liter of air. Note that humans naturally contain about 200,000 pico-curies of radioactivity. EPA's radon deaths are only based on an invalid theory called LNT. They are **not** observed, unlike the drunk driving deaths and others²¹⁶⁻²¹⁷. The cost for radon home testing is about \$40²⁵².

business testing and installing radon mitigation systems in homes. These groups are very unlikely to sponsor seminars, symposia or other scientific meetings to challenge their 'advantageous' positions on the LNT. Remediation of radon costs money, scares away possible home buyers

and decreases the value of the home while increasing in most cases the risk of lung cancer. The cost to remediate in U.S. homes for 1994 was estimated at 50 billion dollars. It is considerably more today. Follow the money for radon mitigation. The average cost per life 'saved' using an action level of 4 pCi/L is \$700,000; actually that is the cost to needlessly take another life that would have been saved by exposure to 4 pCi/L or higher radon levels. The high cost of radon

remediation is a financial boondoggle with the human cost in lives being very high by removing low doses of radon.

Numerous epidemiological studies of environmental radon have clearly demonstrated the benefit of living in high radon regions of the world. There is no relationship for early childhood deaths or cancers associated with living in HBRA areas ¹³⁰. A recent study found that children living in Switzerland are exposed to relatively high levels of indoor radon, giving an annual dose to the lung up to 20 mGy (the mean radon dose in the U.S. is ~1 mGy). A decreased risk of about 10% was observed for cancers common in Swiss children ²⁷ (Table 3). Cancer mortality in Poland is lowered in high radon level areas by 1.2%/mGy/year for all cancer deaths and by 0.82%/mGy/year for lung cancer deaths ⁸³. High radon exposure in Hungarian lowered overall cancer risk in women younger than 61 years ¹¹².

Colorado, where the author now lives, has one of the highest residential radon concentrations in the U.S.

The best remedy to prevent lung cancer is to STOP smoking.

The highest recorded levels of radon in buildings have been observed in several cities of Colorado built with and /or upon uranium mine tailings. Fifty of Colorado's 62 counties have indoor radon levels >4pCi/L. The mean radon level in the U.S. is 1.2 pCi/L; in Colorado it is 7.3 pCi/L. Mitigation for residential radon levels in Colorado shows average radon levels of 480 Bq/m³ before and 51 Bq/m³ after mitigation ²⁴⁵. According to regulations promulgated by EPA, nearly the entire state of Colorado needs to undergo remediation or evacuation to avoid a thousand excess lung cancer deaths a year. Yet mortality from cancer of the lung in Colorado is 25% less than the national death rate. In 2014 the U.S. death rate per 100,000 for all cancers was 192; in Colorado ski country it was 70. Six of the ten counties in the U.S. with the lowest cancer death rates are in the Colorado Rockies. Death rates for breast and colorectal cancers in Madison County, Mississippi in 2014 were five times higher than in Summit County, Colorado ²²².

Country	Mean Radon in Homes (pCi/L)	Radon Action Level (pCi/L)
United States	1.2	4.0
Czech Republic	3.7	5.3
Norway	1.5	5.3
United Kingdom	0.5	5.3
Germany	1.3	6.7
Sweden	2.9	10.7
Switzerland	1.9	26.7

Table 3. Mean radon levels in homes and radon action level in countries of Europe and the United States.

The sad fact is that remediation of indoor radon at 4 pCi/L does not 'save' 21,600 lives per year in the U.S. from lung cancer. Radon remediation at 2-10 pCi/L is much more likely to cause the needless, premature death of thousands of persons from lung cancer. That is because residential exposure to low levels of radon stimulates radiation hormesis which protects against lung cancer formation, 90% of which is caused by cigarette smoking. The best method for preventing lung

cancer in smokers, other than to quit smoking, is to receive an annual older-type CT scan that delivers a whole-body dose of 10-20 mGy or sit in an uranium mine for a few hours a day for ten days. This therapeutic strategy has the potential for significantly reducing lung cancer risk in smokers and non-smokers ²².

The notion that exposure to the radioactive emissions associated with radon and its decay products increases the risk of lung cancer is part of conventional wisdom during the last twenty-five years. EPA and BEIR IV and VI have misrepresented the data on the lung cancer risk of residential radon in the United States. Some call it the radon fraud ¹¹¹. Bernie Cohen (1923-2013) initially started his 4-year radon study to confirm the LNT. His sample size was very large and his results were the opposite of what he expected. In 1995 Bernard Cohen found a highly significant negative correlation between radon exposure and lung cancer mortality in the U.S., even after adjusting for smoking and other socioeconomic factors ²⁹. The study involved about 300,000 radon measurements in over 1600 counties, representing 90% of all counties in the U.S. This result held up under extensive adjustment, with over 500 factors being examined for confounding. Cohen concluded that there was no evidence from this study that low-level radon caused lung cancer at low radon level posited by EPA to cause lung cancer. What Cohen observed was a marked reduction in lung cancer. This was a conclusion that even Cohen had not expected when starting his study.

James Muckerheide published an excellent review of the work of Bernie Cohen and the unwarranted attacks on his work. Cohen's work was vindicated after the intellectual biased smoke had cleared. Cohen had overwhelmingly demonstrated the benefits of residential radon against all skeptics and continued to fight the radiation protection establishment for the rest of his life (Figure 8). Mukerheide's words are given nearly verbatim below ³⁰: "In the 1980s, Dr. Bernard Cohen, at the University of Pittsburgh, personally undertook natural background radiation studies similar to those terminated by the Atomic Energy Commission in 1973 (and by AEC's successors, ERDA and later DOE, and the NRC). He tested the LNT using the significant lung cancer data compared with variations in residential radon. Initially, he found that lung cancer incidence in the high-radon area of Cumberland County, Pennsylvania, was lower than the Pennsylvania average ³¹. Many other studies found similar results.

Because radon data did not exist at the county level, Dr. Cohen obtained at least 100 radon measurements in the 16 large counties with the lowest lung-cancer rates, and the 25 counties with the highest rates. He also found identical results in the various random counties in which 450 university physics professors at 101 universities supported his effort to obtain residential radon measurements.

Dr. Cohen then succeeded in a private effort to do, for radon and lung cancer, what the U.S. government had terminated with the Frigerio study—measuring radon in 272,000 homes in the most populated U.S. counties. These data also consistently found inverse results, in dozens of independent studies of, for example, "all-rural" counties, "all urban" counties, and so on ²⁹. Dr. Graham Colditz of Harvard University, a world renowned epidemiologist, contributed to an interim analysis of the data by counties. He confirmed the validity of the epidemiological analysis of these data ³².

Bernie Cohen did not believe his initial results. He sought the help of a statistician with the intention of finding the confounding influences that made his study appear to demonstrate a counterintuitive result. Together they examined over 500 combinations of confounders; the result showed the same trend, that radon lowered lung cancer rates.

Dr. Cohen also acquired all EPA and state radon data that represented the experience of about 200 million Americans. These data showed an inverse relationship: the higher the radon levels, the lower the incidence of lung cancer. In the full data set, the inverse correlation exceeds 20 standard deviations, compared with the predictions of BEIR IV. The chance of error is equivalent to one in all the electrons in the universe! Any confounding factor must be: (1) much greater than smoking, (2) inversely correlated with radon, and (3) unrecognized. This is inconceivable—except for one postulate: Radon doses at the range of normal background levels stimulate lung tissue functions to protect against lung cancer.

Cohen's conclusion was that a radon exposure to 4 pCi/L did not cause lung cancer but did prevent about 60% lung cancer expected mostly from cigarette smoking. Paradoxically, decreasing radon levels to <1 pCi/L increased lung cancer risk. Only at higher radon exposures of 50 pCi/L does one expect an increased risk of lung cancer³⁴⁻³⁵

Radiation-protection interests ignore the confirmed results of Cohen et al. by alleging simply that “they are ecological studies”; these critics provide no scientific basis to refute the data. In fact, there is no documented scientific criticism of Dr. Cohen's results, just general rationalizations of highly unlikely reasons why one study might not be valid. In fact, Dr. Cohen has produced dozens of separate studies that are consistent. Nevertheless, radiation protection interests use unfounded statements to misrepresent to the

public that Dr. Cohen's data have been refuted.

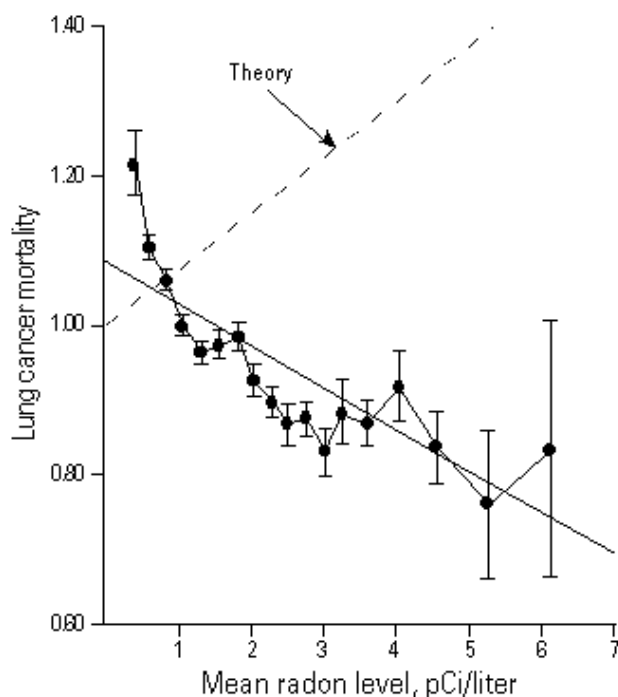


Figure 8. Lung cancer mortality rates compared with mean home radon levels in U.S. counties and comparison with linear model by BEIR IV adopted by the EPA²⁹. (With kind permission by Springer, Charles L Sanders: Radiation Hormesis and the Linear-No-Threshold Assumption, © 2010).

Dr. Kenneth Bogen at Lawrence Livermore National Laboratory independently compared 1950-1954 lung cancer mortality for women of ages 40 to 80 and 60 to 80 (who had smoked little), in 2821 U.S. counties, with EPA county environmental (not residential) radon data. He also confirmed the inverse correlation between lung cancer and radon. Dr. Bogen's biological model applies cellular response data to show that the inverse relationship is consistent with known biological responses^{33, 113}.

LNT supporters erroneously claim that “case-control” studies are “better.” However, the accuracy of such studies is completely dependent on the ability to know individual doses. This is true in most case-control studies where doses/exposures are measured and controlled. However, in most radon case-control studies, individual doses are poorly known... Therefore, “dose groups” are only statistical estimates, without knowing individual doses. Further, with the small numbers in the sample, combined with the uncertainty of the correlation, there are wide errors. Unlike large population studies, case-control cannot produce accurate or replicable dose-response results. In fact, in contrast, the nature of statistics provides statistical power in large ecological studies, because these apply

rigorous statistics that more accurately represent mean doses compared with lung cancer rates.

In addition, the uncertain doses in most radon case-control studies produce much greater bias in the higher-dose region. The high-dose group is likely to include persons who have low-doses, while it is unlikely that the low-dose group will have persons with high-doses. Therefore, the high-dose group will have a bias toward excess cancers that will seem to be shown to result from low radon exposures. In addition, case-control studies do not adequately address cases in the very low-radon regions, where the well-documented effects in Dr. Cohen's data (as well as those in other, more definitive population studies), demonstrate that increased lung cancer is expressed. However, despite all the problems with case-control studies, it has been shown that they do not contradict the results reported by Dr. Cohen and others."

Natural background radiation varies by geographic location up to three orders of magnitude (0.7 to 700 mGy/y). No increase in mortality or decrease in longevity has been observed in people living in high dose regions ²¹. A powerful protective effect against lung cancer was found at radon levels ≥ 2 -6 pCi/l. However, lung cancer mortality increased up to 25% at radon levels ≤ 1 pCi/l ²⁹. This demonstrates the harmful effects of radiation deficiency. These observations indicate that we need our minimum daily requirement of ionizing radiation to achieve optimum health.

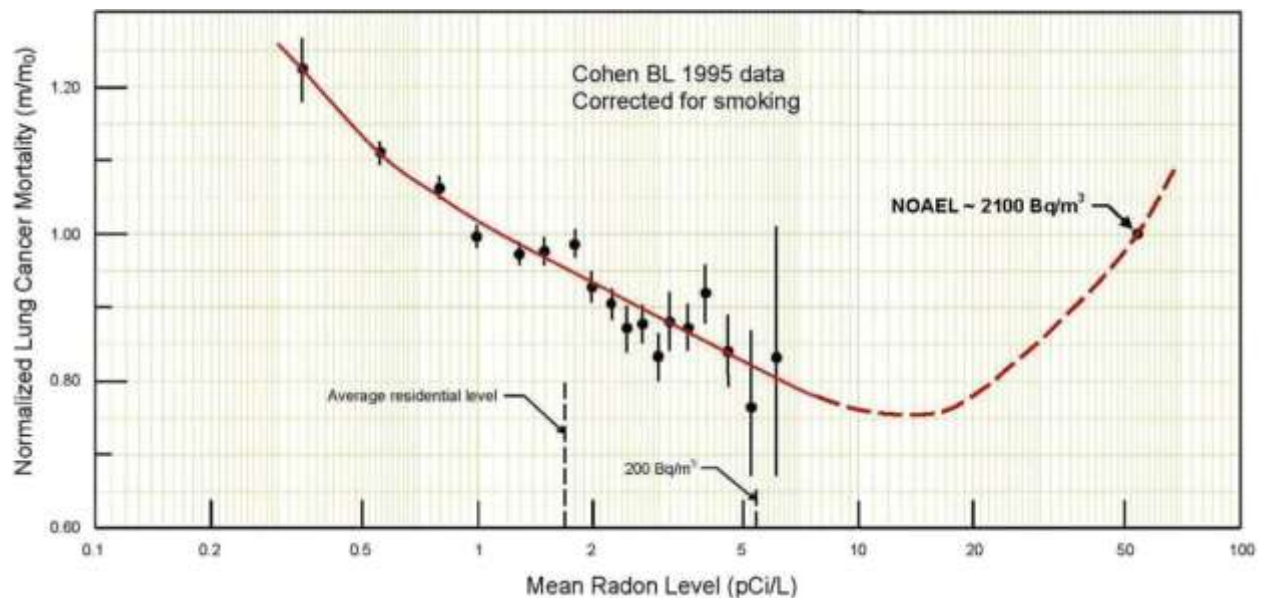


Figure 9. The ratio of lung cancer mortality for residential radon levels was compared to that for U.S. average residential level of 1.7 pCi/L. Residential radon prevents lung cancer at levels which the EPA says should be avoided. At radon levels < 1 pCi/L that the EPA recommends remediating, there is a substantial increase in lung cancer (With kind permission of Jerry Cuttler) ³⁴.

