NUCLEAR SHADOWBOXING

CONTEMPORARY THREATS FROM COLD WAR WEAPONRY

VOLUME 2: LEGACIES AND CHALLENGES

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Appendix Va1
RADIATION, POLLUTION, AND RADIOPHOBIA

Supplementary knowledge about radiation, pollution, and radiophobia is compiled in this Appendix. We have separated this information out of Chapter V in order to provide the inquisitive reader with more details relevant to the topics and analysis of Section A. A prominent public concern is the effect of radiation, especially from nuclear-electricity production; so we place its risks perspective with other relevant lifetime hazards, particularly coal-burning power plants. This leads to some comparative observations about low radiation levels based on objective rather than subjective standards.

A Supplement on Radiation Properties of selected radioactive isotopes has been included in this Appendix, along with a comparison of some natural and artificial radiation source levels. Updates on cancer and mortality rates associated with radiation have been added to the Posterior pages of this Volume.

Radiation Effects

It does not matter whether radiation comes from natural or man-made sources: Its effect is the same, and we find no adverse radiation effects from the low does received from mother nature. To the contrary, the evolution of life and human beings has occurred when, and perhaps because ambient radiation levels were once much higher than they are today. Billions of years ago, bacteria in the ocean were irradiated ten times more than now, with a much higher dose deep in the earth; bacteria are now the largest biomass. No increase of cancers or hereditary disorders has ever been found for animals that live in natural high radiation areas. In fact, human beings might have become intelligent and dominant partly as a result of favorable radiation-induced genetic mutations.

Living organisms have developed powerful biological defense-mechanisms against a multitude of adversities: ionizing radiation, solar radiation, oxygen and its radicals, heavy metals, organic toxins, heat and cold, etc. Humans have even learned how to adapt adverse phenomena to their advantage; for example, bacteria are killed by using ultraviolet light from the ionizing portion of the natural-light spectrum.

The prolonged life of diverse species demonstrates a natural effectiveness of biological defenses against environmental agents, including ionizing radiation. Human life has flourished in, or despite, a milieu of radiation. Now that humans have more control over their environment, optimization of choice and circumstance have lead to inquiry into the best coexistence with voluntary and involuntary radiation.

LNT. Because high-level acute radiation doses are harmful to living species, the question inescapably comes up as to what lower exposure to radiation is not harmful, especially if absorbed over a long period of time. For example, an acute dose of 1.5 sievert (150 rem — see box next page) will probably cause radiation sickness, but if the same dose it spread out over a human lifetime, it is unlikely to cause any noticeable effect.

Because the observable effects of low doses are so small, they are too difficult to compile from individual medical examinations; instead, it is necessary to determine average effects from large populations exposed to low levels of radiation. However, such epidemiological studies have confounding difficulties intensified by extraneous factors that also affect health.

As a result of problems in directly measuring the effects of low doses and rates of radiation exposure, a common practice is to extrapolate downward the data from higher doses and rates. The dose-response curve is assumed to tend toward zero biological response if there is no radiation dose.

However, vigorous disputes have persisted among scientists (and public regulators) over the form of the dose-response curves for cancer risk at low gamma doses: whether to use the linear, no-threshold (LNT) model, which is the simplest extrapolation from high-level radiation effects, or to use a more sophisticated, experience-based model. Figure 1 shows three qualitative alternatives for extrapolating the dose-response data, including the straight line which represents the LNT assumption. The LNT response curve, which postulates the absence of a low-level threshold, amplifies the estimate of risk from minor gamma exposure.

Radioactivity: Units of Measure. In the International System (SI) of units, the becquerel (Bq) is the unit of radioactivity. One Bq is 1 disintegration per second (dps); one curie = 37 billion Bq; 1 Mbq = 27 microcuries; 1 GBq = 27 millicuries; 37 GBq = 1 curie; 1 TBq = 27 curies. Uranium-238 has 0.15 millicuries of radioactivity per pound, while cobalt-60 has nearly 518,000 curies per pound. [http://www.orau.gov/reacts/measure.htm]

Radiation-Measurement Units

	Radioactivity	Absorbed Dose	Dose Equivalent	Exposure
Common Units	curie (Ci)	rad	rem	roentgen
SI Units	becquerel (Bq)	gray (Gy)	sievert (Sv)	coulomb/kilogram

