

## **WHY ARE WE SO AFRAID OF NUCLEAR RADIATION?**

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### **ABSTRACT**

The origin of the LNT model of radiation carcinogenesis is outlined. The A-bomb survivor cancer mortality data is shown to not support this model at all. The nature of cancer and the role of the body's natural defense mechanisms are discussed. A simple biological model of the effect of radiation is shown to be more credible and consistent with the observed beneficial health effects at low doses and adverse effects at high doses. Important therapeutic applications of low dose irradiations are mentioned. Reference is made to the UNSCEAR 2000 Report on sources and effects of ionizing radiation, its comparison of natural and human-made sources and its review of the health effects of the Chernobyl accident. The evidence indicates public fear of low-dose and low-level radiation is unwarranted and blocks efforts to supply reliable, environmentally friendly nuclear energy and important medical therapies. ICRP resolution of the contradictions is urgently needed.

### **INTRODUCTION**

A negative impression of nuclear technology has developed over the past century,<sup>[1]</sup> especially since the 1979 TMI accident. Many of the negative images relate to perceptions of adverse health effects, specifically the possibility of inducing cancer and genetic damage, from any exposure to ionizing radiation. The irony is that we are continuously exposed to radiation from natural sources. Do exposures from human-made sources really increase significantly the normal incidence of cancers and birth defects? What about the beneficial health effects from low doses we've been hearing about? The answers to these questions are rather important because humanity faces severe environmental, energy and medical issues, which greatly impact our quality of life. Nuclear technologies can provide realistic remedies, but fear about exposures to any human-made radiation greatly constrains their application. We make arguments about relative risks, but people make their own judgments about the acceptability of various risks, regardless of our comparisons. It would be possible to gradually change public notions about nuclear technology if, instead of trivial risks, a different, more positive picture of radiation's significant beneficial health effects could be communicated. The problem is strong resistance from influential scientists in recognizing the real benefits and discounting insignificant risks. This has led to a raging controversy over the past decade and pressures from many scientific organizations to change regulatory policy. The facts are quite clear. When the controversy will be resolved is unclear.

## RADIATION CARCINOGENESIS AND THE LNT MODEL

As we know, Röntgen discovered X-rays in 1895, and Becquerel discovered radioactivity in 1896. Since then, a tremendous amount of research has been carried out on the effects and after effects of ionizing radiations, and many very important applications have been found. Harmful health effects following large exposures were identified, almost immediately, and radiological protection advice was issued and updated, as more accurate information became available. The early recommendations were concerned with avoiding burns and late effects from intense short-term radiation. This involved defining a safe limit for exposures (e.g., ~0.2 R/d in 1934 and 0.3 R/wk in 1951) based on a threshold concept. By 1955, this threshold concept was rejected by the International Commission on Radiological Protection (ICRP) in favour of the concept of cancer and genetic risks, kept small compared with other hazards in life. “Since no radiation level higher than natural background can be regarded as absolutely ‘safe’, the problem is to choose a practical level that, in the light of present knowledge, involves negligible risk.”<sup>[2]</sup> This change in philosophy was brought about by new biological information – epidemiological evidence of *excess* cancer malignancies among radiologists and indications of *excess* leukemia cases in the survivors of the atomic bombings at Hiroshima and Nagasaki – “stochastic effects”, whose probability of occurrence, not the severity, was assumed to be proportional to the size of the dose.<sup>[2]</sup>

This is the origin of the linear no-threshold (LNT) model of radiation carcinogenesis. It derives from the hypothesis that a single impact of ionizing radiation on a cell causes an alteration, which could develop into a mutation, which could eventually become the first cancer cell in a tumor, which could cause death. The likelihood of this transformation, from a normal cell to organism death, is assumed to be proportional to dose. Statistically significant data on *excess* cancer deaths following exposures to high doses are fitted by a straight line, which is then extended to zero dose through the entire lower dose region where there was no statistically significant human data. The LNT model for an acute (short-term) exposure is shown in Figure 1. This model is generally used to calculate the excess number of cancer fatalities following exposure to a low dose from a (human-made) source of radiation. A risk reduction factor, in the range from 2 to 10, may be applied to the integrated dose of a chronic (long-term) exposure at a low dose rate. The increase in the average dose (above background) received by the population due to the source is evaluated, and this average dose is multiplied by the slope of the LNT line to predict the increase in the normal fraction of these people (~28% in Canada) who will die from cancer (instead of a different cause). The incremental exposure received by a person due to a source is multiplied by this factor to determine his/her increased risk of dying from cancer.