Interestingly, lifetime exposure to residential radon at the Environmental Protection Agency's action level of 4 pCi L^{-1} is associated with on average a $> 60\%$ reduction in lung cancer cases from very low radon levels ^{29,60}. The BEIR-IV (EPA) linear model (theory dashed line) shows an increasing risk of lung cancer with increasing radon level ^{29,31-32}. Age-adjusted lung cancer rates versus residential ^{222}Rn level for counties in the U.S. show similar declines in lung cancer for both males and females.

Cohen's lung cancer mortality data, from his test of the LNT theory, do not extend to the No Observed Adverse Effect Level (NOAEL) above which inhaled radon decay products begin to induce excess lung cancer mortality. Since there is concern about the level of radon in homes, it is important to set the radon limit near the NOAEL to avoid the risk of losing a health benefit. The NOAEL for radon-induced lung tumors was estimated to be about 2100 Bq/m³. The U.S. Environmental Protection Agency should consider raising its radon action level from 150 to at least 1000 Bq/m³. The annual mean absorbed dose to the lung from 300 Bq/m³ is 7.1 mGy. The annual mean lung dose from 2100 Bq/m³ is 50 mGy. The NOAEL from inhaled radon was estimated to be 2100 Bq/m³ or 50 pCi/L (Figure 9) ³⁴.

Thus, residential radon does not cause lung cancer but rather protects, in an exposure-level-dependent manner, from cigarette-smoke-related carcinogens and oxy-radicals. Radon exposure also gives a very strong negative correlation for smoking-induced cancers of the mouth, larynx, and esophagus, similar to the negative association seen with lung cancer ³⁶.

There are many pitfalls to meta-analyses of lung cancer studies from indoor radon, such as the study published by Lubin and Boice ⁷⁷: these include data manipulation, inaccuracies, inadequate consideration of confounding factors, particularly dosimetry and smoking, and force-fitting data to the LNT. There have been nearly thirty case-control, epidemiological, indoor radon studies carried out in the world. The pooled Bayesian analysis of 28 radon studies shows that there is no evidence for lung cancer risk increase in low dose range ⁷³. Most were poorly controlled for smoking status and dosimetry ²¹⁻²². As with uranium miners, controlling for smoking status is critical since most lung cancers are due to smoking. The relationship between indoor radon exposure and relative risk of lung cancer from a meta-analysis of 20 case-control studies showed no correlation of increased risk of lung cancer with increasing radon level ²¹.

In a meta-analysis of thirty-two case-control and two ecological studies concerning the influence of radon on the risk of lung cancer, found that radon concentrations below ~1000 Bq/m³ (~20 mSv/year of effective dose to the whole body) failed to demonstrate that radon is a cause of any increase in lung cancer incidence ²⁴⁴. A similar observation was made in an earlier study of 20 case-control studies (Figure 10) ²¹.

A radon concentration of 1000 Bq/m³ gives a cumulative lung dose after 91 years of 2.3 Gy in humans, the apparent threshold for increased risk of lung cancer ⁸⁴. All of the existing radon studies can be easily analyzed together as one meta-study, leading to the conclusion that there is no evidence for excess lung cancer risk below 800 Bq/m³ ⁷³. Even when excluding studies that demonstrate benefit from inhaled radon from analysis there is no evidence of increased risk ⁸⁵.

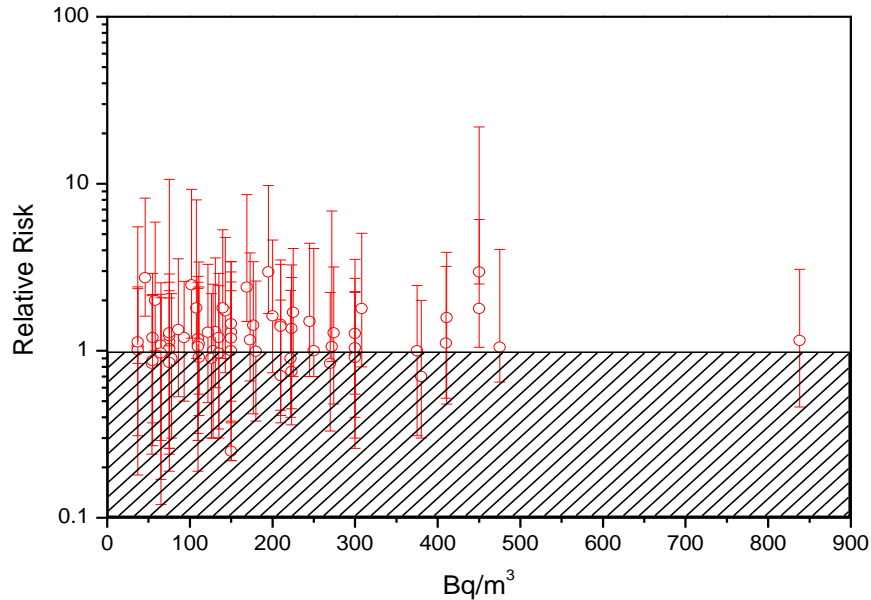


Figure 10. Relationship between indoor radon exposure and relative risk of lung cancer in 20 case-control studies (With kind permission by Springer, Charles L Sanders: Radiation Hormesis and the Linear-No-Threshold Assumption, © 2010).

The best indoor radon case-control study was performed by Thompson who initially was a proponent of EPA radon regulations and the LNT assumption³⁷. His study was controlled for nine categories of smoking with extensive year-long radon dosimetry in homes. The first four radon exposure levels showed significant evidence of radiation hormesis (Table 4). Linear spline is a statistical continuous function formed by connecting linear segments along a dose-response curve. Radon exposure in Thompson's study was evaluated using linear spline terms to model for nonlinearity. Linear spline superimposed on smoothed data for lung cancer and radon concentration showed that radon levels $>400 \text{ Bq m}^{-3}$ were associated with decreased lung cancer incidence³⁸; this equates to a threshold for lung cancer formation of 600-800 WLM.

A recent study of indoor radon and lung cancer in residents of Guam showed a similar response as shown by Thompson³⁷. Radon concentrations that exceeded levels of 3 pCi/L up to 18 pCi/L showed a negative correlation with lung cancer strongly suggesting a hormetic effect. Similar to the results of Cohen, radon levels $< 2 \text{ pCi/L}$ on the dose-response curve were associated with a markedly increased incidence of lung cancer; the linear correlation was significant at $P < 0.005$ level³⁹. Other European studies have also shown no correlation or a negative correlation between lung cancer and low radon concentration⁷¹⁻⁷². A German indoor radon study showed a clear threshold for lung cancer risk which was over 20 pCi/L ²¹.

Radon (Bq m ³)	RR	95% CI
<25	1.00	-
25-49	0.53*	0.24-1.13
50-74	0.31**	0.13-0.73
75-149	0.47*	0.20-1.10
150-249	0.22*	0.04-1.13
>249	2.50	0.47-13.46

Table 4. Most case-control indoor radon studies were poorly controlled for smoking status and dosimetry. This study was controlled for nine categories of smoking with extensive year-long dosimetry. The controls were individually matched to cases. The authors claim that this study is among the most careful ones in both data collection and analysis and that they were totally surprised by the results (*p <0.1 **P <0.05) ³⁷.

Radon Spas and Clinics

For several millennia, the use of special locations for healing, later shown to contain high levels of radium and radon, were known throughout the Roman Empire. The identification and use of mostly ²²²Rn for therapeutic purposes in medicine has been carried out for over a 100 years. There are several potential sources of radon in the environment that have been used for a variety of therapeutic approaches. These include radon in drinking water and air in caves, mines and high-background radiation regions of the world. Today radon therapy is delivered in monitored emanatoriums, baths, spas, saunas and pools.

Centenarians may live in concentrated, scattered pockets as diverse groups around the world. Some live on a vegetable diet while others live on a high fat diet. Some live on the coast and some live in the mountains. The right genetics, hard physical work and lack of pollution with clean drinking water do not fully explain the elevated lifespans. The most common feature appears to be the presence of natural hot springs. In Japan, 42% of centenarians live in Okinawa, which is laden with radioactive ‘sacred springs’ containing high radon levels. The people who live on the island called ‘Land of Immortals’ because of their long lifespan. Centenarians are concentrated at the foot of Nanshan Mountain in China, in Vilcabamba, Ecuador, in Nuora Province, Sardinia and in Tbilisi, Georgia. The male/female ratio of centenarians in Sardinia is 1:1 as compared to 1:5 in the United States. Tbilisi means ‘hot springs’; the city has over 60 natural, thermal baths. An Ecuadorian cardiologist in 1969 found the citizens of Vilcabamba to be largely free of arteriosclerosis, heart disease, cancer, diabetes and arthritis. Sardinia was also famous for its healing hot springs in Roman times ²⁴⁸.

JJ Thompson, discoverer of the electron, in 1903 found radioactivity in well water and discovered that every famous healing hot spring was radioactive.

There are many ancient accounts of temples and gods/goddesses associated with healing and spas containing ‘healing waters’ ^{2,75-76}. Asclepius was a student of Hippocrates and the god of healing for the Greeks and Romans. The most famous locations of

asclepiad temples of healing are found in Ikaria, Trikala Gortys in Arcadia, Epidaurus in northeastern Peloponnese, and Pergamon in Asia Minor. Temple ruins remain today at all sites. The Romans expanded the asclepiad temple in Arcadia into a lavish spa. Epidaurus contains today a mineral springs still used for healing; its asclepiad ruins had 160 quest rooms for patients. Kos also has health spas today. The nearby island of Lesvos advertises a radon spa with low doses of Rn-222 (10-304 Bq/l); however, the annual dose to its fulltime employees approaches doses of 20 mGy. Other ancient spas found in northern Italy have radon levels in water between 2,000 Bq/l (Merano) and 40,000 Bq/l (Lurisia) ^{5,74}.

Yiannis Karimalis moved to Ikaria, Greece in 1970 after learning he would die in months from stomach cancer. In 2009 he found that he had outlived all his doctors ²⁴¹.

The Greek island, Ikaria, has one of the most long-lived populations in the world. Its radon/radium hot spring has been used for therapy for 2500 years. Significantly high levels Rn-222 and gamma irradiation were found in spring water and some soil and rock samples. Water borne Rn-222 gives a maximum dose rate to inhabitants of Ikaria of 35 mSv/y ²⁴². Most of today's island residents regularly visit the ancient springs. The residents are known to have 20% less cancer, 50% less cardiovascular disease and almost no dementias, with a long lifespan (30% live longer than 90 years of age). The average age at death from natural causes is nearly ten years greater than in Greece in general" ²⁴³. The curative properties of the island were known to Herodotus (484-410 B.C.); he recommended a 21 day stay at Ikaria for 'cure' ¹¹⁰. Today, conditions and diseases successfully treated in radon spas of Ikaria using the model of Herodotus include neuralgia-neuritis (including Parkinson's disease), acute and chronic athropathy, skin diseases, respiratory diseases, gout, infertility, osteoporosis, post-traumatic and post-surgical conditions and chronic fatigue syndrome ¹¹⁰.

People with health problems would come to the Asclepion to be healed of a wide variety of diseases. Those who were healed would give a thanksgiving offering to the gods that was representative of their illness or the body part that was healed. Hygela, the daughter of Asclepius and goddess of health and hygiene is found on coins discovered in Jerusalem (Jerusalem was renamed Aelia Capitolina by the Roman ermpperor Hadrian); she is seated feeding a serpent. A serpent encircling Asclepius's rod are still symbols of medicine and pharmacy today ³⁻⁴.

The temple to Asclepius in Pergamon is mentioned in the Bible (Revelation 2:12-13). [*Here a great number of disabled people used to lie—the blind, the lame, the paralyzed* (John 5:3)]. It is here that Jesus healed a man lame for 38 years. The mystic cist was a small box carried in the processions at the Greek festivals for the gods Demeter and Dionysus; the box contained the images of the deities. These images appeared on a series of large silver coins called cistophori that were minted by the kings of the Pergamene dynasty (200-48 BC). Some coins contained a relief of a snake and staff of a god who is administering medicine to a patient. The modern equivalent is the American Medical Association (AMA) logo of a staff with a snake wrapped around it. It was here that the famous Roman physician was born and trained.

Radon/Radium Therapy

Ernst Rutherford talked about radioactive emanations in 1900. JJ Thompson found radioactivity in well water in 1903. Sieveking measured radon levels in eleven European spas in 1906 obtaining values up to 182,000 Bq/L. In 1903-4, inhaled thoron was used to treat tuberculosis in

Europe. Uranium ore and sands were placed in bathtubs for therapy in 1905. Two books were published in German in 1912-3 on the use of radium therapy. The results for gout, rheumatism and neuralgia were described as *extremely successful* in 1907. Meseritzky in 1911 found that radon therapy increased excretion of purines and uric acid in urine accounting for improvement in gout patients. An above ground radon inhalation facility was built in Austria in 1912 for treating gout patients.

Radium was discovered by the Curies; it took from 5 to 6 tons of pitchblende to extract one gram. Extracting radium from carnitine ore was an even more arduous a task; only 1 gm of radium was found in every 500-600 tons of carnitine ore from Colorado. Carnotite ore often had high levels of vanadium¹⁵⁰⁻¹⁵¹. When Madame Curie and her daughters went to Colorado, this is what they saw: In this uninhabited area of southwestern Colorado, and southwestern Utah, pockets of carnitine were discovered from a few pounds, to, in exceptional cases, 1,800 tons. Once the ore is mined, it is taken to a concentration mill nearby, where 500 tons is reduced to 125 tons. It is now in a powdered form, and shipped in 100 pound sacks, by wagon, and where possible, by motor trucks, the 65 miles to Placerville, Colorado. Here a narrow-gauge railroad takes it to the transcontinental railroad at Salida, Colorado. From Salida it travels the 2,300 miles to Canonsburg, Pa., just outside Pittsburgh. In Canonsburg, which Madame Curie had visited earlier in her trip, the pure radium salts were produced on a massive scale, using the exact procedure she and Pierre had devised 23 years earlier. Only here, the most modern technology of the day was at hand, and the quantities were much larger.