SI-Unit Prefixes and Symbols

Multiple	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n

Equivalents

1 becquerel	1 disintegration per second
1 curie	3.7×10^{10} disintegrations per second
1 millicurie (mCi)	37 megabecquerels (MBq)
1 rad	0.01 gray (Gy)
1 rem	0.01 sievert (Sv)
1 roentgen	0.000258 coulomb/kilogram
1 megabecquerel (MBq)	0.027 millicuries (mCi)
1 gray (Gy)	100 rad
1 sievert (Sv)	100 rem
1 coulomb/kilogram	3880 roentgens

Radiation Conversion Factors

To convert from	To	Multiply by
curies (Ci)	becquerels (Bq)	3.7×10^{10}
millicuries (mCi)	megabecquerels (MBq)	37
microcuries (µCi)	megabecquerels (MBq)	0.037
millirads (mrad)	milligrays (mGy)	0.01
millirems (mrem)	microsieverts (µSv)	10
milliroentgens (mR)	microcoulombs/kilogram	0.258
becquerels (Bq)	curies (Ci)	2.7×10^{-11}
megabecquerels (MBq)	millicuries (mCi)	0.027
megabecquerels (MBq)	microcuries (µCi)	27
milligrays (mGy)	millirads (mrad)	100
microsieverts (µSv)	millrems (mrem)	0.1
microcoulombs/ kilogram	milliroentgens (mR)	3.88

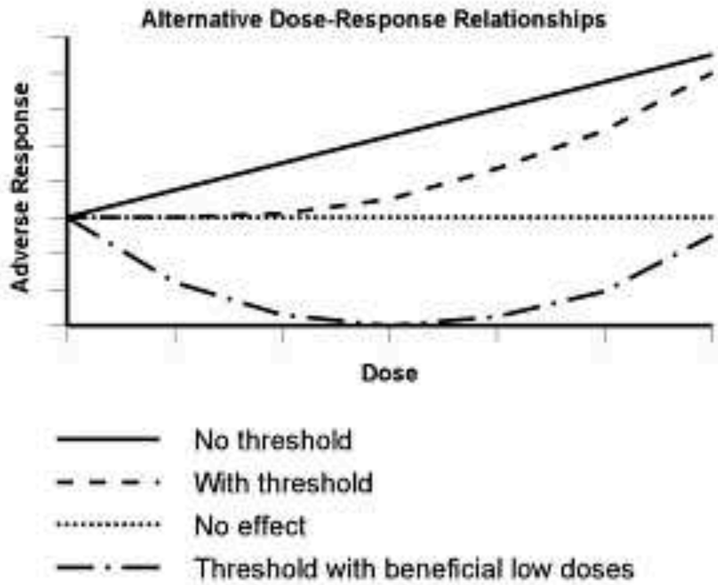

Figure 1. Three Alternative Extrapolations of Radiation Response to Decreasing Dosage

The distinction between the therapeutic and toxic properties of an agent is distinguishable by the dose. Examples of extrapolations of these relationships, which are done in the absence of definitive data for low doses, are shown in Figure 1. Zero dose is at the leftmost extreme of the abscissa, and measurable doses begin to have statistical significance at the rightmost extreme.

For the "no threshold" linear representation (LNT), the adverse effect is expected to decrease steadily as the dose approaches zero. In the "with threshold" case, zero adverse response is assumed before the dose reaches zero. The "no effect" line corresponds to the baseline with absence of any expected response, good or bad, regardless of dose. The "threshold with beneficial low doses" curve is discussed under the next topic, radiation hormesis.

LNT, which is the model used in the absence of adequate defining data, has no underlying established scientific basis, nor is it realistic, but the model had simplified earlier regulatory work. The problem is that LNT has resulted in overly stringent radiation standards.

For readable, though slanted, objections to less-stringent radiation-exposure standards, an article by environmental activist LeRoy Moore is available in the *Bulletin of Atomic Scientists*.[1] Moore, of the Rocky Mountain Peace and Justice Center, has been an appointee to the National Council on Radiation Protection and Measurements.