## NON-LINEAR EFFECTS AND NON-SCIENTIFIC INFLUENCES

It is fascinating to review the early investigations that were carried out to determine what radiation does to living things. Thousands of these studies revealed a variety of beneficial health effects following exposures to low doses. Many people actually began to consume small amounts of a radium solution, sold in bottles as an elixir, until the practice was stopped after several well-publicized cases of radium poisoning due to over consumption. Epidemiology on

the famous radium dial painters by RD Evans identified a maximum body burden of radium (0.1  $\mu\text{Ci}$ ), including a 10-100 safety factor, and a threshold (lifetime) skeletal dose ( $\sim 1000$  cGy) below which no long-term excess cancers or other adverse effects appeared.<sup>[3, 4]</sup> Why was the very large amount scientific information on beneficial effects and on thresholds for adverse effects ignored when the LNT model was formulated, and afterwards when more research was carried out?

To understand the answer, we have to consider the social and political environment when the new radiation protection recommendations were formulated. Scientists were agonizing over their roles in the development and actual use of A-bombs in war. The creation of large stockpiles of more powerful nuclear weapons in several countries raised enormous moral issues and fears about their potential use. Scientists realized they could not put “the genie back in the bottle”, so they began to campaign against further A-bomb development, testing and production, and for nuclear disarmament. Concerns began to be expressed about potential, long-term adverse health effects following exposures to very small amounts of radioactive fallout; the information about beneficial health effects and thresholds, up until then, was not rigorously scientific. Over the past 50 years, many research programs were carried out to study the incidence of adverse biological effects, measured at high doses and extrapolated linearly to zero dose; many observations during the past 30 years of beneficial health effects were either ignored or suppressed.<sup>[5]</sup>

## A-BOMB SURVIVORS

The principal scientific evidence that supports the LNT model is the 1950-2020 Life Span Study (LSS) of cancer mortality among the Hiroshima-Nagasaki survivors. The two A-bombs dropped in August 1945 killed between 150,000 and 200,000 of a total population of 429,000 people.<sup>[6, 7]</sup> The LSS cohort of 86,572 people contains roughly half of the survivors who were within 2.5 km of the bombs.<sup>[8]</sup>

Based on the many concerns expressed over the past fifty years about the risk of fatal cancers from nuclear radiation, how many of the A-bomb survivors would we expect to have died from cancer, in excess of the normal incidence of cancer? Several people I asked recently indicated they would expect 20 to 50% of the survivors! So, let us examine the recent data in Table 1.<sup>[8]</sup> It is very surprising to note only 344 *excess* deaths, forty years after the event, among this very large cohort! Now 36,459 people were far enough away to have received no significant radiation exposure, so we might consider the fraction  $344 \div 50,113 = \sim 0.7\%$ , or  $344 \div 7578 = 4.4\%$  as the attributable risk. But the authors of this LSS prefer the ratio  $[344 - (-42)] / (7578 - 3013) = 8\%$ . Of this cohort, 56% were alive in 1991, and 38,092 had died. So we could conclude that  $\sim 1\%$  of them died from radiation-induced cancer.

Survivors under 20 years of age at the time of bombing constitute 40% of the population, but a much smaller fraction of the deaths because cancers generally occur late in life. The final results will depend strongly on what happens to these survivors as they enter their cancer-prone years after age 50. Those over 50 at the time of bombing did not live long enough to show

evidence of radiation-induced cancer, because of the ~20 year latency period. Leukemia was the first malignancy to appear. By 1985 almost all the radiation-induced leukemias to be observed were recorded; the number of *excess* deaths determined is 87. Ralph Lapp states there were ~300,000 survivors in 1950 when the LSS was undertaken. He estimates that in 2020, about 800 will have died from A-bomb radiation, or ~0.3% of the H-N population. Since one of every four survivors (or 75,000) will die of cancer, one in a hundred of these deaths will be caused by the A-bomb radiation.<sup>[6]</sup>