In the early 1900s radium pendants, natural radon water, uranium blankets and thorium-laced ‘medicines’ were used to treat rheumatism and enhance vigor and digestion. George H. Stover of Denver, Colorado, was the first American physician to obtain a supply of radium, purchasing radium chloride in August 1903 from a Paris dealer. He was one of the first

Americans to conduct self-exposure experiments with radium⁴⁷. In 1903, Hermann Strebel of Munich was the first person to propose the use of after-loading, which was then recognized for use in radium brachytherapy, including for cancer therapy⁴⁸. Radium baths were early used experimentally to treat arthritis, gout, and neuralgias⁶.



Figure 11. Ward's Radium Ore Healing Pads (1916-1918) was one of eleven products marked by the company. Another one was called a ‘radon pillow’. The brochure for the pad says: *A magic relief of constipation, gout, rheumatism, lumbago, sciatica, coughing at night, pains anywhere internally.* The instructions included: *Apply tightly to the flesh over the source of pain, soreness or swelling, 4-6 hours at a time...Helpful in any kind of chronic disease or pain.* The price of the pad was \$5.00. The dose rate at one foot from the pad was 20 $\mu\text{R/h}$ above background. The Oak Ridge Associated Universities calls all radium healing devices quack cures

A bottle of Radithor contained at least 1 microcurie each of Ra-226 and Ra-228. The Revigator (1912) was constructed of clay containing uranium (radium) ore. The radon-solubilized in water was routinely drunk. About 300,000 units were sold with no reports of harming anyone.

sufficient inhalation to be effective. This was controlled by erecting a tent over a tub. The emanation was produced by 2-74 milligrams of radium, giving a concentration of from 0.003 to 0.8 microcuries per

liter of air. Best healing results were obtained with 25 milligrams of radium²⁰⁷. Radium emanations were found effective in treating many diseases, including lupus erythematosus, tuberculosis adenitis, gout, rheumatism, polyarthritis, angioma, keloid and other scars and chronic suppuration causing tinnitus and deafness²⁰⁹⁻²¹². Irradiating the kidneys with radium rays was found most effective in lowering blood pressure. Vigorously passing 300 cc radium water (20 $\mu\text{Ci/L}$) back and forth in the mouth was quite successful in treating alveolar pyorrhea²¹³. A paper published in Radium in 1913 described the treatment of 657 cancer patients with radium rays, 12% of which were cured; the greatest success was found for breast cancer²¹⁴. By 1915 papers published in Radium talked about the relative value, efficiency and limitations of radium therapy because of documented harmful side effects.

Painful inflammatory conditions were historically the first to be successfully treated with radon and radium. Hundreds of radon and radium gadgets for exposure to radium were marketed during the 1920s to 1940s to improve people's health, including the Revigator (a water cooler lined with carnotite ore). Surface radiation dose-rates varied among the various radium devices: The radioendocrinator was 200 mR/h; radiothor was 3.5 $\mu\text{R/h}$; radium bromide was 4 $\mu\text{R/h}$; the National Radium Emanator was 5-8 mR/h; and the Thomas Cone was 30 $\mu\text{R/h}$. The radioendocrinator was a 2" x 3" case that contained paper impregnated with 250 μCi radium-226; the dose was sufficient to cause illumination on a fluorescent screen. By the 1920s radium was given in a variety of eatable and uneatable products as a cure for arteriosclerosis, arthritis, diabetes, epilepsy, heart disease, high blood pressure, infections, prostatitis, rheumatism, senility and impotence. A 1929 pharmacy in Europe offered eighty radioactive products¹⁹¹. All these conditions and many more are potentially treatable by LDR (Low Dose Radiation) today..

Radium was early seen as a way to treat disorders that were not affected enough by X-ray treatment because it could be applied in a multitude of ways and lower doses where X-rays were not readily applied. External sources of radium exposures from impregnated pads and blankets were promoted, along with oral intake in water and 'health foods'. From 1910-1940, the healing powers of a wide variety of products, such as radium-impregnated bed blankets and radium- adulterated crackers, tea, coffee and chocolate, were advertised. Different methods of applying radium had been tested, which fell into two categories: the use of radium emanation (now referred to as radon), and the use of radium salts. Inspired by this, bath waters using preparations of radium salt were suggested as a way for patients to be treated at home, as the radioactivity in the bathwater was permanent.

Over 400,000 bottles of Radithor, a popular and expensive mixture of Ra-226 and Ra-228 in distilled water, was sold for \$1 per bottle from 1925-1930. Each bottle contained 1-2 μCi Ra-226⁵⁰. Early attempts were made to treat arthritis with injections totaling 70-350 μCi Ra-226. A small group of patients were treated for hypertension in 1927 with radium water given by

intravenous injection. Thousands of patients diagnosed with schizophrenia were treated with up to 300 μCi Ra-226 at Elgin State Hospital in Illinois in the 1930s. The study failed to demonstrate efficacy.

The manufacturer guaranteed that Radithor was harmless in every respect, proved false. Radithor is one radioactive cure marketed in the first half of the twentieth century that can be unambiguously linked to someone's death, specifically to that of Eben Byers at age 51. He was an U.S. amateur golf champion and industrialist who died from consumption of very large amounts of Radiothor believing that the more you took the healthier you would be. The massive amount of daily ingested radium was 2,000,000 times greater than the current EPA limit of 5 pCi/L. Byers did not die of cancer but of bone necrosis associated lesions, which required the surgical removal of his jaw. A belief that radiation is harmful at low doses was published in a 1936 report for the National Research Council (NRC); the NRC suppressed the well-known data at the time that low doses of radiation were beneficial. Prior to the unwise use of radium by Mr. Byers, the many radium products and applications proved effective in treating painful, inflammatory conditions for several decades. Paracelsus dictum that it is the dose that determines where radium is beneficial or harmful was ignored by politicians.

Ward's Radium Ore Healing Pads was one of eleven products marketed by the company (Figure 11). Another one was called a 'radon pillow'. The brochure for the pad says: A magic relief of constipation, gout, rheumatism, lumbago, sciatica, coughing at night, pains anywhere internally. The instructions included: Apply tightly to the flesh over the source of pain, soreness or swelling, 4-6 hours at a time...Helpful in any kind of chronic disease or pain. The price of the pad was \$5.00. The radium industry faltered and by 1950, Cold War propaganda had made such an industry unthinkable. Like for radon and radium, radiation dangers were exaggerated to prevent the proliferation of the A-bomb.

Radon inhibits inflammation¹⁶. Home radon prevents lung cancer³⁵. Pain-related inflammatory conditions are commonly benefited by radon therapy. Nerve injury-induced inflammatory responses, mediated by TNF- α levels, norepinephrine levels and migration of inflammatory leukocytes, play important roles in neuropathic pain¹⁰⁰. Both pretreatment and post-treatment with radon inhalation have beneficial roles in controlling neuropathic pain¹⁸.

In the 1950s the American Medical Association (AMA) roundly denounced radon health mines and radium-radon therapies as quackery, and has not reconsidered its stance since. There is abundant and widespread medical evidence from patient's testimonials regarding the effectiveness of radon spa treatments for a variety of inflammatory illnesses¹¹⁷. Elsewhere, particularly in central Europe, Russia and Japan, radon therapy for arthritis relief is an established alternative medicine. In Germany, constructed radon tunnels are accessible by prescription only, as part of the country's national health system.

Radon therapy is available today in the form of baths, spas, steam rooms and mines. Europe has a long history and tradition of radon therapy. The Radium Palace in the Czech Republic was founded by Marie Curie in 1906. Today the facility treats 14,000 patients each year with a waiting list. Bad Schlema located in the mountains of Saxony was a mine five centuries ago. After 1946 the mine supplied 220,000 tons of uranium ore for the U.S.S.R. until German unification in 1989. Today it is a radon health spa. Today people come from all over the world to

eight sanitariums in the town of Khmilnuk, Ukraine, which treat 50,000 patients annually for a variety of chronic inflammatory conditions. Patients receive radon pool therapy (25-35 nCi/L) in series, each for about 30 minutes ²⁰³.

Europeans often consider radon as a part of standard medical practice. Japan has the largest number of healing hot springs in the world. These springs are very popular. EURADON promotes the use of radon for autoimmune and respiratory diseases along with pain alleviation in European spas. Radon therapy carried out at Gastein, Austria, in a 2.5 km-long tunnel, have goals of reduction of pain and morbidity, particularly for inflammatory and degenerative conditions of the musculoskeletal system, respiratory tract and skin. The cumulative radon dose is determined by the number, duration and type of therapies. The mean radon concentration is 43 kBq/m³. A classical cure at Gastein provides a dose of only 2.3 mGy. Locomotor disorders are treated with ten-2 mGy cycles. Up to 90% of patients visiting Gastein experience pain relief, improved quality of life and often reduction in need for medication. Gastein attributes their healing responses to biological mechanisms of radiation hormesis ⁶⁹.

In comparison to chemical pharmacological drugs used to treat proliferative and inflammatory diseases, no medical complications have been observed with radon therapy. Randomized double-blind studies demonstrated significant positive radon health benefits ⁶. Radon therapy spas were visited by thousands of patients daily in the United States from the 1920s to 1950; the most popular spa was found in Saratoga Springs. Today an association of German Radon Spa Physicians (Radon Balneology) treat about 75,000 patients annually at 14 sites in Europe. There have been over a dozen books written on radon therapy since 1982. Typical annual effective dose to patients from one sequence of therapy is 2-3 mGy. Radon therapy personnel may receive more than 100 mGy per year without adverse effects ⁶⁻⁷.

“Who would voluntarily breathe in radioactive gas? These days, there are people who do. They swear by the notorious noble gas radon, created by decay of uranium: They inhale it deeply. Most believers in the healing qualities of radiation are suffering from a chronic inflammatory disease...The gas, they argue, alleviates their problems for months. In Bad Kreuznach, in the German state of Rhineland-Palatinate, brave spa quests even trek into the tunnels of an abandoned mercury mine, attracted by the radon-filled air in the mountain...As has now become clear, these people are right: Radioactivity is good for them. These are the initial findings of an ongoing large-scale trial conducted by researchers from four German institutes. The leader is radiobiologist Claudia Fournier...Hundreds of patients in the spa resort of Bad Steven, in Upper Franconia, allowed themselves to be thoroughly examined for the study. The researchers found that after a series of radon baths, the blood of the test subjects had fewer signs of inflammation. Their immune defense...also seemed to have calmed down. Accompanying experiments on arthritic mice delivered a further surprise...bone loss, which typically goes along with joint inflammation, was also reduced ¹⁰⁴”. Every year about 56,000 people in Germany die from septicemia, usually contacted within hospitals, associated with multiple organ failures. Dr. Luis Moita at the University of Lisbon has shown in a mouse model that low dose radiation protects against septicemia. A study has been requested to offer terminally ill septicemia patient’s radiation therapy ¹⁰⁴, since enhancement of the immune system may cause a beneficial response in patients with septicemia ¹⁴¹.

Once you convince the public that low dose radiation can effectively and inexpensively treat painful inflammatory diseases without any side effects with an enjoyable therapeutic experience, they will demand it.

‘Gambanyoku’ is Japanese for hot spring where one

lies down on warm rock surfaces. The rocks may emanate radioactivity. The health effects of the Tamagawa Hot Springs have been well documented as a location to treat cancer, rheumatism and diabetes. Japan has considerable empirical experience for several centuries with health spas later found to be associated with radon. The most famous is found at Misasa, where maximum radon levels of 8,000 Bq/l are found. Clients and staff have a lung cancer incidence that is about 50% less than that found in low radon regions of the country; the mortality rate for all types of cancer is 37% less than expected^{8,17}. Patients bathe in a warm room with a radon concentration that is about 100 times background (2080 Bq/m³). This therapeutic regimen has proven effective for osteoarthritis, ankylosing spondylitis and bronchial asthma⁹⁻¹¹. Radon baths have a therapeutic benefit on peripheral vessel diseases, decrease pain and normalize the sleep cycle. Radon has a beneficial effect on lipolysis in adipose tissues, helping to reduce body weight.



Figure 12. Free Enterprise Radon Health Mine near Boulder, Montana (With kind permission of Patricia Lewis).

Pain is often the motivation for trying unconventional therapies. An older-age group comprises a large segment of people who seek radon therapy¹²⁻¹³. A pattern of improved range of motion was found in those sitting in the mine even in those with advanced destructive joint and bone damage who were not expected to improve¹⁴. There is significantly reduced pain in rheumatoid arthritis patients bathing for 20 minutes in water with a radon concentration of 0.3-3 kBq/L or following a stay of

one hour in caves or rooms with natural radon levels of 30-160 kBq/m³¹⁵. The British Journal of Rheumatology recommends soaking in radon baths as a component of rehabilitative intervention.

According to the American Nuclear Association there are about 5,000 hospitals in Russia that use bath water containing radon. Radioactivity in a Russian spa was first investigated in 1902. Radon therapy in Russia today uses portable radon-222 generation units (from radium-226)¹⁴⁴. Radon hospitals in Russia treat 1000 individuals daily for asthma, arthritis and rheumatism. About 75% of patients respond favorably to this treatment⁶. The best results obtained were for rheumatic diseases, skin diseases and hypertension. The greatest benefit for systolic hypertension was found in baths containing 40-120 nCi/L radon; the drop in blood pressure was followed with a decrease in heart rate¹⁴⁰. Other conditions that respond to radon therapy include Menieres disease, vertigo, imbalance, tinnitus, and genetic neuromuscular diseases.

There is a scarcity of pain control strategy in many locations of the United States. The fear of opioid addiction and the federal Drug Enforcement Administration's (DEA) war on doctors who abuse their prescribing privileges has made physicians, patients and pharmacists collateral damage, making it difficult for patients to receive adequate medication to control pain. Legitimate patients with chronic pain have been left to find their own way. The result has been a

victimization of chronic pain patients, and not the installation of palliative care free of conflicts



Figure 13. Mostly elderly people with painful inflammatory conditions anxiously sit in a Montana health mine during the early 1950s to receive their hour of exposure to radon.

of interest and political manipulation. Health care workers fear legal consequences for legitimate practice ¹³⁶. Low dose radon therapy is an effective way to treat a variety of painful inflammatory diseases, while avoiding the side-effects of long term use of anti-inflammatory drugs (steroids and NSAIDs). Radon therapy has been incorporated into traditional allopathic medicine ⁷⁸. The effectiveness of a radon therapy sessions in an old uranium mine, taking up to two weeks, typically lasts up to a year ^{6,16}.

