Nuclear Energy and Health,
And the Benefits of Low-Dose Radiation Hormesis

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INTRODUCTION

As populations grow and developing countries strive for a high standard of living, the rate of energy consumption rises (Figure 1). By 2030, global energy demand is projected to increase by 50%, with electricity generation nearly doubling worldwide. Nuclear energy is receiving much attention because of concerns about our energy sources. Environmental groups urge large reductions in combustion of coal and hydrocarbons, the source of more than 85% of our primary energy; however, they advocate options that avoid nuclear power. They believe that the nuclear option would expose people to radiation and more risk of weapons proliferation.

Reactors could supply most of the demand in a safe, sustainable manner were it not for fear of radioactivity. Any releases would likely deliver radiation within the range of naturally occurring exposures, to which life is already accustomed. Reference 1 discusses the key areas of concern. Studies of actual health effects, especially thyroid cancers, following exposures are assessed. Radiation hormesis is explained, pointing out that beneficial health effects are expected following a low dose or dose rate because protective responses against stresses are stimulated. The notions that no amount of radiation is small enough to be harmless and that a nuclear accident could kill hundreds of thousands are challenged in light of experience: more than a century with radiation and six decades with reactors. If nuclear energy is to play a significant role in meeting future needs, regulatory authorities must examine the scientific evidence and communicate the real effects of radiation. Negative images and implications of risks derived by unscientific extrapolations of the high-dose effects must be dispelled.

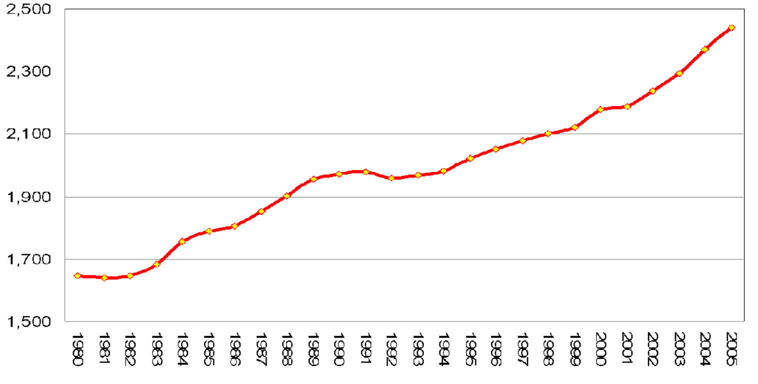


Figure 1. Per Capita World Electricity Consumption 1980-2005
(kWh/person/year vs. year)

HEALTH EFFECTS: EVIDENCE AND DISCUSSION

This paper summarizes the surprising evidence and discussion presented in Reference 1 about health effects of low dose radiation. In the mid-1980s, radon gave 55% of the U.S. collective dose (Figure 2). Since then, the medical component has increased from 15 to 50% of the total (Figure 3). Based on the concerns about radiation, we would expect a rise in the incidence of leukemia; however, there has been no increase. A test of the linear no-threshold assumption of radiation carcinogenesis disproved it (Figure 4); lung cancer mortality is lower in those U.S. counties where the radon concentration in homes is higher. In the few counties with very low radon levels, mortality is higher. The Life Span Study of Hiroshima-Nagasaki survivors was expected to show evidence of cancer due to radiation; however, the results published in 1996 indicate only 344 excess solid cancer deaths and 87 excess leukemia deaths among the study cohort of 86,572 (half of the survivors within 2.5 km of the bombs). They suffered also severe burns, other wounds, infections, starvation, pollution and other adverse conditions. The evidence of beneficial health effects of low doses that was presented has been ignored.