A rough assessment of the statistical uncertainties (standard deviations) of the excess deaths in Table 1 indicates that they are quite large below doses of 0.5 Sv (50 rem). And there is controversy over the LSS rejection of the T65D dosimetry in favour of DS86 dosimetry, which underestimates the neutron contribution and leads to a much higher risk estimate. This suggests there are no significant excess deaths below 1 Sv (100 rem). There is no mention of important confounding factors for cancer incidence, such as the widespread, severe malnutrition, the pollution caused by the A-bomb blasts/fires; the psychological stress from burns, sickness and loss of family members, friends, homes; the loss of medical care, etc. The LNT model is not supported by *any* statistically significant evidence.<sup>[9]</sup> It should also be noted that there was no detectable increase in the incidence of mutations in the children or grandchildren of the A-bomb survivors.

## NATURE OF CANCER

Since fear of cancer is the issue, let us briefly examine the nature of cancer.<sup>[10]</sup> Cancer is a single disease and it is a hundred diseases. The unifying aspect of cancer is uncontrolled growth – the appearance of disorganized tissues that expand without limit, compromising the function of organs and threatening the life of the organism. Each cell type, each tissue, may spawn a distinct type of tumor with its own specific growth rate, prognosis, and treatability.

Virtually all malignant tumors are now thought to be monoclonal in origin, that is, the starting point for a tumor is a single abnormal cell, rather than a large cohort of normal cells being recruited by some agent into becoming cancer cells. Human tumors often become apparent only after they have grown to a size of 10-100 billion cells, in a person of 10 to 100 trillion cells (cell weight is  $\sim 10^{-9}$  g). Cancer is generally a disease of old people because it usually takes a long time to accumulate the multiple mutations required to accelerate cell growth and disable growth suppression. To become a fatal tumor, a normal cell must undergo many changes – a long, complex series of successive changes in its behaviour. Several decades must pass from the initiation of the tumor to its ultimate detection in the clinic.

The most disquieting fact about carcinomas is that they do not respect territorial boundaries. They grow locally, and eventually progressing further, shed small clumps of progeny cells able to start new colonies – so-called metastases – in other organs. These progeny cells travel through blood or lymph to lodge at distant sites. Cancer cells evolve into a large number of diverse cells with new traits that allow them to grow more rapidly, compete more effectively with normal cells and evade defences. Tumor cell populations sooner or later exceed the ability

of the host to nourish them. Often, long before that, tumors will compromise the functioning of a vital organ, leading to illness and then death. The incidence of cancer increases exponentially with age, compatible with multistep, time-dependent tumor progression. For example, in the USA, the annual death rate from colon cancer rises from 14 to 83 to 400 per million, as people age from 40 to 60 to 80 years, a factor of ~6 and ~30. The risk increases approximately as the fifth power of elapsed time (ref. 10, p 157).

What causes formation of abnormal cells or acceleration of the process leading to cancer? Many factors and carcinogens have been identified: genetics, diet, chemicals, biological agents, ionizing radiation, etc. More are discovered every week; the list appears endless and growing. But recent research has revealed an immensely high rate of cell damage caused by normal metabolic activity due to attack by reactive oxygen species.<sup>[11]</sup>

## STIMULATION OF DEFENCES

Living organisms have many defences, both within and outside the cell, to prevent, repair, remove cell damage.<sup>[11]</sup> These defences can limit cell proliferation by signaling growth factor rationing and growth suppressor genes, and by other means. In addition to removing cells with persistent DNA damage, the immune system also plays an important role fighting certain types of cancers, especially if it becomes stimulated.<sup>[11, 12, 13]</sup> Severe psychological stress, leading to depression and despair, adversely affects the defences creating hormonal imbalance and suppressing immune activity, allowing faster cancer progression.<sup>[14]</sup> As organisms age and mutations accumulate, their defense mechanisms become weaker and less effective in preventing new cancers and controlling the many cancers that have already started. For a long, healthy life, it is very important to maintain and enhance the performance of our natural defences.