Falkenbach described five trials of radon therapy for rheumatoid arthritis, three of which were double-blind studies ¹⁵⁻¹⁶. Radon therapy as compared to interventions without radon inhalation showed significantly better pain reduction with significantly reduced NSAIDs use ¹⁴²⁻¹⁴³. Clinical and experimental radon exposure is associated with enhanced antioxidant enzyme activity ¹⁸. In addition to arthritis and pain control, radon therapy was shown to be

effective in treating hypertension, diabetes, skin diseases lupus, scleroderma, ankylosing spondylitis, psoriasis, atopic asthma, bronchitis, cardiovascular disease and dyslipidemia. chronic polyarthritis, fibromyalgia, scleroderma, rheumatoid arthritis, and degenerative and deforming joint infections [arthrosis, spondylosis, osteochondritis, neuralgia, ovarian cysts, endometriosis, and chronic pain from trauma, sinusitis, and allergic illnesses such as hay fever and neuro-dermatitis. Successful radon treatments of complications involving the endocrine system, menopausal symptoms, impotence, and many other conditions have been documented ^{6,15-16,19-20,79-80}. Radon therapy has been shown to increase blood estradiol levels in menopausal women and blood testosterone levels in men ⁸¹. Radon may be a useful therapy for erectile dysfunction ¹³⁹.

Montana Radon Health Mines



Figure 14. Sitting in the Free Enterprise mine (With kind permission of Patricia Lewis).

There are only half a dozen radon health mines in the United States, and all six of them are located within twenty minutes' drive of each other in western Montana. The Free Enterprise Mine is the oldest of the bunch, opening for business as Montana's first uranium mine in 1949, before transitioning from its uranium extraction focus to the more intangible resource of personal health just three years later (Figures 12-14). The Merry Widow Mine and Free Enterprise mines are located about one hundred miles north of Yellowstone Park; the Merry Widow is located nine miles from the Free Enterprise mine in Boulder, Montana. National Geographic in 2004 did a piece on sufferers from arthritis, asthma, cataracts

and other chronic diseases gathering in the 1950s in the Merry Widow Mine in Basin, MT, to inhale radon gas that seeps naturally from this old silver and gold mine ¹⁴⁹. A 1952 Life

Magazine piece shows Edna Kirsch entering the Free Enterprise mine in a wheelchair and leaving walking, after her third day ¹²⁴.

In a 1952 the wife of a mining engineer visited the Boulder, Montana Free Enterprise Mine. Upon emerging she found her arm that had been immobilized by bursitis could move without pain. Word spread fast and within a few months, 750 people had come to sit in the mine to relieve their suffering. Mine owners around this small region of Montana stopped mining and opened their mines to healing. ‘Experts’ said radon gas could not help anybody. Nearly all of the more than 250,000 visiting the mine for the next several decades felt otherwise, claiming that their mine stay had done them good. During the 1950s, people would line up at the entrance of the Merry Widow Mine in Basin, Colorado, and be admitted in groups of fifty for a one hour stay ¹²⁴. Believers claim that ten days in the mines, breathing in radioactive gas and drinking radioactive water, will cure a whole host of ailments. Hundreds of thousands of people have come from all over the world to sit in a radon mine for one-hour treatments three times a day. Miracles have happened here not just to believers in radon but to nonbelievers as well. Sue collects mud from the walls of the mine, swearing that it heals skin infections. Most visitors end up taking some of the mine away with them—even little pillows filled with radioactive gravel. Stories like Sue’s brought Tanya Beck from Duluth, Georgia. Her four-year-old daughter, Allison, suffers from progressive rheumatoid arthritis; her doctors, having run out of solutions, predict she will spend her life in a wheelchair...When we got here to the mine and I saw what it was, it was kind of like a *Twilight Zone* thing...But Allison is running and playing now ¹⁴⁹.

The radon health industry faltered because of Cold War propaganda making such an industry almost unthinkable. Radiation dangers were exaggerated to prevent the proliferation of nuclear weapons. No one wanted to even encounter radiation. A brief visit to a radon health mine changed many of their minds. Wade Lewis and his granddaughter, Pat Lewis, found from observations of thousands of people treated in their abandoned uranium mine, starting in the early 1950s, that their exposure regimen was effective in treating arthritis and a variety of other chronic inflammatory diseases ¹². The Free Enterprise Radon Health Mine is a place where people sit in comfortable chairs 85 feet below ground. Clients breathe a high concentration of radon gas and radon daughter products from decay of surrounding uranium-238 in the mine walls, ceiling and floor ¹²⁹. The mine attracts many Canadians and Amish Americans who ignore the warnings of the EPA replacing them with common sense.

The Free Enterprise mine exposes patients to an average radon concentration of 1600 pCi/L with a range of 770-2200 pCi/L. The radon levels in the mine are regularly determined by independent laboratories ⁸². Background radiation levels outside the mine are >1000-fold less than in the mine. Mean dose-rate in the mine is 170 µGy/h. Treatment at Free Enterprise normally consists of several hours a day in the mine for ten consecutive days.

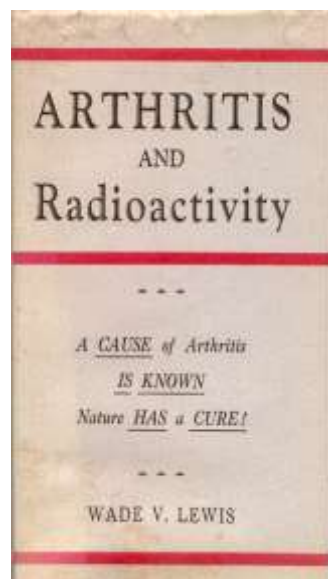
Wade Lewis was one of the first to write about the beneficial health effects of internal radionuclide exposures ²⁰⁶ in a book about radon and arthritis (Figure 15) ¹². The mine is currently operated by his granddaughter, Pat Lewis, who started managing the mine in 1994. Mine exposures are external whole body, internal inhaled and water borne radon and daughter products. In addition to painful inflammatory conditions, Lewis has also seen positive responses in stage IV breast cancer and in neuropathy associated with diabetes ²²³. She says that neuropathy

is slower to respond and requires longer exposures. She has also observed improved mobility associated with knee problems. Pat Lewis does not use the term 'cure' to her clients, although many clients experience pain relief. Pat Lewis has been promoting the pro-radon therapy message for over 20 years; for most of that time she has been 'drawn and quartered' by LNT-promoting critics.

The Free Enterprise Health Mine charges \$8 for a 60-minute visit; the mine has a pink-carpeted elevator furnished with a single red chair that takes you down into a wood-framed mine shaft, 87 feet beneath the surface. The walls are decorated with moss, graffiti, and rusted mining tools. Wall niches have padded benches and chairs sitting under heat lamps. Over the course of a typical treatment, clients spend between 30 to 60 hours down in the Health Mine, spread out over a 10-day period^{68, 129}. This corresponds to a cumulative dose of ~5-12 mGy. Pat Lewis has thousands of records of people who have visited the Free Enterprise Mine and experienced good to excellent results in their health status. Below are a few of them based on their physician-directed diagnosis.

Ankylosing spondylitis

At the age of 35 I had already suffered AS for 10 years. Prior to my discovery of Radon Therapy, my disease had advanced to such an extreme level that I was devastated to think that I would be forced to leave my physically demanding career as a farrier. Conventional drug therapies had failed and the specialists had no answers that didn't come at the high cost of drug side effects. I scoured the internet looking for alternative treatments, tried crazy diets and spent a bunch of money on stuff that did not work. My inflammation was high and my joints were starting to fuse. I found out about Radon Therapy on an internet AS forum. I did my homework. After tremendous amounts of investigation I felt comfortable enough to drive to Montana to give it a try in 2008. The results were amazing! My pain levels decreased almost immediately and within three months the symptoms were virtually gone. This has allowed me to keep my drug levels to a minimum and to continue life in my occupation. I highly encourage others to become familiar with this option to control their symptoms (Brad Erickson, Farrier, Bear Lake ID, www.braderickson.com)



The Story of the Free Enterprise Uranium-radon Mine

After 12 years of observation and research, more and more individual medical doctors are sending patients to the Free Enterprise Radon Mine in Boulder, Montana, or arriving at intervals for their own afflictions. Among these afflictions are arthritis, bursitis, sinusitis, neuritis, asthma, eczema and allied glandular connected ailments. Physical benefits are now claimed by thousands of mine visitors. Scientific reasons for this are provided by medical and technical sources, some of which are quoted and contained in this volume. It now appears that the factors of radon therapy and ionization, as provided by nature in the underground atmosphere of the Free Enterprise Radon Mine, are more far reaching than at first supposed. It is now evident that nature's treatment not only eliminates painful symptoms, but reaches a basic CAUSE of many physical problems.

Figure 15. Pamphlet on efficacy of radon for treating inflammatory diseases written by the grandfather of Patricia Lewis (With kind permission of Patricia Lewis).

I could no longer deal with the intense back pain and brain fog. I needed more answers: an internet search produced the Free Enterprise Mine. I was convinced that there would be benefits. Spring 2006 was my first stay with improvements at day 8. My second 10 day stay was October 2006. I'm now at home doing what I love to do instead of in a doctor's office thinking about my aches and pains (Pam Alvarez, Educator & Entrepreneur, Springville UT, alvarezps@hotmail.com).

My doctor knows I come here and he says that in my condition I am a walking miracle. He says that whatever I am doing, he wants me to continue doing it. It had been 20 years since I felt as good as I do since mine therapy. Mr Wilcox died in 2016 at the age of 90 (Don Wilcox, Construction, Winnipeg Manitoba).

In 2005, at the age of 47, I visited the Mine to see if it would help for my pain associated with AS - a condition I was diagnosed in 2003. Within a week I was able to stop my 3x/week Enbrel and have never resumed the injections. Two months later, a mammogram showed no sign of the calcifications that caused me concern for breast cancer - a condition I'd been tracking for about 2 years. My blood pressure diastolic dropped to normal. I made no other changes in my stressful lifestyle and must attribute these results to radon therapy. I am lucky to live nearby to take advantage of the Free Enterprise Radon Health Mine (Anonymous, Certified Nurse Operating Room, MT)

That I was skeptical would be a huge understatement - but desperate times call for desperate measures. I took 20 1-hour sessions underground in 1993. Five weeks passed. I began to notice a feeling of strength - something foreign to me for the previous 25 years. Living close by allows me regular attendance. In my opinion, God has given us each the opportunity to make an informed choice for this alternative to drug therapy (the patient also had fibromyalgia) (Anita McCartney, Artist/Homemaker, 315 Morningside Dr., Hamilton MT 59840).

Actually, the doctor's wife no longer uses her wheelchair because she started visiting the Free Enterprise Health Mine. But seriously, the difference this place has made in my life is nothing short of miraculous. I have Ankylosing Spondylitis (which like most medical conditions comes w/an additional laundry list of U.C/fibro/IBS etc. Since my annual trek to the mine started 8 years ago, I am now pain free and rx free. Doctors can't explain it, but I can (Anonymous).

Rheumatoid Arthritis and Osteoarthritis

After about two days in the mine I became very ill - I was ready to leave. Everyone said that was a good sign and they were right. I was home about four weeks and my neck broke loose and I started getting relief from the pain. My doctor had told me to be prepared for a wheelchair - instead, I've put it in storage. I continue the mine therapy almost annually (Jim Gatschet, Diesel Mechanic, 509 Walker Road, Pleasant Hill MO 65080, (816) 540-3157).

The pain has gone away - no more pills. My family and friends can't believe what they see. It is just wonderful to sleep all night to see another pain-free day. I've been visiting since 1990. I'm ashamed to say I feel so good (Marie Klassen, 7230 Acorn Ave #1009, Burnaby BC Canada V5E 4N9).

Two auto accidents left me with chronic pain from neck and back injuries. Surgery, therapy and chiropractic had minimal success. I understood that there was a possibility that the Mine therapy could give me some relief from pain. I started visiting in 2004. I can honestly say that I have less pain, that I am walking better and that I can sit more comfortably than before. Thank you for a wonderful facility. (Albert Wurst, Tool & Die, Kent WA, wuraldi@yahoo.com).

I was diagnosed with MS in 1998 and spent years battling pain. My option was to increase pain meds. What did I have to lose? First visiting in 2006, I noticed improvement within 4 days, then pain free before heading home. The disease is still there, but not the symptoms - I take no pain medication. I regret using this as a last resort and will return annually. (The patient also has multiple sclerosis and fibromyalgia.) (Bev Moulton, Wenatchee WA 98801, maisygrace@gmail.com).

Multiple Sclerosis

I was diagnosed with MS 22 years ago. I heard about radon therapy from a friend of my sister. This woman had been suffering from MS for 20+ years. She was in a wheelchair. She spent 10 days at the mine and never used her wheelchair again. Of course, I had to try it. I went last year in September. I spent 10 days and nearly 100 hours in the mine. I have regained at least 10 years of my life. I can walk without a cane. I have no balance problems. In fact, I have none of the symptoms I had been experiencing for the past 2 decades. The only thing that reminds me I still have MS, is that I get fatigued once in a while. I no longer take any of the meds I was on for symptomatic relief. My Dr. was truly amazed. The biggest thing for me is that I do not have any pain!!! My heart breaks for those who won't even consider trying this alternative treatment for any chronic pain or illness. The price is considerably less than the hourly rate when you stay for 10 days. The facilities are exceptionally clean and comfy. The cost for me was just under \$500.00, and that included my room and the use of the facility 24/7. I didn't mention that I went to the Free Enterprise Radon Health Mine and it is an annual trip for me (Anonymous).

Bronchitis

I have been going to the Free Enterprise Mine since 2002 with great success. The most important improvement is relief from bronchitis. I no longer suffer from weeks of an annual bronchitis cough. Additionally, years prior to my discovery of the Mine, I broke my wrist. I would have to rest my wrist on a pillow while traveling. That wrist has been pain free for the last ten years (Grace Hartell, High River, Alberta, Canada)

Ulcerative Colitis

I've struggled with this disease for 17 years. Finally my surgeon wanted to remove my colon immediately. Instead I had heard about the Free Enterprise Mine and wanted to give it a try - I did so in October 2006. I felt improvement, which was confirmed by my doctor and via biopsy. I visited again in early 2003. Biopsies from latest colonoscopy show no dysplasia and no need for surgery. In my eyes, this is a miracle and an answer to prayers. I'll be back for more "mine-time" (Bill Stripling, Appraiser, Norcross GA 30092, billstripling@gmail.com).