Annex B of UNSCEAR 1994 summarizes 192 studies that show the “adaptive” response of organisms to low-dose radiation (e.g., Figure 5). Many more studies have been carried out that demonstrate radiation “hormesis” stimulation of protective mechanisms by low doses, Figure 6. The biological mechanism of this beneficial effect can be understood by referring to Figure 7. The DNA in each cell would be damaged at an enormous rate by the free radicals present in cells (from the oxygen that they use for energy); however, antioxidant production prevents most of the potential damage. About 10^6 DNA alterations per cell per day occur, but enzymes and other mechanisms repair almost all of the DNA damage, bringing the number down to about 10^2 persistent DNA alterations per cell per day. Cell suicide, immune system attack and other processes reduce the number of cells with damaged DNA by a factor of about 100. There is evidence that low-level radiation stimulates DNA damage prevention, DNA repair and damaged cell removal. The combined effect of stimulating these protective mechanisms is illustrated in Figure 8, where a factor of ten increase in background radiation, from 0.1 to 1 cGy/y (1 rad/y), could increase each by about 7%. In this case, the net reduction in cancer mortality would be about 20%.

CONCLUSIONS

More than 85% of the global energy demand is provided by burning coal and HC fuels, and the demand is growing rapidly. Society has concerns about the impact of emissions on the environment and health. Fuel extraction and supply have significant adverse effects, and sources of oil are not sustainable. Our dependence on and funding of hostile countries that supply these fuels is a worry. Fission energy could sustain humanity indefinitely; however, use of this option is seriously impaired by health myths and anti-nuclear political activity.

Nuclear plants and the methods of designing, constructing, operating and maintaining them are very well understood. They provide a very high level of nuclear and industrial safety, as long as the designers, builders, operators and maintainer are properly trained and imbued with a strong safety culture. The designs have many layers of defence-in-depth, for tolerance of human error. As a result, most failures do not release radioactivity. The worst realistic case, with fuel and containment failure, is expected to cause few, if any, public fatalities. The industry is well aware of the social fear of radiation and the media’s desire to publicize and exaggerate the significance of any nuclear incident.

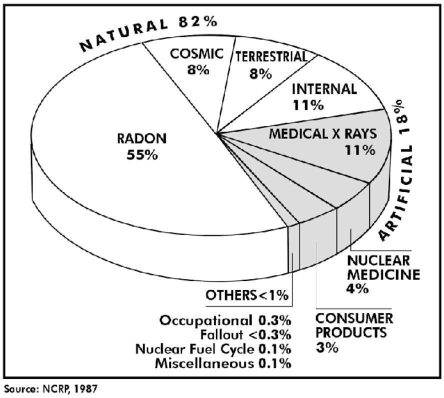


Figure 2

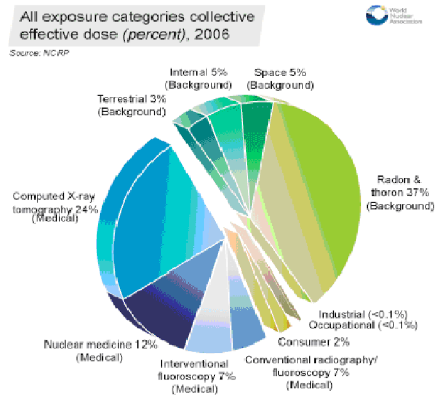


Figure 3

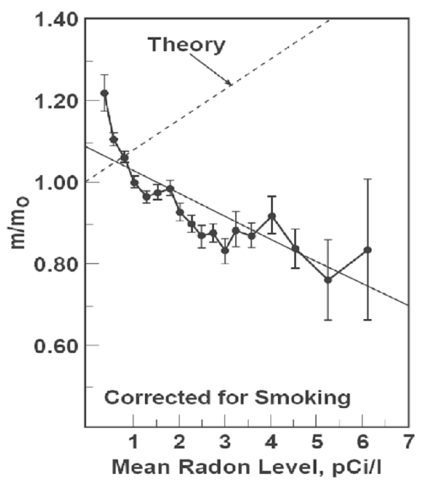
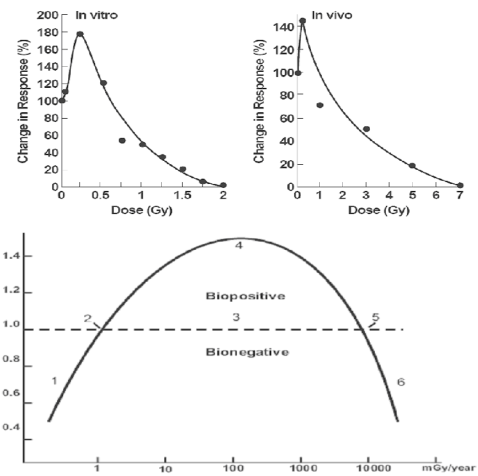