It was mentioned earlier that a large number of investigations were carried out over the past century into the effects of radiation on many different biological organisms, including plants. Many of these studies revealed significant beneficial health effects after exposures to low doses. There is overwhelming evidence of this phenomenon,<sup>[15, 16, 17, 18, 19, 20]</sup> and a model of the effect of ionizing radiation on living organisms has been provided by Pollycove and Feinendegen.<sup>[11]</sup> Recent studies show that low doses of radiation stimulate many cellular functions, including oxidation damage prevention, enzymatic repair, and immunologic and apoptotic removal of DNA damage (Figure 2). Acute, large doses (>50 cGy) impair these functions, causing adverse health effects. But chronic low doses, such as a ten or even hundredfold increase in background radiation, stimulate prevention and repair of DNA damage and the immune system (Figure 3) that decreases gene mutation rate (Figure 4), leading to the beneficial effects of decreased mortality and decreased cancer mortality. Therapeutic stimulation of these defences by low dose body irradiation (Figure 5) prevents and removes cancer metastases in mice, rats and humans (Figure 6).<sup>[21]</sup> The cell damage caused by the low dose radiation is insignificant compared to the metabolic oxidative DNA damage prevented, repaired and removed by the stimulated defences, leading to overall beneficial effects (Figure 7).<sup>[22]</sup>

Many medical studies have been carried out to determine the cancer risk following diagnostic and therapeutic treatments involving radiation with very surprising results. The Canadian breast cancer study, published in 1989, compares breast cancer mortality against dose, following fluoroscopic examinations for tuberculosis, between 1930 and 1952.<sup>[23]</sup> The plotted data from nine provinces (Figure 8) show a surprising decrease in risk at low doses (34% and 16% at the dose points of ~15 and ~25 cGy).<sup>[24]</sup> A recent study of hyperthyroidism treatment with radioiodine (average total dose of ~300 MBq, ~50,000 cGy to the thyroid and ~28 cGy whole body) revealed a significantly lower cancer incidence and a lower cancer mortality.<sup>[25]</sup>

Japanese scientists, in fourteen universities and two research institutes, have been researching beneficial effects of low radiation doses for ~20 years and found remarkable bio-positive effects,<sup>[18]</sup> which could be grouped as:

- rejuvenation of cells (increase of SOD and cell membrane permeability)
- moderation of psychological stress through stimulation of key enzymes
- suppression and therapy of adult diseases, such as diabetes and hypertension
- suppression of cancer through enhancement of the immune systems
- suppression of cancer and radio-adaptive response by activation of DNA repair and cell killing.

## THERAPEUTIC APPLICATIONS OF LOW DOSE IRRADIATION

One of these Japanese scientists, K. Sakamoto, provided total-body low-dose irradiation (LDI) therapy (6 MV X-rays) in conjunction with local high-dose palliative radiation treatment to a patient with advanced ovarian cancer, following surgery. The LDI therapy, 15 fractionated doses of 10 cGy over a five-week period, achieved total elimination of the cancer metastases. This led to a program of LDI therapy for ~150 non-Hodgkin's lymphoma (NHL) patients, including many intermediate and high-grade cases. This LDI therapy was given to patients who had previously received localized high-dose radiation and chemotherapy, and did not get better. LDI enhanced their immune systems and other defences, thereby achieving many cures, which have lasted more than ten years. Figure 9 shows that the recurrence-free survival rate of NHL patients was increased by this therapy from ~50% to ~84%.<sup>[26]</sup> Nevertheless, this controversial program ended recently when Dr. Sakamoto retired.

Similar effectiveness of LDI therapy for NHL had been noted at the Harvard Medical School in the 1970s and more recently in France.<sup>[27]</sup> This success has led to the recent approval of a proposal for a clinical trial of LDI therapy in Europe.<sup>[28]</sup> A comprehensive review of this application indicates that significant therapeutic benefits can be expected.<sup>[29]</sup> Nevertheless, oncologists seem to be very reluctant to use or even consider this controversial therapy, as can be noted from the current experiences of an American patient who has been requesting LDI therapy for a rare lymphoma (blood cancer). Only one oncologist, at the Johns Hopkins Medical Institute, has been willing to provide this therapy. The improvement observed following this treatment has been comparable to that achieved with chemotherapy, but with no symptomatic adverse side effects.<sup>[30]</sup>

## THE CHERNOBYL ACCIDENT AND THE UNSCEAR 2000 REPORT

April 26 was the 15<sup>th</sup> anniversary of the tragic Chernobyl accident, which was followed by an immediate and very strong reaction of fear and outrage throughout the world. Many people expected the radioactivity released to cause millions of cancer deaths and abnormal babies, but the reality is totally different.