Hepatitis C Infection

I have Hep C. I went to the Mine in 2004 and while I didn't get my liver enzymes checked before I left for Montana, my joint and muscle pain went away while I was there. And my liver test was low when I returned home and got tested. I continue my annual visits to the Mine (Ned Haskin (2010), Sound Engineer, Landover MD, feanor17@covad.net).

Scleroderma

I was diagnosed with scleroderma in 1995. This disease causes hardening of the skin and internal organs in addition to joint damage. I first visited the Mine in 2001 after reading about it in our local paper. I have had unbelievable results. The skin on my face is much softer and my hands are more flexible and overall I find I am able to move around more easily. I truly believe that coming to the Mine has kept my disease from progressing and has even reversed some of the damage. I will continue annual visits to maintain my health and to reduce my need for medication for inflammation (Ann Bumsted, Truck Driver/Finance, Box Elder SD, cookiemaker2222@msn.com).

Asthma, Behcet's Syndrome and Psoriasis

I first visited in 2000. The psoriasis is gone. My asthma is almost gone and I've given up a long list of steroid medications. I love being back on my feet after so many years. Bob's arthritic knees no longer hurt him. We both look forward to each year's R&R (radon & rest). It really feels like home away from home. (Linda & Bob Cruz, PO Box 3434, Bay City OR 97107).

Migraine Headache, Gout and Fibromyalgia

Additionally the Mine helps me with carpal tunnel and rheumatoid arthritis (Elaine Wilcox (2010), Banker, Winnipeg, MB, elaine_wilcox@hotmail.com).

Primary Pulmonary Hypertension

In 1997, my dad brought my mother, Mary, to the mine. He had pulmonary fibrosis. He visited once more but lived 4 years more than the doctors gave him. Then I brought my mother for a number of years. I have primary pulmonary hypertension (PPH): irreversible, progressive and fatal. My breathing always improves at the Mine. I am better now than in 2002 when I was diagnosed. I am thankful for the Mine and will continue to visit. (2008: My physician no longer detects evidence of PPH.) (Cheri Sweet Sundwall, Property Investments, Alpine UT, jcsundwall@yahoo.com).

Glomerulosclerosis

This disease causes scarring of the tiny blood vessels in the kidneys. My doctors state that I would soon need a kidney transplant. Since 2007, I have visited the Mine 6 times. The disease has not progressed as predicted. Though my husband is ready to donate a kidney, we both would prefer to visit the Mine instead (Bev Tuel (2010), Dental Hygienist, Clark Fork ID, mbtuel@yahoo.com)

Carpal Tunnel

My mom, a mine visitor since 1989, suggested that the mine might help my severe carpal tunnel in both hands. The doctor was ready to do surgery. Within a month after visiting the mine I was painting the front porch - it has worked wonders. Now my once doubtful husband joins me for help with his arthritis. An annual trip to Montana keeps me from surgery - and keeps us working (Teri & Michael Kenowski, 1222 S Cuyler Avenue, Berwyn IL 60402, mtkenowski@ameritech.net).

Here are some more unedited testimonials from the Free Enterprise Mine: You would never believe my testimonial if I told you...Alright, if you insist I must tell you. I have no pain in my back or anywhere else for that matter (Marisol Ojeda, 2012). I will never be able to thank you enough for giving my my life back and taking away the pain, No pain at all (Kathy Franum, 2012). I spend ten days a year in the mine. It's definitely made me more functional. It's allowed me to live without pain (B Blackburn, 2012). We like lots

In 2002 I visited the Free Enterprise radon mine in Montana. I drank many glasses of water containing dissolved radon. The severe pain from an infection below a molar tooth disappeared after a day (Jerry Cuttler, SARI).

I spent ten days, six hours per day, in the Free Enterprise radon mine accumulating a radiation dose of about 10 mGy. My wife experienced noticeable relief from fibromyalgia, while my suffering from plantar fasciitis for 20 years is gone (Don Miller, SARI).

of people were very skeptical at first about radon therapy. After a 10-day stay, I will never question the treatments again. It works (Avis Czerniewski, 2011). Our arthritis in shoulders and hands goes away after mine therapy (Eunice Boeve, 2011). My wife's arms are still pain free after 20-years of pain (Joe Zehr, 2011). Marked improvement in arthritis for me, my husband and our dog (Donna Lutz, 2010). I have had a disc problem since 1995 causing pain in my arms. Radon made me feel like I did before 1995 (Melissa Baldwin, 2009). I had ankylosing spondylitis at the age of 37. I greatly improved after a stay at the radon mine that lasted for over ten months (Brad Erickson, 2009). I had carpal tunnel in my wrists and could not wring out a dish rag or open a pop can or open and close my hand. Now I can do all easily (Teri Kerowski, 2001).

Today there is a growing recognition in the U.S. and Europe that health care is driven to a significant extent by an emphasis on consumer choice and demand. As consumers, people regularly choose their own solution for health promotion and maintenance, solutions which may or may not be sanctioned by mainstream medicine ⁴⁹. Among these alternatives is radon therapy. Thousands of people annually chose to sit in abandoned uranium mines or upscale radon spas exposing themselves to radon for therapeutic purposes. No evidence of increased cancer has been shown in 100,000s of patients that are annually treated by radon in former uranium mines or spas.

Low dose radiation or radon therapies are ignored, scorned and arrogantly dismissed by many U.S. physicians. The American system of health care and governmental institutions (AMA, EPA) ridicule people sitting in an abandoned radon mine. Chronically ill people usually take expensive medications with serious side effects. Most of these people are elderly. Pharmacokinetics is different in the aged, medications are typically multiple and drug side effects are more serious in the aged. Also drug dose often needs to be increased more in the aged to achieve its initial effectiveness. Follow the money. American doctors and pharmaceutical companies may 'avoid' radon therapy or any effective natural therapy irrespective of benefits because of the very limited profit potential.

Radium Dial Painters

The Radium Chemical Company produced a watch dial paint containing radium and zinc sulfide along with rare earths; radiation from radium caused fluorescence so that the watch dial could be seen at night. Radium dial painters were mostly women who tipped the end of a camel's hair paint brush with their tongue ingesting varying amounts of radium into their gastrointestinal tract, from where some was absorbed and deposited into bone. Women were paid \$18 for a 40-hour work week. After 1925 when harmful effects of this practice were observed, the tongue tipping was stopped.

Argonne National Laboratory (ANL) in Argonne, IL carried out the largest epidemiological study of humans exposed to internally deposited radionuclides ⁵¹. A total of 2403 former radium dial painters were studied by ANL with respect to radium distribution in the body, radiation dose determinations and cancer development, particularly in the skeleton and nasal cavity. The probability of developing a bone tumor (mostly sarcoma) was up to 50% if more than 5,000 μCi Ra-226 had been ingested. This threshold level for bone tumors or other diseases corresponded to a dose of about 10 Gy to the skeleton. This threshold for bone tumors is more than 125,000 times the annual limits for radium in drinking water which is 5 pCi/L. There was no lifespan shortening at bone doses <10 Gy; the last report of the radium dial cohort actually showed the painters living longer than unexposed controls. The conclusion to the over 30 year study was that radium-induced malignancies in humans were not seen below a dose of 10 Gy ⁵¹. Josephine Lamb, a radium dial painter, was still alive in 2006 at an age of 100. Bureaucrats in Washington did not want to see research promoting the benefits of ionizing radiation particularly at these high doses. This exceptionally well-done study had received rave reviews by DOE but was still terminated by DOE in 1990 even though about 1000 radiation dial subjects were still alive.

Robley Evans made the first measurements of exhaled radon and radium excretion from a former dial painter in 1933. At the Massachusetts Institute of Technology he gathered dependable body measurements from 27 dial painters. This information was used in 1941 by the National Bureau

of Standards to establish the tolerance level for radium of 0.1 μCi (3.7 kBq). Evans showed in 'force' a LNT assumption response. In 1981, the now retired Evans, showed that there were no bone sarcomas or nasal carcinomas in dial painters with cumulative bone doses <10 Gy. DOE then initiated a beginning termination of the dial painter study in 1983. In contrast, the Radiation Effects Research Foundation (RERF) which has studied the Japanese A-bomb survivors for 'life' and produced consistent biased and false data that 'fit' the LNT assumption was allowed to continue. Robert Thomas, radiobiologist at Los Alamos National Laboratory and Argonne National Laboratory with a stint in between as program manager at DOE, proposed a threshold for dial painters and bone sarcomas of at least 4 Gy. Robert Rowland, then director of the dial painter study at ANL said: All 64 bone sarcoma cases occurred in the 264 cases with more than 10 Gy while no sarcomas appeared in the 2,119 radium cases with less than 10 Gy⁵¹⁻⁵². An analysis by Pacific Northwest Laboratory in 2012 of cumulative incidence of bone tumors in radium dial workers showed a linear increase in bone tumors occurring after having achieved a threshold dose of 11.6 Gy to the skeleton (Figure 16).

Charles Mays and Raymond Lloyd from the University of Utah clearly misrepresented the dial painter data and 'manufactured' a linear result for BEIR IV. EPA then took the same data and forced it into a linear response to establish widely unrealistic radium limits in water. Simply put, science is irrelevant in the campaign to mislead the public about the hazards of radium and radiation in general. The thousands of people who had used radium supplements (e.g., Radiothor) in moderate amounts had not experienced any adverse effects. This information was intentionally ignored by EPA, BEIR and all other radiation protection agencies.

Otto Raabe, Radiobiologist UC Davis, and former President Health Physics Society said: "By grouping the Evans data into six non-uniform dose groups selected so that only one dose group included no bone cancer cases (one with average skeletal alpha doses from zero to about 500 rad or 10,000 rem) and so that the next highest dose group included a few cases of bone cancer (cases were only observed for average skeletal alpha radiation doses that exceeded 1,000 rad or 20,000 rem), Chuck Mays and Ray Lloyd created the appealing, but misleading, linear plot shown on page 198 of BEIR IV. In their plot the "threshold" region, which is below 1,000 rad, is obscured near the origin since the abscissa is extended to 16,000 rad and only one dose group was assigned to this region. Their plot proves nothing about linearity. Evans's analysis shows that no linear model fits these data¹⁹⁰.

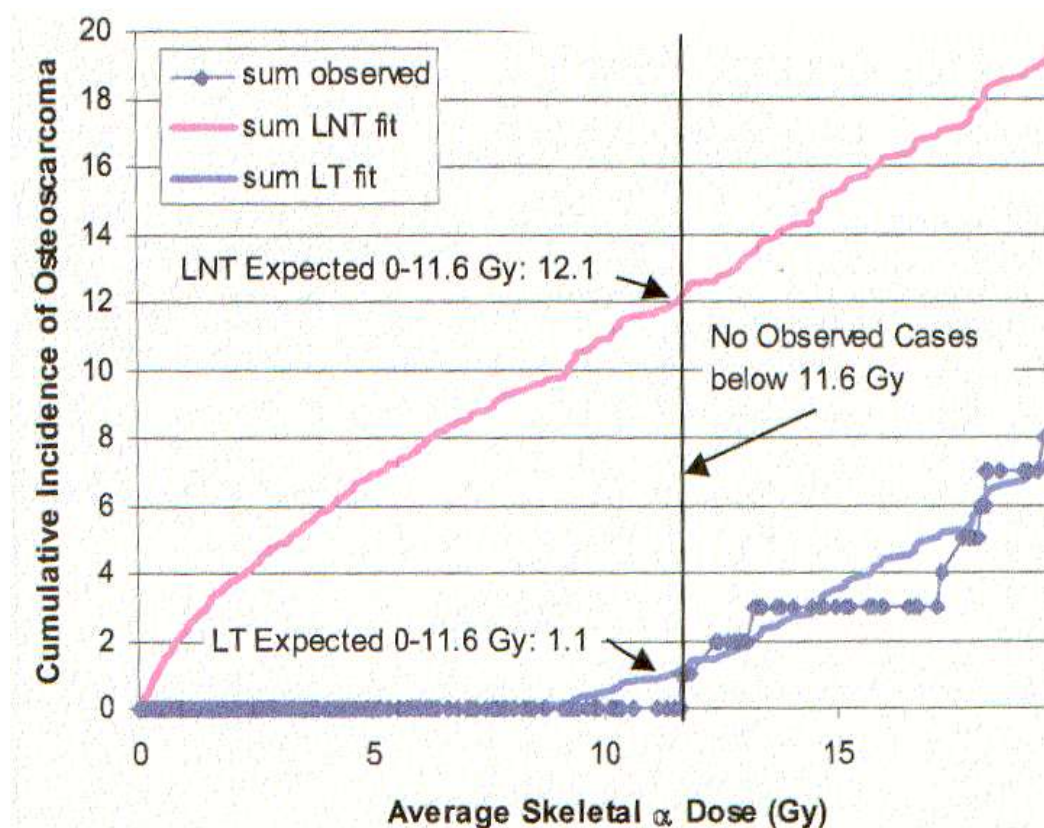


Figure 16. Incidence of bone tumors in 2800 radium dial painters. Fits for Linear-No-Threshold and Linear Threshold models. Blue line is observed and red line is expected using the LNT. There were no observed cases of bone tumors below a bone dose of 11.6 Gy (Courtesy of Pacific Northwest Laboratory, Richland, WA).

Don Wiles was employed at Eldorado Mining and Refining as a radium chemist in 1944. He used fractional crystallization of barium-radium bromide mixture to refine radium much as Marie Curie had done 40 years earlier. Using this procedure, Wiles was exposed to aerosolized radium. He collected 75 curies Ra which was used to irradiate a bag of diamonds because the owner felt that radiation made them more brilliant. Robley Evans in 1950 measured his radon exhalation while at MIT as 25 times the legal limit⁵³. There were no radiation detectors in the room during the procedure. Wiles did wear a film badge down below a 3 inch lead shield (shielding from chest to crotch). The badges were usually black every day (and changed every day). This dose was interpreted at the time 'as three daily doses'. Gamma ray peaks suggestive of Ra-226 were clearly evident in his early 80s. Wiles is still alive and healthy and has three children (Figure 17). He expects to live to 100⁵³.



Figure 17. Dr. Don Wiles, who will be 93 years-old in August, 2018.