Data from the atomic bomb survivors in Japan have generated much useful information on radiation effects, but the application of these results is limited for two reasons: First, the dose rate was extraordinarily high, and second, severe stress on survivors of the blast undoubtedly resulted in many deaths and abortions from causes other than radiation. In any event, current estimates and modeling of health risks from low-level radiation have been extrapolated in part on that singular experience of high dose rates. In essence, data from Japanese survivors — that is, the population exposed to a brief burst of gammas and neutrons — can at best set upper limits to when extrapolated to the effects of low-dose, low-rate exposures. Nevertheless, it is worthwhile to note that, including cancer deaths, the survivors are living longer on the average than Japanese not exposed to the atomic bombs.

Pittsburgh University's Dr. Bernard L. Cohen is a physicist and meticulous researcher who has thoroughly studied available data on post-millennium cancer risk from low-level radiation.[2] He looked into data of the International Agency for Research on Cancer on data from nearly 96,000 monitored radiation workers in the United States, United Kingdom, and Canada, which found that

> For all cancers except leukemia, there were 3830 deaths but no excess over the number expected [in the absence of radiation].

Cohen attributes the small low-level radiation risk partly to prolonged latency between carcinogenic radiation exposure and cancer death; that is, people outlive the actual development of cancer from low radiation levels. He found, in general, that the LNT model "grossly" overestimated the cancer risk from low radiation doses and exposure rates.

Radon — one of many natural radiations from soil — seeps out of rocks and sometimes concentrates indoors. Indoor rates of radiological exposure to members of the public have been found to occasionally exceed the occupational (whole body) limit for nuclear workers. In searching for a risk value to attach to radon, the National Research Council's BEIR VI report declared that about one lung-cancer death out of seven can be attributed to radon; for nonsmokers, the rate would be about one in four. Those estimates, however, are not based on empirical evidence, but rather on an arbitrarily assumed linear extrapolation from high dose rates (LNT).

The BEIR VI Committee estimated that 2700 of 68,000 underground miners died of lung cancer, primarily because most of them were smokers. Besides tobacco smoking, the inhalation of dust and other pollutants in mines complicates the analysis.

Considerable data on radiation effects have been accumulated. Some of the occupational-exposure results, documented by Massachusetts emergency-management engineer James Muckerheide, are mentioned in the box on the next page.[3] The comparative societal costs associated with various public-health options have been evaluated by many scientists. For example, Bernard Spinrad, whom we knew as a competent and highly experienced researcher, said:[4]

> The health effects of pollution from all extractive industries (mining, agriculture, forestry) are doubtless more severe than those from radiation, and the health effects of crime, poverty, and ignorance more severe still.

A major psychological barrier in dealing with radiation is the irrational fear (radiophobia — see below) that has developed about low doses.[5] As a result, "the use of radiation has, at times, been unnecessarily restricted and beneficial outcomes forfeited."[6] For example, costs of reactor safety in the United States have been estimated at $2.5 billion per life saved; this overly conservative

Occupational-Exposure Analysis. A 1989 study of almost 36,000 white male workers who had lifetime exposures of 20 to 200 millisieverts (2 to 20 rems) at three U.S. nuclear weapons plants found that they had a lower total cancer mortality rate than a comparable control group. The workers had a lower cancer mortality rate (leukemia and lung) than the U.S. population. "[The data] strongly suggest that the optimum lifetime exposure for ***decreased*** cancer mortality is greater than0.25 sieverts [25 rems]." In other words, the nuclear workers had less cancer.

Four thousand nuclear workers at a Canadian energy plant had average exposures of 70 millisieverts over a 20-year period, but they had a ***lower*** cancer mortality rate than 21,000 unexposed workers. At another Canadian facility, similar results were obtained in comparing 4000 exposed workers with 4000 other workers in the same plant.

Of the 6660 deaths occurring from 1955 to 1988 for 95,000 predominantly male workers at several British nuclear weapons plants, the total cancer mortality rate ***receded*** with increasing radiation exposure. According to Muckerheide, "The optimum lifetime exposure for the 33 years appears to be at least 20 cSv [20 rems], about 0.6 cSv [0.6 rem] per year."

Although some studies that have shown increased cancer mortality in small isolated groups of workers, about 8 million person-years of data on chronic exposure to humans have been evaluated, showing overall ***decreased*** cancer mortality for low levels of radiation.

Among 100,000 registered Japanese A-bomb survivors, males exposed to less than 40 cGy showed significantly ***lower*** mortality from non-cancerous diseases than age-matched unexposed males.