We know this from the 1220-page UNSCEAR 2000 Report: *Sources and Effects of Ionizing Radiation* that was released last June<sup>[31]</sup> and tabled in September at the UN General Assembly. It took the 146 committee members and staff, from 21 countries, six years to collect and study the facts in 5400 documents and prepare the 20-page summary<sup>[32]</sup> and ten annexes of technical details. This report is the most credible information on this subject, and was written by an independent, non-nuclear organization.

This report compares the radiation dose that an average person receives from all types of natural and human-made sources. It estimates the health effects, including those caused by the Chernobyl accident. The average natural radiation dose is 2.4 mSv (0.24 rem) per year, but the report presents data (see Figure 10) indicating that ambient radiation levels are many tens and hundreds times higher in some geographical regions where many people live. No adverse health effects related to radiation were ever observed among people exposed to such high natural doses. Human-made sources expose the average person annually to much less radiation – 0.4 mSv (0.04 rem) medical diagnostics, 0.1 mSv (0.01 rem) A-bomb tests in the 1960s, 0.05 mSv (5 millirem) Chernobyl accident and less than 0.01 mSv (1 millirem) nuclear electricity. Since radiation from natural or human-made sources affect living cells in the same way, we should not expect the health effects to be any different for the same dose from either source, both being short-term or long-term.

Of the 134 Chernobyl employees who developed symptoms of acute radiation disease, 28 died from radiation sickness and two died from fire and falling objects – the others recovered. Many emergency workers came to the station to remove radioactive debris, to allow the staff to continue operating the other three reactors. No increases above the natural incidences of cancers or leukemias were observed among these 381,000 clean-up workers. The authorities moved 116,000 people from their homes in 1986, and 220,000 more afterward, to avert a lifetime (70-year) dose more than 350 mSv (double the world natural average), even though many people live very healthy lives in areas that are much more radioactive.

Careful health screening of all the people in the Chernobyl area began in 1986. Nothing like this existed before. So far, this has identified a total of about 1800 thyroid cancers. Before the accident, the incidence of thyroid cancers noticed in children was ~0.2 per 100,000 in Belarus and Ukraine; no data are available from Russia. The maximum incidence rates registered in 1987-1998: Belarus 17.9, Ukraine 4.9 and Russia 26.6 per 100,000 children. Does it mean these cancers were caused by the accident? Normally, it takes ten or more years for cancers to develop, if radiation is the cause, but half of these cases were found sooner (in Russia in the second year after the accident: 9.1 cases per 100,000). Also, the number of these cancers is lower in areas of higher dose! Could they be occult (small, stable) thyroid cancers? These

happen naturally, and rarely cause medical problems.<sup>[33]</sup> Typically, there are many thousands of such thyroid cancers in a population of 100,000. The number varies according to geographic location and depends on many different factors. In the USA there are 13,000 per 100,000 people (24,000 per 100,000 in Hawaii). Is it valid to imply an increase in thyroid cancer incidence after the accident, when there was no equivalent screening before the accident?

In a report<sup>[34]</sup> of the US National Council on Radiation Protection on thyroid cancer, we have the remarkable statement, “available human data on low dose I-131 exposures have not shown I-131 to be carcinogenic in the human thyroid.” The National Cancer Institute carried out a 14-year study of thyroid cancers found all over the United States, in the thirty-year period after the hundred A-bomb tests in Nevada, in the 1950s and early 1960s. The 1997 report<sup>[35, 36]</sup> compared the number in each area with the amount of radiation, and did not find any evidence to associate thyroid cancer to this radiation. So, it seems that the 1800 "excess" thyroid cancers, in the Chernobyl screening, were not caused by radiation.

The UNSCEAR report concludes that no increases in cancer incidence or mortality have been observed that could be attributed to ionizing radiation; the risk of leukemia does not appear to be elevated, even for the clean-up workers, and there is no evidence of other non-malignant disorders that are related to radiation. There were many psychological reactions, but these were caused by fear of the radiation, not the actual radiation. There is no need for anyone to live in fear of serious health consequences from the Chernobyl accident. For the most part people were exposed to radiation levels comparable to, or a few times higher than, the average natural background level.