Figure 4



Figures 5 and 6

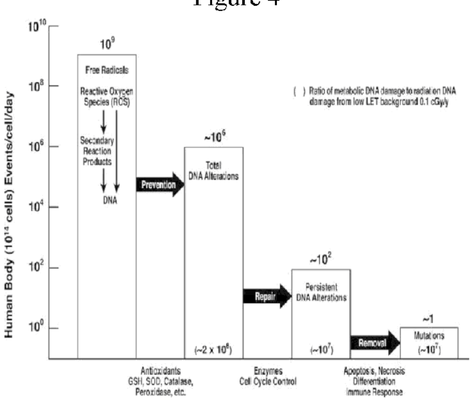


Figure 7

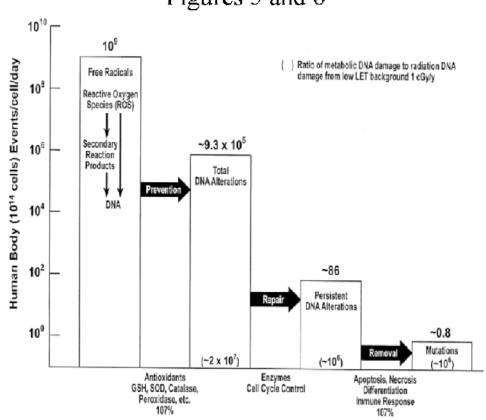


Figure 8

Technologies are available for many types of nuclear plants, including breeder reactors that can convert U-238 and Th-232 into fuels. With breeders, it is feasible to extract uranium from the oceans and still keep the fuel cost below one percent of the cost of electricity. Rivers carry uranium into the oceans at a rate that would allow at least 6,500 tons of uranium to be extracted each year, adequate to generate about ten times the world's present electricity usage. Fission of uranium in breeder reactors is consistent with the definition of "renewable" energy in the sense in which that term is generally used.

Techniques have been tested to recycle used fuel so as not to produce materials and pathways for nuclear weapons; however, this is not widely known. The amount of used fuel (and waste from recycling) is small. Compared to fission, roughly 50 million times more coal, oil or gas material is needed for the same amount of energy, and the amount of waste is very large. The half lives of the major radionuclides from completely recycled fuel (Cs-137 and Sr-90) are relatively short, about 30 years. Surface storage of used fuel and waste in robust containers presents no hazard because there are no exposures. Geological disposal has been shown to be technically feasible. Demonstrating social acceptance is challenging because we created a fear of adverse health (cancer and birth defects) after low doses of human-made radiation.

Severe nuclear accidents and fatalities are low in number. Because of the very high power output and the large amounts of activity, great care has been taken to control power, cool the fuel and contain radioactivity. Safety is priority one! Accidents are very costly due to the loss of power to the consumers who depend on it, the very high cost to repair the damage, and the loss in revenue. Employee injuries would result from high radiation doses. Plant owners will maintain very high safety. Accidents that release any radioactivity reduce social acceptance.

Thyroid cancer is claimed to be the most common effect of low dose radiation exposure in children. Nuclear regulations are based on tight radioiodine dose limits. A review of recent scientific articles does not support this assumption. Thyroid cancer is a common occurrence in most populations; it does not appear to be related to radiation exposure. Radioiodine therapy of hyperthyroidism does not appear to cause a detectable increase in cancer. On the contrary, decreases in overall cancer incidence and mortality are reported.