Thresholds for induction of skeletal tumors in beagle dogs were seen at skeletal doses of 0.9-1.4 Gy for α -emitters and 28-70 Gy for β -emitters. The lowest doses at which malignant bone tumors were observed in animals injected with Ra-226 or Ra-228 were about 1 Gy. Similar

results were seen for monomeric Pu-239, Am-241 and Th-228. For the β -emitter, Sr-90, the lowest dose where bone tumors were found was 18 Gy⁵⁴.

About two thousand German patients between 1944 and 1951 received fractionated injections of Ra-224 for treatment of tuberculosis and ankylosing spondylitis. Bone tumors were found at a threshold skeletal dose of 1 Gy in children. The higher injected dose (rather than much smaller daily doses from tipped brushes) and shorter physical half-life of Ra-224 (than Ra-226) resulted in bone tumors at lower doses (than radium dial painters) in the German patients^{54,55,56}. Radium chloride has been more recently used to treat 308 ankylosing

Radium emanation was quite effective in 1915, increasing agricultural yields of many vegetables by mixing 2-3 milligrams of radium per ton of soil; yields increased from 35-70% for lima beans, carrots and sweet corn²⁰⁸. A significant growth stimulation was also seen *S. scoparium* grass cultivated with 50-500 mg depleted U/kg soil²⁴⁰.

spondylitis patients with radiological evidence of spinal involvement in Germany. Most of these patients received the full cycle of 10 injections (a total of 10 MBq radium-224). Patients showed significant improvement in pain control at 6-months post-treatment⁵⁷. Protracted Ra-223 injections offer a clear increased survival benefit and improved quality of life in men with bone metastases from prostate cancer that no longer respond to hormone therapy⁵⁸.

Nasal radium irradiation (NRI) treatment, an accepted medical treatment from the 1920s until the 1960s, was used to treat aerotitis media in submariners and aviators in the military and to treat about 2.5 million children with hearing loss, chronic otitis, and other conditions. Radiation dose estimates were 2000 rad to local tissue, 24 rad to the pituitary gland, 5 rad to the brain, and 2 rad to the thyroid. These NRI treatments did not cause cancer or any other harm¹³³⁻¹³⁴.

Thorium

Thorium is a naturally occurring radioactive element that was discovered in 1928 by a Norwegian mineralogist and a Swedish chemist. Thorium is used in many applications from lantern mantles to radiological imaging in medicine. Prior to the appearance of electric lights, illumination was principally achieved by gas or kerosene flame causing incandescence in a mantle manufactured in part with thorium. During World War Two, the largest single stored supply of thorium was transferred from a company in France to Germany. A potential nuclear fuel cycle based on the conversion of thorium to U-233 could theoretically be used to make A-bombs in Nazi Germany. Fortunately, the thorium supply from France was not destined for bombs but for toothpaste⁸⁹.

Nuclear power reactors today burn uranium-235, which is comparatively rare. Thorium is an abundant heavy metal. Factory-manufactured liquid fluoride thorium reactors (LFTRs) can produce energy 40% cheaper than coal, and 80% cheaper than wind or solar energy¹³⁵. Economics alone can drive world-wide adoption of this clean energy source, without contentious, unworkable carbon taxes. Thorium-based power reactors can provide cheap and an inexhaustible energy. China and India are both interested in developing LFTR technology¹²⁶.

Thorium is transmuted into uranium-233 for fission; the resultant fission products are different than seen for fission of uranium-235. In fact, thorium could fuel the atomic energy needs of the future. The thorium reactor would produce heat and steam which would drive a turbine just like a

uranium reactor. One gram (g) thorium would be equivalent to over 7000 gallons of gasoline in energy; 8 g would power a car for a century. A thorium fuel car was designed in 1957 as the Ford Nucleon Concept and again in 2009 as the Cadillac World Thorium Fuel Concept. Although small, a thorium reactor would produce a series of radioactive daughter products similar to those of uranium.

Thorium-232 has a half-life of 1.4×10^{10} years and like U-238 (half-life of 4.5×10^9 years) is ubiquitous throughout the earth present in nearly all locations at ppm or less amounts in rocks and soils. Th-232 decays through a series of ten radionuclide daughters before finally reaching stable lead. One of the decay products is Rn-220 (Thoron) which has a half-life of 56 sec and emits a 6.3 meV alpha particle.

On the Atlantic coast of Brazil and the southern coast of India are beaches with sand high in thorium-rich monazite and zirconite (Table 5). India has about 30% of the world's thorium reserves including monazite-bearing beach sands. Monazite contains 2-7% thorium by weight. The mean thorium-related radioactivity level of monazite bearing soil of Chavara, Kerala, was 56 times greater than the national average for India; the indoor Rn-220 levels were up to 26 times greater than normal levels for India ⁹⁵⁻⁹⁶. Residents living in houses built on thorium-rich black sands of Kerala, India experience a mean annual dose of 17 mGy.

Thoriated gas mantles are widely used in India for lighting both outdoors and indoors resulting in an average, annual dose of 2 to 8 mGy, respectively ⁹⁵. Thorium workers involved with lantern mantle production from 1920s to 1973 experienced radiation levels in 1952 of 5-50 $\mu\text{Gy/h}$ at locations within the plant. No increased risk of cancer was observed in workers ⁹¹. People in parts of Iran use the ash from burned thorium-containing mantles for healing of skin wounds. Radioactive lantern mantle ash has been shown to enhance healing of excision wounds in the skin of rats ⁹².

Location	Th-232 Concentration
Preta beach, Brazil	128-349
Dois Rios beach, Brazil	12-87
Visakhapatnam, India	300-600
Northeast coast, Spain	5-44
Ullal, India	1841
Valencia, Spain	1-11
Kalpakkam, India	352-3872

Table 5. Concentration of Th-232 (Bq/kg) in sand samples of beaches in the world ⁹⁰.

A recent review of high level radiation background areas of India failed to show any increased risk of cancer ⁹⁸. The population living in Kerala, India (~200,000), presents a unique opportunity for studies on the health effects of chronic exposure to high environmental radiation dose levels. The frequency of DNA double strand breaks in peripheral blood mononuclear cells for residents of Kerala coast was less than in low radiation areas of India (0.078 ± 0.004 at 11 mGy/y compared to 0.095 ± 0.009 at 1.3 mGy/y) ¹³¹. Cancer risk, adjusted for smoking and other confounding factors, was decreased from expected levels compared to low dose regions of India, for residents of Kerala ⁶⁴. A negative correlation of lung cancer with increasing Rn-220 concentration was found in an epidemiological study in the Haryana State of India. A negative

correlation was also found for all cancer incidence and mortality with increasing external natural background dose-rate in cities of India ⁹⁷.

A facility comprising 19 wooden warehouses and 2 hangers in the Sverdlovsk region of Russia had been used since 1960 as a storage site for 82,000 tons of monazite sand stored in 50 kg bags. The mean ambient gamma radiation dose-rates for the facility was 90 $\mu\text{Gy/h}$ inside the buildings and 44 $\mu\text{Gy/h}$ just outside the walls. The mean Rn-222 levels in the buildings was 220 Bq/m^3 compared to 19 Bq/m^3 outside. A total of 438 temporary and regular workers have been employed at the facility for up to 50 years. The maximum cumulative external dose received by a worker was 330 mGy and the maximum internal + external dose was 1300 mGy. An epidemiological study including 4679 non-exposed local controls showed no significant impact on health for the facility employees ⁹⁴.

One thorium compound has shown significant risk of cancer formation at a high radiation dose is thorotrast, a colloidal contrast material comprised of highly insoluble, tiny Th-232 dioxide particles that was used for angiography in thousands of European patients from 1930-1950. Just prior to World War II, thorotrast was removed from the approved drug list in the U.S. A published paper in 1940 said: thorotrast should never be introduced into the human body because of the danger of inducing tumor formation. Intravenous injected thorotrast, typically given as a single 25 ml injection, concentrates and is tenaciously retained in reticuloendothelial (RES) tissues of the bone marrow, spleen, lymph nodes and liver, causing significant radiation doses from α -particle emissions.

Radiation-induced cancers were not seen at organ/tissue doses <1 Gy. Excess cancer was seen in thorotrast patients at a threshold dose of 3-7 Gy for liver, 3 Gy for bone and bone marrow and 1 Gy for lung ^{89,198}. Lung tumors were caused by exhaled thoron gas. Ten cases of carcinoma of the paranasal sinuses and mastoid air cells have been recorded in humans who received antral injections of thorotrast ²¹. The use of thorotrast in human patients has also been implicated in occasional mesothelioma formation in the peritoneal and pleural cavities at very high doses from thorium particle concentration ^{56,221}.

Inhaled thoron has been used to treat human health conditions. Seventy-six subjects (mean age, 62) inhaled thoron (~ 4900 Bq/m^3) for 2 weeks. The α -atrial natriuretic peptide level of an rheumatoid arthritis group was increased and the blood pressure was decreased. These beneficial effects were associated with an increase in SOD activity, an enhanced concanavalin A-induced mitogen response and an increased level of CD4-positive cells and decreased level of CD8-positive cells. The results indicated that low level inhaled thoron therapy may prevent and treat age-related chronic diseases such as diabetes and rheumatoid arthritis ⁹³.

Low Dose Rate Radiation and Radon Studies in Animals

Several experimental studies in animals have been published that demonstrate the health benefits of radon and low dose radiation. Mice which inhaled radon at a concentration of 2000 Bq/m^3 for 24 h significantly activated anti-oxidative functions in the liver and kidney, inhibiting induced hyperuricemia by activating anti-oxidative functions ⁷⁰. Studies in rodents exposed to radon in air showed increased blood insulin levels, suppression of induced type I diabetes, and pain relief

from formalin and carbon tetrachloride administration ¹⁰¹. Radon suppresses atopic dermatitis and tumor metastasis in mice ²³⁷. Short-term exposure to radon illicit an adaptive response in Balb/c mice ²⁰¹. Mice were given tail injection of 10×10^4 B-16 melanoma cells and then given radon-containing water (203 Bq/L) every day; metastatic colony formation was determined 14 days later. Metastases were significantly inhibited under these conditions ²³⁶. Mice living on PCV-impregnated with monazite that gave a dose-rate of 5.2 $\mu\text{Gy/h}$ developed EMT6 transplanted tumors at a longer time period than un-irradiated controls ($P = 0.02$). This appears to be the lowest dose-rate of irradiation to significantly influence a tumor response in animals ²⁴⁷.

Human salivary gland tumor cells were cultured over very low-dose-rate monazite sheets emitting 4.3 $\mu\text{Sv/h}$ or 27 $\mu\text{Sv/h}$. The surviving fraction of cells after radiation was significantly greater than in un-irradiated controls; the effect was considered to be associated with more efficient repair of double-strand DNA breaks in irradiated tumor cells ²⁵⁴.

Polycyclic aromatic hydrocarbons (PAH) can be powerful carcinogens. Low dose radiation protects against PAH-induced carcinogenesis. Gamma radiation given as a single or fractionated doses to a total dose of 60-600 mGy decreased benzo(a)pyrene-induced lung tumor formation in mice ¹⁰⁵. Gamma-radiation suppressed 20-methylanthrene-induced tumor formation in mice at a dose-rate of 1 mGy/h ¹⁰⁶. Skin tumor formation in mice caused by methyl-nitro-nitrosoguanidine was suppressed by beta-irradiation ¹⁰⁷. Cigarette smoke contains polonium-210 and sixty chemicals that adduct to DNA. Using a revised hormetic relative risk model for cancer induction that accounts for both epigenetic activation (epiactivation) and episilencing of genes, Scott demonstrated that, on average, >80% of alpha-radiation-induced rat lung cancers were prevented by chronic, low-rate gamma-ray ANP ¹¹⁶

Recent Japanese Radon Therapy Studies

Japanese physicians have successfully treated four patients with advanced cancer (liver, uterus, lung, colon) that had all failed chemotherapy, by using inhaled radon as an adjuvant and primary therapy. The Kojima team provides treatments in a hormesis room for individuals who come into their clinic (Figure 18). The head of the clinic is an MD who is licensed to treat patients with ionizing radiation. These treatments are not available in hospitals. A research ethics board reviews the funding available for a proper clinical study, which costs millions of dollars. The



Figure 18. Hormesis room. The room is constructed using natural monazite excavated from a mountainous area in Japan. The average radiation level is 11 $\mu\text{Gy/h}$ at any point inside the room, even at a distance of 30cm from the wall. The average concentration of radon is 9800 Bq/m³, ²³⁶.

facility has several small rooms with wooden walls. The rooms are warm and humid with sources of radioactivity (monazite) embedded in the walls. Water with dissolved radon is delivered to patients. Cuttler recently described a new patient with lung cancer metastatic to the brain, who underwent remission after 3 months of radon therapy (Dr. Jerry Cuttler, personal communications).

Kojima's group in Japan has used a radon treatment model: A uranium ore sample of about 150 g is placed in a 8 L flask and partially filled with 4 L water. After waiting

for 12 h, 150 ml of radon water is withdrawn and used by inhalation with an ultrasonic nebulizer. Patients are exposed in a hormesis room with natural monazite on the walls giving a dose of 11 $\mu\text{Gy/h}$ and an average concentration of radon radioactivity of 200,000 Bq/m³ measured with a TRACERLAB Alpha-Scint-1 monitor. Flexible silicone sheets containing monazite had a surface dose of 37 $\mu\text{Gy/h}$ ²³⁶. The effective dose to the lung for each 40-minute radon exposure was about 0.4 mGy. Takatori developed radioactive sheets made from silicone that are impregnated with thorium (monazite) ²²⁷. The sheets are commercially available in Japan for the treatment of chronic pain and inflammatory diseases. The sheet dose-rate is 66 $\mu\text{Sv/h}$, of which only 3.8 $\mu\text{Sv/h}$ is γ -rays ²²⁶.

One case was a patient with advanced prostate cancer who was given 150 mGy x-rays per week for 30 weeks. His PSA dropped from 5.0 to 0.085 during this time. A second case was a patient with inoperable end-stage prostate cancer with bone metastasis; x-ray doses were given three times a week to a weekly dose of 150 mGy which was repeated ten times for a cumulative dose of 1.5 Gy. The patients PSA decreased from 1.0 to 0.008 and his bone metastasis were successfully controlled. The third case had intractable ulcerative colitis since the age of 15 that was treated at age 31 in the hormesis room twice a week for 40 minutes each visit and given 200 ml radon-water (330 Bq/l) each visit. The patient is now healthy and free from colitis symptoms ²³⁶.