## CONCLUSIONS

Policies and myths that were created half a century ago by the ICRP have convinced many people that radiation is harmful in any amount. The authorities and many scientists continue to ignore statistically significant contradictory evidence of no adverse effects from high levels of natural radiation in many regions and the evidence of significant overall beneficial health effects to medical cohorts (including cancer patients) and nuclear workers who received low doses of radiation. The ethics of this behaviour is being questioned and debated.<sup>[37, 38]</sup>

This makes it very difficult for many scientists to respond in a credible manner to public fears and concerns about radiation, by presenting the scientific evidence of the actual beneficial effects that have been observed on humans and other living things. It is therefore not surprising that the very important UNSCEAR 2000 Report received very little publicity. So the myths about cancer and abnormal babies will continue, as scientists continue to carry out more and more politically correct research on the response of cells and mice to radiation.

These myths block efforts to supply reliable, environmentally friendly nuclear energy, which is needed by humanity. It also blocks the widespread use of LDI therapy to cure or control cancer and other diseases. Hopefully the current concerns about energy supplies and health care

will cause people to pay attention to the scientific results, discount the myths, and take action to reap great societal benefits.

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Table 1. A-bomb survivors: observed and expected deaths from solid cancers, 1950-90,  
Pierce et al<sup>[8]</sup>

<b>Dose (Sv)</b>	<b>Dose (rem)</b>	<b>Number of Subjects</b>	<b>Observed Deaths (1)</b>	<b>Expected Background (2)</b>	<b>Excess Deaths (1) – (2)</b>	<b>Standard Deviation* <math>\sqrt{(1) + (2)}</math></b>
0	0	36,459	3013	3055	- 42	78
0.005 – 0.1	0.5 – 10	32,849	2795	2710	85	74
0.1 – 0.2	10 – 20	5,467	504	486	18	31
0.2 – 0.5	20 – 50	6,308	632	555	77	34
0.5 – 1.0	50 – 100	3,202	336	263	73	24
1.0 – 2.0	100 – 200	1,608	215	131	84	19
> 2.0	> 200	679	83	44	39	11
	<b>Totals:</b>	<b>86,572</b>	<b>7578</b>	<b>7244</b>	<b>334</b>	