After reviewing the above information, Muckerheide concluded that "substantially misrepresented" data have been used to support the linear-no-threshold hypothesis, and that "billions of dollars are wasted in the unnecessary cleanup of sites to background levels." Replacing the LNT with a more realistic model could bring nuclear [power] to a more cost-effective level, [and] nuclear medicine could also benefit [because the costs] have been driven largely by regulatory burdens and problems with producing and handling isotopes and controlling nuclear material.

No data exist that support adverse health effects below at least 10cGy (10 rems), and hundreds of billions of dollars in environmental cleanup costs are producing no public health benefits.

standard has forced utilities to forgo nuclear plants in favor of coal-burning power plants, each of which during its service life kills about 1000 people with polluted air (see Appendix Ve).

Permitted radiation-release levels for nuclear facilities are thousands of times lower than natural radiation in high background areas — and even lower than radiation emitted from many coal-burning power plants. If the nuclear environmental-protection standards were applied to coal plants, $2.5 trillion would have to be spent to improve smoke-emission controls — close to the annual U.S. gross domestic product.

One reason for the disparity between standards and reality is the reluctance of lawmakers to enforce expensive environmental controls on fossil-fueled power plants. Another reason is the public's emotional phobic response to radiation. A lethal one-hour dose of ionizing radiation is about 10 million times higher than the average natural dose; yet more than $100 billion in the United States alone has been spent on fighting what has been called a "phantom risk" of low radiation doses.[7]

When Congress asked the National Cancer Institute in 1983 for a tabulation of the "probability of causation" of cancer for those exposed to fallout from atomic weapon tests, the response was that for almost all of the "downwinders" who developed cancer, the probability was less than 50 percent that the tests were the cause.[8] It was simply a tossup; it was just as likely that other factors were responsible for the cancers.

Hiroshima and Nagasaki atomic-bombing survivors who had less than 200 millisieverts (20 rems) have not suffered significant induction of cancers.[9] After fifty years of study, the progeny of survivors who had much higher, near-lethal doses have not developed adverse genetic effects.

Such meticulous findings are ignored when the LNT assumption is justified. Although the LNT hypothesis played an important role in effecting a nuclear-test moratorium, and later a ban on atmospheric nuclear tests, it has otherwise had a negative societal, health, and economic impact. The LNT model has contributed to a worldwide fear of radiation, with the result that nuclear-energy growth has been inhibited in many countries, including the United States.

The concept of "dose commitment" is another morally suspect offspring of LNT. The individual "commitment" accumulated over the past 130,000 years of existence of *homo sapiens*, is 286,000 mSv for a now-living human, which corresponds to ~100 short-term lethal doses per person. Each of us is burdened with this or similar dose "commitments;" yet the medical effects of these enormously high "commitment" doses have quite possibly been biologically essential or beneficial to living species.

In short, the proposition that low-level radiation is a significant cause of cancer is still controversial — more than a century after the discovery of ionizing radiation, and long after recognition of its other effects (harmful and beneficial).

Also controversial, but gaining in credibility, is the proposition expounded by some scientists that a small amount of radiation can be beneficial, as we discuss in the next topic.

Radiation Hormesis. Radiation-induced cell repair or regeneration is a contested phenomenon. Yet, many natural mechanisms exist for DNA repair in a cell.

In the bottom curve of Figure 1 above, low doses represent a therapeutic effect, namely an initial benefit (reduction in adverse outcomes) shifting gradually to an adverse effect as doses become higher. This pattern is called hormetic. Hormesis is being reconsidered by regulatory officials in the light of new data, not just for radiation but for other toxic substances; for example, the dose effects of lead have been shown to be both a potential carcinogen and as a systemic toxicant.[10]

Adverse biological effects such as mutations and malignancies originate in the cell nucleus; DNA is the target that could lead to radiation sickness and death. Originating outside the nucleus is natural radiation which can cause ionization in cells. However, most DNA damage in humans is spontaneous and caused by thermodynamic decay of free radicals from oxygen metabolism; in fact, something like 70 million of such spontaneous DNA-damaging events occur in each cell per year. Only if armed with powerful defense system could a living organism survive that high rate of DNA damage.

A natural radiation dose of 2.2 mSv per year corresponds to five DNA damages/cell/year; this is feeble compared to other noxious agents, such as significant body-temperature changes or the ingestion of heavy metals, and it is a ten-millionth of the normal cellular damage rate.

Radiation hormesis is a disputed theory based on observed health-improvements of individuals subjected to low radiation doses.