Inhaled ²²³Rn was also effective in treating arteriosclerosis, osteoarthritis and bronchial asthma ²³⁵. Two cases of advanced breast cancer were treated with inhaled Rn-222 (0.5-1.0 MBq m³) for 40 minutes twice daily, 3 times a week. One patient started radon inhalation in August, 2016 and completed therapy on April, 2017. Another patient started therapy in May, 2014 and completed it on August, 2015. The first patient had metastasis to the brain and the second patient had metastasis to the skeleton. Both breast cancer patients were free from tumor at end of therapy with radon ²³⁵. A group of 97 patients suffering from painful, degenerative inflammatory diseases were given 1200 Bq/l radon by inhalation; most experienced long-term pain relief ²⁴⁹.

Two patients with advanced breast cancer and two patients with severe rheumatoid arthritis and dermatomyositis were exposed to radon and γ -rays from monazite sand for one hour, three times weekly, for a period of 3 to 36 consecutive months. Radon-222 (200 pCi/l) was delivered at a dose to the lung of 25 $\mu\text{Gy/h}$ while monazite delivered 40 $\mu\text{Sv/h}$ from γ -rays. The weekly dose was ~ 200 μGy and the monthly dose was ~ 1 mGy. Both showed beneficial results from this therapy. A 73 year old with severe rheumatoid arthritis underwent an amazing recovery after 15 months of radon treatment; she now receives maintenance treatment twice a month ²⁵⁰. A 69 year old female with a severe case of pemphigus and hyperglycemia, received 29 radon (1 MBq/m³) inhalation treatments. Her blood glucose levels returned to normal and her dermal condition was largely resolved ²⁵⁵. A 70 year old man with recent type I diabetic, who had showed no improvement with insulin injections, received nine months of inhaled radon (0.2 MBq/m³); his HBAIC (%) decreased from 11.2 to 6.2 after therapy ²⁵⁵.

All patients had failed orthodox therapy. In each case bio-positive changes were noted, including a decrease in tumor marker antigens, improved tumor control, and improved appetite, muscle strength and exercise ability ⁸⁶. Patients with advanced cancer are currently being treated using thin silicon plates (50 X 50 cm) containing concentrated monazite which give about 2000 $\mu\text{Gy/h}$

from beta and gamma radiations⁸⁸. No significant side-effect was found in any patient during the clinical course. Bio-positive effects could be observed in patients with benign and malignant tumors⁸⁷

Similar results were found by Takatori in Japan. Tumor reduction has been observed in a female patient with advanced gastric cancer and a male patient with pancreatic cancer using monazite and radon gas emanation. The therapy room provided 2 mGy/h at a distance of 10 cm from the walls and a radon gas concentration of 100,000 Bq/m³. Patients were also treated with radioactive silicon sheets⁸⁶⁻⁸⁷. One patient at Takatori's clinic was a 61 year old male who had undergone surgery in 2010 for advanced rectal carcinoma with multiple metastases in lung, liver and sacrum. The patient had received two cycles of chemotherapy. In addition he received low dose radiation therapy at home using a radon gas aspirator for 15 minutes, 3 x daily – 17,000 Bq/m³ radon-222 in a vinyl bag. The patient exhibited a decrease in tumor markers and dramatic sacral pain relief; no significant change in tumor size or location were seen⁸⁸. Radon and radium were also used to treat many benign conditions, including hemangiomas prior to 1960¹³².

Xofigo (²²³RaCl₂) has been approved in Japan in 2016 for the treatment of castration-resistant prostate cancer with bone metastases. Radon was given by inhalation in 40 minute sessions at a concentration of 2080 Bq m³ (56 pCi/l). Inhaled ²²³Rn has a half-life in the body of 3.8 days. This gave a whole-body dose of 50-67 µGy. A Phase III study of ²²³RaCl₂ enhanced survival by about 30%, increased time to bone metastasis from 9.8 months to 15.6 months, and significantly improved quality of life.

Inhaled radon-222 has been shown to improve the effectiveness of chemotherapy for various types of advanced cancer, including hepatocellular carcinoma and cancer of the colon, uterus and lung. Radon concentrations up to 6 MBq/m³ were shown to be very effective in treating metastatic disease. Even radon by itself appears to be effective as a primary therapy for advanced cancer²⁵⁶.

Natural Nuclear Reactor on the Colorado Plateau

Fourteen natural nuclear reactors have been found in Oklo, Gabon, Africa. Regions within the reactors contained concentrations of up to 70% uranium oxide in meter(s) thick uranium ore seams in sandstone¹⁵². This natural, thermal neutron reactor was moderated by ground water which slowed down the neutrons to make them easier to cause fission as well as absorbing neutrons for breeding of plutonium and other transuranics. The Oklo natural reactor was predicted by Kuroda many years before its discovery in 1972^{153,180}. The Oklo uranium bed contained a higher percent of U-235, estimated to be between 3-6% at the time the natural reactors intermittently went on and off as the water ebbed and flowed through the bed. Plutonium and radioactive fission products created by the Oklo bed were found throughout the rocks²⁴⁵⁻²⁴⁶.

Uranium contains only one naturally occurring isotope, ²³⁵U, which can sustain a nuclear chain reaction using water to moderate and reflect neutrons at a concentration of ~3%. The Oklo reactor

It also seems likely that other natural reactors were operational in the past. Other parts of the world have large, high assay deposits of uranium mineralization in sedimentary strata, so the circumstances which led to the formation of the Gabon reactor may not have been unique. It seems safe to assume that this process may have taken place throughout the history of the earth. Indeed, there is evidence that a natural reactor was operational in the Colorado Plateau and elsewhere in the U.S.¹⁶².

consumed an estimated 5-6 metric tons of ^{235}U and produced an equal mass of fission products and trace amounts of plutonium. Uranium deposits found at this site had a ^{235}U abundance as low as 0.44% (0.72% is normal). Overall, the isotopic composition of the Gabon uranium ore resembled aged spent nuclear fuel^{152, 163}. Found at this site was a high concentration of the fission product, Ru-99, along with the fission-product gas, xenon, trapped in geologic remnants, and transuranic radionuclides such as plutonium.

Isotope fractionation between ^{235}U and ^{238}U is not normally considered significant given the small <1% difference in mass. The $^{238}\text{U}/^{235}\text{U}$ ratio has generally been considered invariant in nature with a value of 137.8. Two modal values of the isotopic ratio exist. Their relative difference, 0.03% is statistically significant. The lower mode is found in ores from the Colorado Plateau. This difference was recognized in 1963 by the U.S. Atomic Energy Commission but the substantiating data have not been published. Insufficient data presently exists to attribute this difference either to chemical differentiation of the uranium isotopes in the sandstone deposits of the Colorado Plateau, or to dilution with ore deposits depleted in ^{235}U by nuclear reactions¹⁷¹.

Uranium chemistry is about as complex as any of the natural elements – one aspect is that uranium, while soluble in oxygen-saturated water, is insoluble in waters that lack oxygen. Uraniferous mineralization consists primarily of the oxides, uraninite and pitchblende¹⁵⁴. Uranium deposits form when oxidized groundwater that had leached uranium from surface rocks flowed down into aquifers, where it is reduced to precipitate uraninite, the primary ore mineral of uranium. Diffusion is a probable process for isotope fractionation. Both diffusion in solids and diffusion in liquids may occur, the latter being more important¹⁷². Sequential leaching experiments of U-rich minerals indicate that mineral weathering is a possible mechanism by

An anti-nuclear scientist was giving a lecture in a Salzburg, Austrian school while demonstrating the use of a Geiger counter. He scanned a collection of rocks in the classroom and the counter jump 200X normal from a rock obtained from a uranium mine. The entire school was immediately evacuated. The rock was estimated to deliver a dose of about 200 mGy per year at its surface. A search of 336 other regional schools found eleven with radioactive rocks¹⁹⁹.

which ^{235}U can be fractionated from ^{238}U in ground waters¹⁷³. A low temperature change in the redox state of uranium ($\text{U}^{6+} \leftrightarrow \text{U}^{4+}$) is the primary mechanism for separation of the ^{238}U from ^{235}U ratio¹⁵⁴. Depleted ^{235}U from sandstone due to uranium ore precipitation from ground waters reflect a temperature-dependent separation of ^{235}U and subsequent concentration within nearby geological layers¹⁵⁵. Sufficient separation and concentration of ^{235}U to ~3% level required to sustain a nuclear reaction appeared to have occurred among rocks from a Utah mine, and likely have occurred in ‘spots’ of many uranium mines in the Colorado plateau.

Uranium, fission products, and small amounts of transuranics are held together in carbonaceous sandstone deposits of uraninite from Oklo¹⁵⁷. Pitchblende is a brown to black mineral that contains 50-80% U along with Ra, Pb and rare-earth elements. The origin of pitchblende is difficult to determine based on its mechanism of crystallization, its phase transformation and composition and morphology, since natural pitchblende is an aggregate of several mineral phases¹⁶⁹. Uranium is precipitated out of solution near petroleum deposits in nuclear reaction zones. Organic matter of asphaltic type combined to form pitchblende in high uranium sandstone deposits, such as found in reactor zones in Oklo that were rich in partly graphitized bitumen, kerogen and liquid oil inclusions^{157, 176}.

Plutonium-239 is created by the absorption of a neutron by ^{238}U leading to emission of a β -particle forming ^{239}Np which emits a β -particle forming ^{239}Pu . Plutonium-239 has been found in pitchblende and uraninite ores from Canada and Belgium Congo ¹⁵⁸⁻¹⁵⁹; an upper limit was set at one part ^{239}Pu in 4×10^{15} parts ore to 0.7 parts ^{239}Pu in 10^{12} parts ore concentrate, respectively ^{159, 177}. Much lower levels of ^{238}Pu , ^{240}Pu , ^{241}Pu , ^{242}Pu and ^{244}Pu than ^{239}Pu were also found in Congo ore concentrate ¹⁷⁷.

Uranium mine tailings are usually not considered to be very radioactive ¹⁶⁴. However, there are exceptions. Sandstones from an abandoned uranium mine, emitting γ -rays at 5-10 $\mu\text{Gy/h}$ from their surfaces, were used to build a Navaho Hogan in Monument Valley, UT ¹⁶⁵. The γ -dose-rate from tailings of the Radium Hill mine in Australia was 12 $\mu\text{Gy/h}$ at the rock surface ¹⁶⁶. The γ -dose-rate in a uranium mine in Tanzania showed hot spots of 30-100 $\mu\text{Gy/h}$ ¹⁶⁷. One uranium mine rock in France kept at the home of a worker had a surface γ -dose-rate of 1000 $\mu\text{Sv/h}$ and a dose-rate of 18 $\mu\text{Gy/h}$ a meter from its surface ¹⁶⁸. A few rocks from the Free Enterprise mine near Boulder, Montana have γ -dose-rates of up to 46 $\mu\text{Gy/h}$. These relatively high dose-rates indicate natural nuclear reactors as source of excessive radiation.

In 1955 there were 800 mines on the Colorado Plateau producing uranium ore. Uranium ore is included in sandstone-type (roll front) deposits which are abundant in the sedimentary rocks of the Colorado Plateau. This type of uranium deposit is easier and cheaper to mine than the other types because the uranium is found near the surface. In some deposits, like those found in Colorado and Utah, reduction took place along curved zones which represent the transition from oxidized to reduced conditions in the aquifer ¹⁶⁰⁻¹⁶¹. Very rich uranium veins may have undergone hydrodynamic separation of uranium-235 from uranium-238, concentrating the uranium-235 to at least 3% within interstices of porous limestone rock resulting in an *in situ* geological nuclear reactor ^{160,172-173}. The process of uranium isotope separation and concentration and nuclear fission needed water for neutron moderation. Irradiation also alters the valence state of uranium ¹⁸⁴.

Initially uranium ore only contains the uranium isotopes ^{238}U and ^{235}U . Within a few days, ^{231}Th (U-235 series), and within a few months, ^{234}Th and $^{234\text{m}}\text{Pa}$ (U-238 series) grow in. The activity then remains stable for more than 10,000 years. After this time, ^{230}Th and all other decay products of the U-238 series, and ^{231}Pa and all other decay products of the U-235 series grow in. Beta-particles (ranging from 0.2-0.9 MeV) in the U-238 decay series include $^{234\text{m}}\text{Pa}$, ^{214}Pb , ^{214}Bi and ^{210}Bi . Gamma emissions from the U-238 decay series come mostly from ^{214}Pb (0.2 MeV) and ^{214}Bi (0.9 MeV) ¹⁸⁵. For uranium ore, about 50% of γ -dose comes from energies <30 KeV, 29% from energies of 30-250 KeV and 21% from energies >250 KeV ¹⁷⁴.

The $\gamma + \beta$ dose-rate from pitchblende is 310 $\mu\text{Gy/h}$ of which 90 $\mu\text{Gy/h}$ is from γ -rays. The neutron dose-rate from pitchblende ore is ~0.07% of the α, β, γ dose-rate, or too small to be included in dose calculations. The high level of ^{226}Ra in pitchblende is a significant source of γ -radiation ¹⁵⁸. The α, β, γ decay of ^{238}U daughter products alone is insufficient to account for the high Utah mine rock radioactivity.

The contribution from actinides and their daughter products to beta decay in CANDU (CANadian Deuterium URanium) reactor spent fuel becomes significant after 200 years and is

dominant at times greater than 300 years, at which time the radiation dose is predominantly from beta decay ¹⁷⁵. Like ore from the Oklo mine, rocks from a Utah mine show radiation profiles similar to aged spent nuclear fuel ^{152, 163, 176}.

Radioactive limestone rocks were obtained from an abandoned uranium mine near Monticello in San Juan County, UT. Ore from this region contained high levels of U and V ¹⁸¹. The mine near where the rocks were obtained had the highest grade uranium ore found in the continental U.S. A large amount of very high grade uraninite (up to 87% U₃O₈) was found in the mine. The ore was contained within a matrix of calcareous sandstones (filling interstices in the sandstone) and conglomerates colored dark gray to black ¹⁸².