\* a rough assessment of the statistical uncertainties

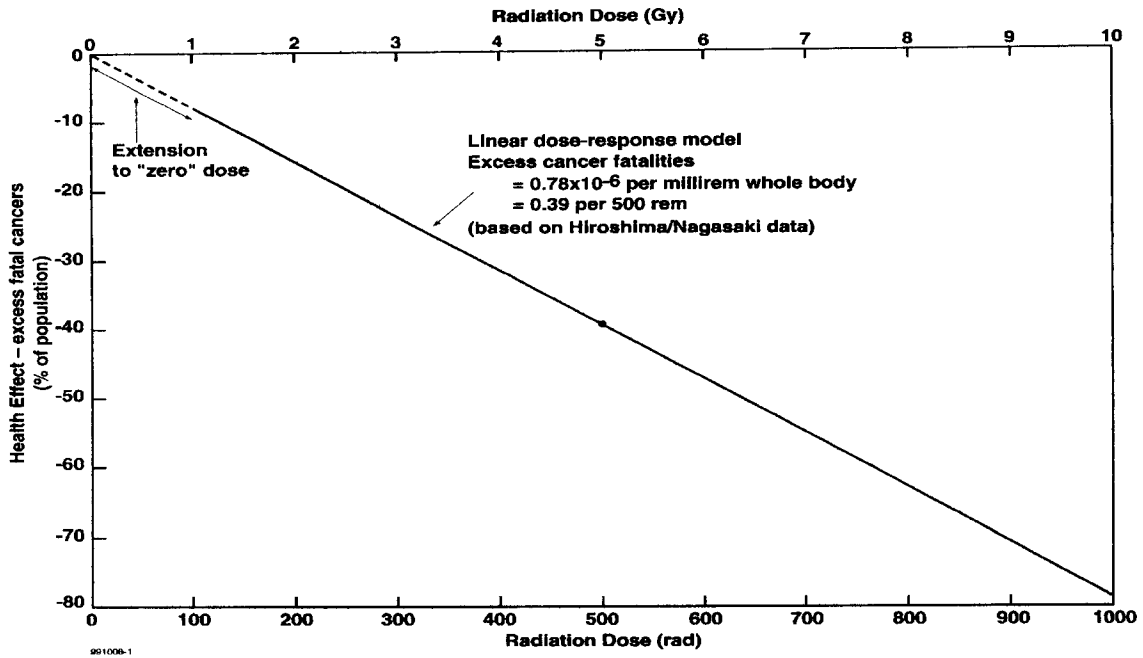


Figure 1. The linear dose-response model for radiation-induced cancer, Cuttler<sup>[22]</sup>

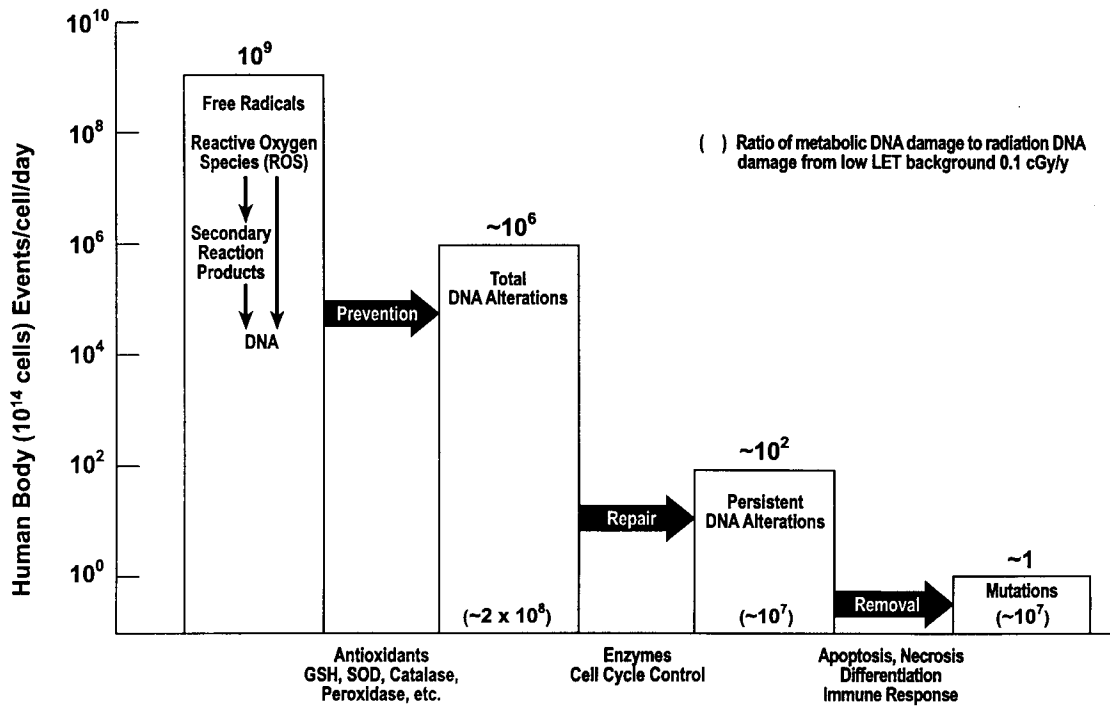


Figure 2. Biological model of our DNA damage-control system, 0.1 cGy/ year normal radiation, Pollycove and Feinendegen<sup>[11]</sup>