One of our Argonne colleagues, Norman Frigerio, carried out a study that correlated cancer rates with the average background radiation in each U.S. state. His results contradicted LNT model: he found consistently lower cancer rates in high-background-radiation states. This correlation has since been confirmed by others.

Studies in populations exposed to high-background radiation have consistently failed to find adverse health consequences; instead, they often report indications of beneficial effects, one example being a stable Chinese peasant population of more than 70,000 who have been living for generations in high radiation areas.

In the 1980s, Bernard Cohen undertook systematic studies of the effects of natural background radiation. He tested the LNT model by comparing lung-cancer data with variations in residential radon, measured in 272,000 homes in the most populated U.S. counties. LNT invariably overstated the effects of radiation. As an example, lung-cancer incidence in the high-radon area of Cumberland County, Pennsylvania, was lower than the Pennsylvania average. Many other investigators have gotten similar results.

Because radon data did not exist at the Pennsylvania county level, 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. In the various randomly chosen counties in which 450 university physics professors at 101 universities assisted, Cohen's residential radon measurements faulted the LNT model. Additionally, he acquired all Environmental Protection Agency and state radon data, which showed that the higher the radon levels, the lower the incidence of lung cancer — just the opposite to the LNT assumption.

Dr. Kenneth Bogen at Lawrence Livermore National Laboratory independently compared EPA environmental (not residential) radon data, county by county, with 1950–1954 lung-cancer mortality records for women of ages 40 to 80 and 60 to 80 (who had smoked little). He too confirmed the inverse correlation between lung cancer and radon.

In 1974, a pre-eminent radium health-effects researcher, Dr. Robley Evans of the Massachusetts Institute of Technology, reported that for thousands of cases of radium dial painters worldwide, there were still no occurrences of bone cancer or nasal carcinoma in individuals who had ingested less than 250 microcuries of radium-226 (an estimated dose of 10 grays [1,000 rads] to the bone).

A study of radiologists in Britain supports the theory that low-dose-rate radiation stimulates the immune system, after taking into account the added longevity of those exposed.[11] Prior to 1920 (at which time safety standards were improved), radiologists received large radiation exposures; while having enhanced cancer death rates, their death rate from other causes was reduced by about the same extent.

A Canadian analysis of breast cancer in 32,000 women with tuberculosis who had fluoroscopy showed that below about 30 centigrays (30 rads), there was a statistically very consistent reduction in breast cancer.

Regardless of the growing body of evidence favoring radiation hormesis, the idea is not yet universally accepted. One critic is anti-nuclear-power physicist Frank von Hippel. He agrees that such effects have been verified for single-cell systems under certain conditions, but disagrees that multicellular experiments on animals and humans have so far supported the adaptive response of cells to low radiation doses.[12] Von Hippel disputes a radiation-induced decrease for latent cancer in humans. A few health physicists too, although aware that many studies contradict the LNT hypothesis, still dismiss radiation hormesis simply because it does not fit prevailing regulatory doctrine.[13]

Radiophobia

Radiation, omnipresent and everlasting, is innocuous at normal levels; why does it cause such universal apprehension? Radiophobia is an irrational fear that any level of radiation is dangerous. Why do radiation-protection authorities have a public dose limit as low as 1 mSv per year? This is less than half of the average natural dose, and under 1 percent of doses in some countries? Why does the world spend billions of dollars per year to maintain the standard?

No fatal accidents involving radiation have occurred in the United States for the past quarter century; yet nearly three million have died of other accidents.[14] The author of that observation, Bernard L. Cohen, believes that public misunderstanding is the main reason that risks of nuclear power have been "grossly exaggerated" by the news media.

Having an undergraduate degree in journalism, one of the authors of this book, DeVolpi, can attest to the limitations of the journalism profession in terms of scientific and technical understanding. (Moreover, each of the authors of *Nuclear Shadowboxing* has had decades of experience with controlled and accidental exposures to all forms of nuclear radiation.)

Cohen also points a finger at "a few publicity-seeking scientists who tell [journalists] what they want to hear." While the slightest indication that radiation seems dangerous gets tremendous coverage, contrary evidence is generally ignored.