Short-term effects of radiation on living things have been extensively studied for more than a century. Over the past 50 years, many studies have been carried out on long-term health. Adverse effects are seen after high doses, and data has been fitted by a straight-line function of dose. Adverse effects have been impossible to detect after a low dose, so (cancer) risk has been assumed to be proportional to dose (DNA damage?) by extending the straight-line fit to zero dose (LNT assumption). Professional societies (HPS, ANS) issued position statements advising against using the LNT assumption to predict excess cancer mortality in the low dose range. Studies that looked for beneficial effects generally showed increasing stimulation versus dose, to a maximum. Beyond the optimum, as exposures were increased, decreasing stimulation was noted, followed by a crossover into the inhibitory range (radiation hormesis). Results of such important studies are not considered in radiation protection regulations.

It is the effect of radiation on an organism's defences that determines its health effects, not the amount of DNA damage. Low doses stimulate them, while high doses inhibit them.

Based upon human data, a single whole body dose of 150 mSv (15 rem) is safe. The high background of 700 mSv (70 rem) per year in the City of Ramsar, Iran is also a safe dose limit for continuous chronic exposure. Both dose limits are also beneficial.

People are not familiar with nuclear radiation. While they understand visible light and accept cell-phone radiation, they have been taught to fear ionizing x-rays and nuclear radiation. Most people are frightened of human-made radiation, but some are aware of, and accept, naturally occurring radiation (about 15,000 events in the body per second).

Ionizing radiation was discovered over a century ago, and low doses have been used to cure infections and other illnesses for about 50 years, even though the biology underlying the reason for beneficial health effects was not understood. Fear of radiation was created by the nuclear community, and the anti-nuclear activists endorsed it. Radiation was abandoned as a stimulatory agent for most applications after the advent of antibiotics and other biochemical agents in the 1950s. Today, tumors are irradiated with high doses to kill cancer cells. X-rays and radioisotopes are widely used in medical imaging, but concerns continue to be raised about genetic effects and risk of cancer from these low doses.

Between the early 1970s and the present, low-dose radiation treatments have been provided to many patients to prevent and cure various types of cancer. Good results were achieved. These treatments, which stimulate protective biological processes, are still not accepted.

RECOMMENDATIONS

Professional and scientific societies should organize meetings/events to discuss the benefits of low-dose radiation and the changes that are needed to technical standards, procedures and to regulatory standards. Compliance with standards, based upon the transparently erroneous LNT assumption, costs hundreds of billions of dollars annually.

Regulatory authorities and health organizations should examine the extensive scientific evidence and their own attitudes about the health effects of radiation. New standards for protection should be prepared that are based on evidence from radiobiological science and the ubiquitous occurrence of natural radioactivity. The new standards should reference carefully reviewed scientific publications, particularly those ignored or dismissed by policy-setting studies. There is strong evidence of beneficial effects and no definitive evidence of harmful effects after exposures to low doses. Harmless doses of radiation should not be regulated.

After bringing the nuclear community and its policies and practices into line with the science, a communication program should be carefully developed, including a strategy to explain the reality of low-dose radiation hormesis effects. The beneficial health effects of low doses and low dose rates should be emphasized. This program, to achieve widespread social acceptance of nuclear technology, would enable it to supply a major portion of the world's growing need for energy. (A further benefit would be a rational public reaction to terrorist "dirty bombs.")

The standard for releases of radioactivity from geological nuclear waste repositories should reflect radiobiology and the response of humans and other living species to natural and medical radioactivity.

Used fuel management should reorient from deep geological disposal to breeder recycling.

Even though low doses are beneficial, plant owners and operators should continue to exercise great care in preventing radioactive releases and controlling worker exposures.

Probabilistic risk assessments identify weaknesses in design and operation, to reduce the likelihood of accidents. In light of radiation hormesis, PRAs should not be used to calculate low-dose health risks because the result, a prediction of an increased cancer risk rather than a decreased cancer risk, would be both erroneous and misleading.

Emergency response personnel should be taught the reality of radiation effects, and they should factor this information into their plans and procedures.

REFERENCE:

1. Cuttler J.M. and Pollycove M. *Nuclear Energy and Health, And the Benefits of Low-dose Radiation Hormesis*. Dose-Response 7, p.52-89 (2009). Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2664640