Examination of the Utah rocks by gamma ray and laser-induced breakdown fluorescence spectroscopy indicated trace amounts of plutonium and other transuranics and fission products in addition to expected ²³⁸U daughter decay products (Figures 19-21). The Utah mine rocks exhibited radiation profiles similar to aged spent uranium nuclear fuel with a surface dose distribution of 93% due to β particles and 7% due to γ rays. The β, γ -ray surface dose-rates for mud packs ranged from 10 to 450 μ Gy/h (20-2000 times background in Loveland, Colorado) ¹⁸⁶. The γ -ray surface dose-rates for mud packs ranged from \sim 1 to 30 μ Gy/h. The half-value distance for γ -rays in air was about 1.5 cm with 10% of surface dose-rate found at about 9 cm from the rock surface. Minute amounts of americium and curium have also been found in pitchblende ¹⁷⁸. Laser-induced spectroscopic sensitivity for Am(III) in 0.1 M HClO₄ is 1×10^{-8} M ¹⁷⁹. The americium content in a Utah rock as determined by laser fluorescent spectroscopy appears to be much greater than has previously been determined in high grade uranium ore.

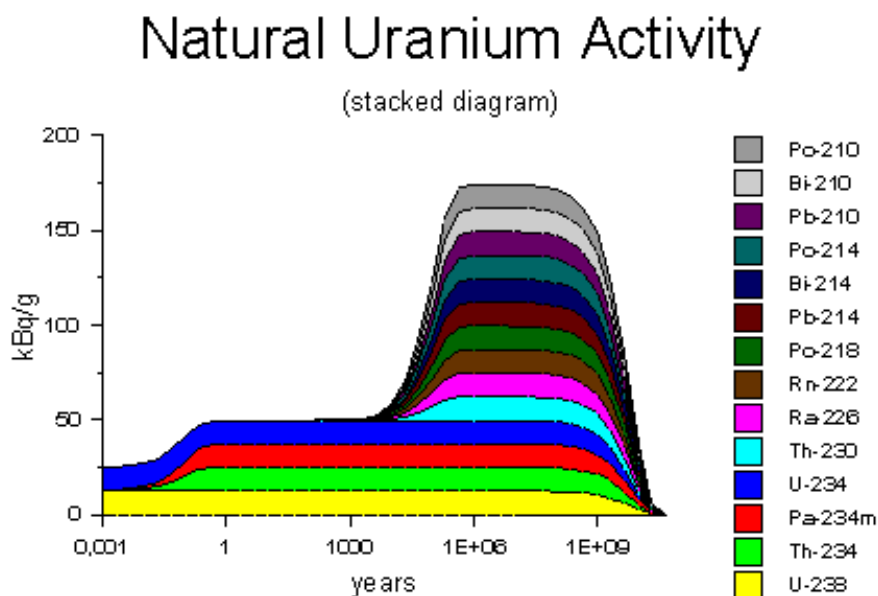


Figure 19. Buildup of daughter products in the U-238 and U-235 decay series to over a billion years. (With kind permission of Wise-Uranium, Arnisdorf, Germany) ¹⁶⁴.



Figure 20. Gamma ray spectroscopy of typical oxidized uranium ore sample; Ra-226, Bi-214 and Pb-214 are well defined (Kind permission of Stratamodel Professional Geologic Services) ¹⁸⁵.

Minute amounts of americium and curium have also been found in pitchblende ¹⁷⁸. Laser-induced spectroscopic sensitivity for Am(III) in 0.1 M HClO₄ is 1×10^{-8} M ¹⁷⁹. The americium content in a Utah rock as determined by laser fluorescent spectroscopy appears to be much greater than has previously been determined in high grade uranium ore.

Laser-induced breakdown fluorescence spectroscopy was used for elemental analysis of eight regions on a small flat rock that had a dose rate of 9.8 μ Gy/h. The entire rock had a high vanadium content. Only in one region was there found a high uranium content which was associated with a small but detectable amount of americium.

The maximum range of β -particles, with energies >0.8 MeV, in soft tissue is about $\frac{1}{2}$ their energy in MeV given as range in cm. Thus, a 2.3 MeV β -particle has a range of 1.1 cm and a 1.1 MeV β -particle has a range of 0.5 cm in soft tissue. The vast majority of β -energy is absorbed by the first cm of skin. Gamma photons are much more penetrating in tissues. The mixed type dose-distribution pattern was similar to that seen with aged spent nuclear fuel.

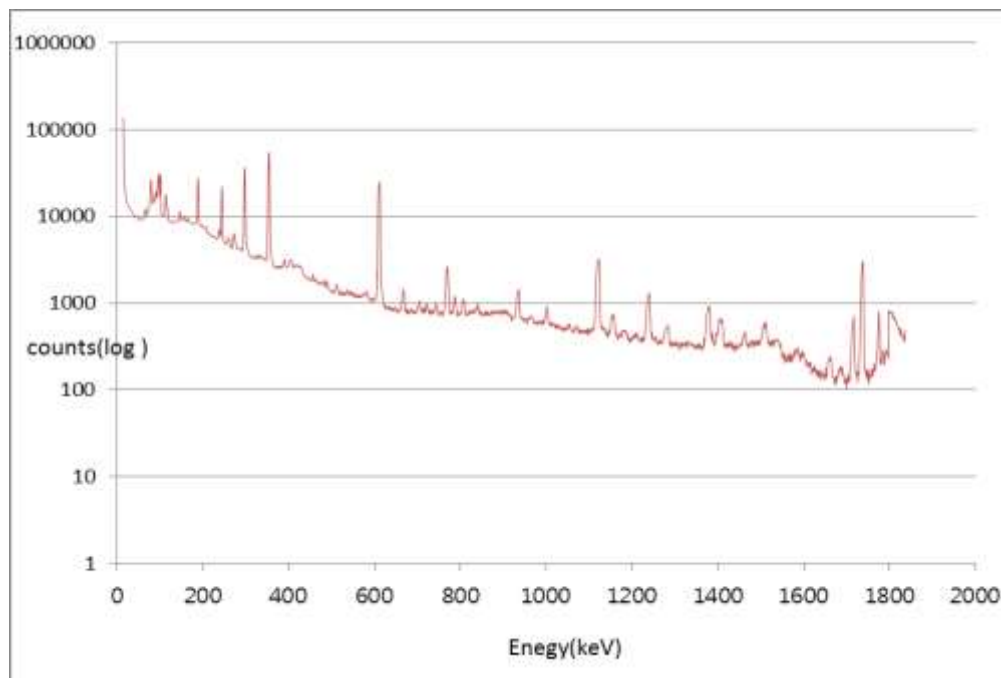


Figure 21. Gamma ray spectroscopy of a small flat rock from an abandoned uranium mine in Utah; the surface γ -dose-rate was 11 $\mu\text{Gy/h}$ and the β , γ dose-rate was 140 $\mu\text{Gy/h}$; semi-log scale. Presumptive fission products and transuranics in addition to expected ^{238}U decay products were found in Utah rock samples.

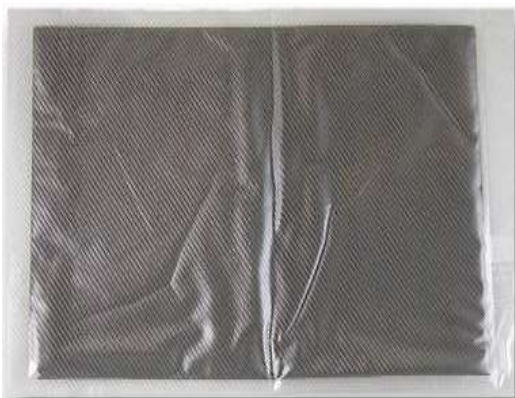


Figure 22. Mud pack comprised of uranium ore dust from the Utah mine was produced by a diamond saw and enclosed in a sealed plastic envelope may deliver from 2 to 720 $\mu\text{Gy/h}$. Radiation dose from surface (not including alpha) is 93% beta and 7% gamma.

Individual rocks from the Utah mine and the Free Enterprise Montana mine had surface γ -dose-rates up to 45 $\mu\text{Gy/h}$. B, γ dose-rates from the mud pack surface ranged from 30 to 300 $\mu\text{Gy/h}$. Indigenous radioactive rocks were obtained near an abandoned mine in Utah that produced the highest grade uranium ore found in the United States and exhibited radiological characteristics of a natural nuclear reactor. The 'mud' packs made from the Utah mine were comprised of finely pulverized rock dust (obtained with use of a diamond saw) enclosed in heavy plastic bags (Figures 22-23). This removed

dose inhomogeneity of rocks, provides a large range of dose-rates, making dose-rate estimates at the pad surface quite easy to measure and allows them to be formed around anatomical regions you wish to irradiate

Gamma ray spectroscopy was performed on the surface area of a small flat rock that had a surface γ -dose-rate of 11 $\mu\text{Gy/h}$. The spectrum was

quite different from that seen with typical uranium ore samples. Gamma ray spectroscopy of typical oxidized uranium ore shows well defined gamma ray peaks for ^{226}Ra , ^{214}Bi and ^{214}Pb and other ^{238}U daughters. Presumptive radionuclides detected in the Utah rock included ^{214}Bi , ^{214}Pb , ^{125}Xe , ^{226}Ra , ^{133}Ba , ^{196}Au , $^{111\text{m}}\text{Cd}$, ^{114}In , ^{237}Pu and ^{242}Am . These radionuclides were associated with ^{238}U daughters and fission products and transuranics associated with a nuclear pile like reaction.

The γ -ray dose rate in air was determined at intervals up to 27.5 cm from the rock surface for six rocks. A similar absorption pattern in air was seen for all six rocks. The half-value distance for γ -rays from the surface in air was about 1.5 cm with 10% of the surface dose-rate found at 9 cm from the rock surface and 2.5-3.0% of surface dose-rate found at about 25 cm from the rock surface.



Figure 23. Rock obtained from a uranium mine in Utah.

Red circles show area of analyses at KAIST by laser-induced spectroscopy. The rock had a dose-rate of 11 $\mu\text{Gy/h}$, γ -rays. Red circle 1 had a high level of uranium and a significant amount of americium. The entire rock also had a high level of vanadium.

Radiological comparison of Uranium and Thorium Containing Minerals

Torbernite was discovered by Torbern Bergman (1735-1784). The presence of torbernite has been used by prospectors as an indicator of uranium deposits ²²⁹. Torbernite is a green copper uranyl phosphate tetragonal crystalline mineral (density of 3.22 g/cc) found mostly with granites and other uranium-bearing deposits, in phosphate-bearing systems. Its chemical structure is $\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 12\text{H}_2\text{O}$ with an elemental breakdown by weight as uranium (48%), copper (6.4%), phosphorus (6.3%), hydrogen (2.2%) and oxygen (37%) ²²⁹. Torbernite readily converts to meta-torbernite with the loss of water ²³². Torbernite is found in the Joachimsthal mine where the Curies mined pitchblende from which they discovered radium and polonium, as well as in other places of the Czech Republic, Germany and France, and Utah and North Carolina in the USA ²²⁸.



Figure 24. Origin of uranium bearing mineral samples and maximum radiation dose-rate levels for beta, gamma and for gamma alone; the latter was taken through 3mm thick aluminum. Background radiation level in Loveland, Colorado is $0.5 \mu\text{Sv/h}$ or 4.4 mSv/y . All readings were made with a Digital Geiger Counter, GCA-07 (photos by Yingying Zhao).

- a. Uraninite from U.S. uranium mine (rockswithattitudes.com, South Carolina). Dimension: 10 x 5 x 3 cm (weight, 420 g); dose-rate is 320 $\mu\text{Gy/h}$ β,γ and 120 $\mu\text{Gy/h}$ γ .
- b. Uraninite from U.S. uranium mine (rockswithattitudes.com, South Carolina). Dimension: 8.0 x 6.5 x 5.0 cm (weight 650 g); dose-rate is 500 $\mu\text{Gy/h}$ β,γ and 195 mGy/h γ .
- c. Thorite from the Kemp Prospect, Cardiff Township, Ontario, Canada. Dimension: 3.7 x 3.5 x 2.3 cm (weight, 60 g); dose-rate is 55 $\mu\text{Gy/h}$ β,γ .
- d. Uraninite/Pitchblende from Night Hawk Minerals, Pritchett, CO. Rock obtained from an abandoned uranium mine in Utah. Dimension: 4.0 x 3.5 x 0.7 cm; dose-rate is 130 $\mu\text{Gy/h}$ β,γ and 20 $\mu\text{Gy/h}$ γ .
- e. Torbernite from Lawson Mine, Spruce Pine District, Mitchell County, North Carolina, USA. Dimension: 6.0 x 5.0 surface area with crystals on granite; dose-rate is 20 $\mu\text{Gy/h}$ β,γ .
- f. Torbernite from Les Bois Nais, Puy-de-Dome, France. Dimension: 11 x 4.5 cm surface area with crystals on granite; dose-rate is 85 $\mu\text{Gy/h}$ β,γ .
- g. Torbernite from Margabal, Aveyron, France. Dimension: 2.0 x 1.5 x 0.4 cm volume of crystals on granite (estimated crystal weight, 4 g); dose-rate is 130 $\mu\text{Gy/h}$ β,γ and 12 $\mu\text{Gy/h}$ γ .
- h. Torbernite from Margabal, Aveyron, France. Dimension: 2.4 x 1.5 x 0.5 cm volume of crystals (estimated crystal weight, 6 g); dose-rate is 245 $\mu\text{Gy/h}$ β,γ and 30 $\mu\text{Gy/h}$ γ .

Beta radiation dominates to about 80% of radiation dose delivered by uraninite, torbernite and thorite rocks (Figure 24). The remaining dose is from gamma radiation. Previous analyses of Night Hawk rock samples in Korea showed 8% of total dose due to gamma irradiation (Figure 23)¹⁸³. Previous published measurement of dose-rate for a 10 g spherical sample of torbernite gave a dose-rate of 122 $\mu\text{Gy/h}$ and 12 mGy/h for a 1000 g sphere (Table 6)²²⁸.

Table 6. Radiation dose-rate of pure, spherical, 10 g weight, radioactive, crystalline minerals²²⁸.

Mineral	Dose, $\mu\text{Gy/h}$
Uraninite	198
Torbernite	122
Thorite	42



Figure 23. Uraninite necklace (Night Hawk Minerals, Pritchett, CO) Dimensions: 5.5 x 3.0 x 0.6 cm. Dose-rate along lower blackened edge is 120 $\mu\text{Gy/h}$, β,γ .

Cumulative doses of up to several hundred mGy from pulverized Utah rocks as mud packs have been used to successfully treat a wide variety of inflammatory, fibrotic and proliferative conditions in humans (Chapter 7) ¹⁸³.

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- hobbles into the Radon Room. Designed for those too claustrophobic to travel below ground to the original uranium mine, it pumps in radon gas.”
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