Factors that have helped create or sustain radiophobia include the following:

- government insensitivity in testing nuclear weapons in the air, underground, above ground, and at sea;
- emotional impact from using atomic bombs over Hiroshima and Nagasaki;
- excesses of the Cold War nuclear-arms race and the accompanying psychological warfare;
- demonstrably false projections of casualties made after the Three Mile Island and Chernobyl-reactor accidents;
- negative lobbying by fossil-fuel industries;
- crass interests of radiation researchers for recognition and budget allocations;
- self-serving politicians using radiophobia as a weapon in seeking power;
- misleading "dirty bomb" scares by careless analysts;
- public fear induced by news media that profit by hyping news;
- counterproductive interests of "greens" (psuedo-environmentalists) who thrive by scaring the public; and
- undue complacency and laxity withing the nuclear-industry.

Psychosomatic radiophobia is linked to the popular but false belief that any amount of radiation can cause harm. Ironically this is connected to two good-news/bad-news examples:

• The first is about the easy detectability of (ionizing) radiation. The good news from this is that radiation monitoring instruments detect most forms of radiation at extremely low levels and at great distance; the bad news is that false alarms occur simple because a small flux of radiation is detectable.

• The second example is about the inability of human beings to directly perceive ionizing radiation: Human senses are unreceptive to radiation, which is tasteless, odorless, intangible, invisible, and inaudible. That's good news when it's harmless, as is most of the time, but bad news in the rare case when the doses might add to cause latent physical trauma.

Because radionuclides escaping from Chernobyl were easy to measure all over the world, the accident was a "windfall" for anti-nuclear activists who were able to trumpet the increased levels of radioactivity, especially in western Europe. Yet, UNSCEAR found 31 early deaths among plant workers and rescue operators largely as a result of acute radiation exposure. No proven premature radiation-induced deaths were identified among the public. The latter should not be surprising, because so much of the estimate is based on simple-minded extrapolation from high dose levels and rates. (This mistake is not much different than estimating the effect on a person taking one aspirin a day for a thousand days, by comparing it with the effect of a thousand aspirin taken in one day. It doesn't qualify as science.)

As described in Appendix Va2, the reduction in life expectancy for nuclear power is about ***one hour*** according to most scientific estimates (or as much as 1.5 days if you preferred a Union of Concerned Scientists estimate). Largely as a result of recurrent radiophobia, all new power plants ordered in the United States have been fossil-fuel burners, which (according to Cohen) condemn the public to ***hundreds of premature deaths annually***.[15]

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The LNT hypothesis has outlived its usefulness. With improved epidemiological data and better understanding of radiobiological effects, the linear model cannot be considered a valid scientific description of low-dose radiation impact on living organisms. In fact, its misuse is responsible for unconscionable distortion of biostatistical information about projected effects from low levels of radiation.

Compared to burning coal, nuclear-power generation is benefits human life expectancy by a factor of ten to a hundred (see next Appendix).

Those who contribute to, tolerate, or amplify radiophobia have abandoned objective standards of science and ignored the systematics of probability. By making unfounded extrapolations for low-dose exposures, they are aggravating a profound waste of society's time, resources, and health.

Endnotes for Appendix Va1

1. L. Moore, "Lowering the Bar," *Bulletin of Atomic Scientists* (May/June 2002).
2. B.L. Cohen, "The Cancer Risk From Low Level Radiation: A Review of Recent Evidence," www.haciendapub.com (2001).
3. J. Muckerheide, "Low Level Rad. Health Effects: Compiling the Data," quoting T. D. Luckey, http://cnts.wpi.edu/rsh/data_docs/1-2/2/1221lu94.html.
4. B.I. Spinrad, "More on low-level radiation," *Nuclear News* (May 1981).
5. Z. Jawarowski, *Physics Today* (May 2000).
6. Jawarowski
7. Jawarowski
8. Richard Wilson, "Probability of Causation: Its Use in Compensation Schemes," Nuclear News (June 2001).
9. Jawarowski (Sep. 1999).
10. http://www.adeq.state.az.us/environ/waste/ust/download/rbca/appo.pdf
11. J. Cameron "A Critique of NCRP Report No. 136," unpublished (8 Aug. 2001).
12. F.N. von Hippel, *Physics Today* (Apr. 2000).
13. G. Walinder
14. B.L. Cohen, "The Hazards of Nuclear Power," a Chapter based on B.L. Cohen, *The Nuclear Energy Option*, Plenum, NY (1990) http://russp.org
15. Cohen, "The Hazards of Nuclear Power."