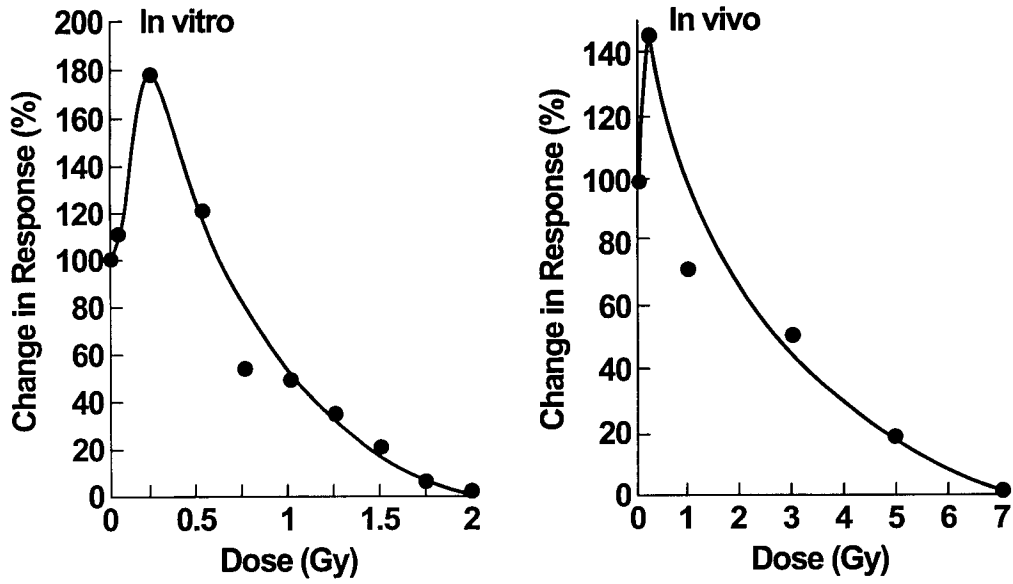


Figure 3. Stimulation of immune system with radiation, Makinodan and James<sup>[20]</sup>

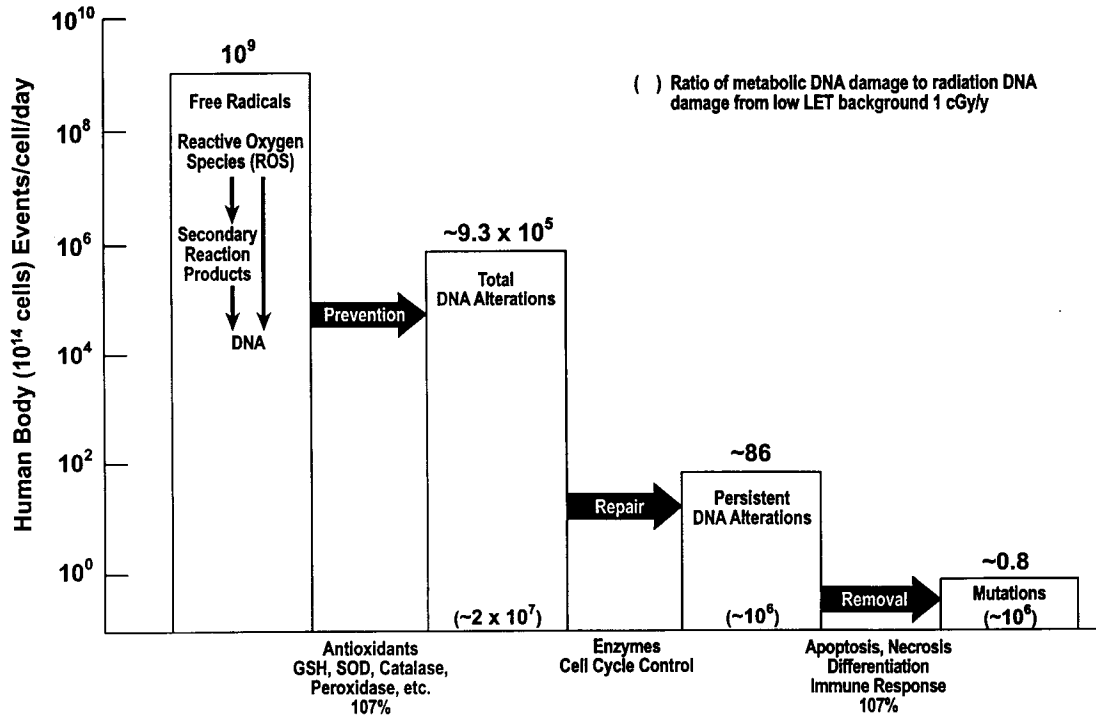


Figure 4. Potential effect of 1 cGy/year background radiation on rate of DNA mutation, Pollycove and Feinendegen<sup>[11]</sup>

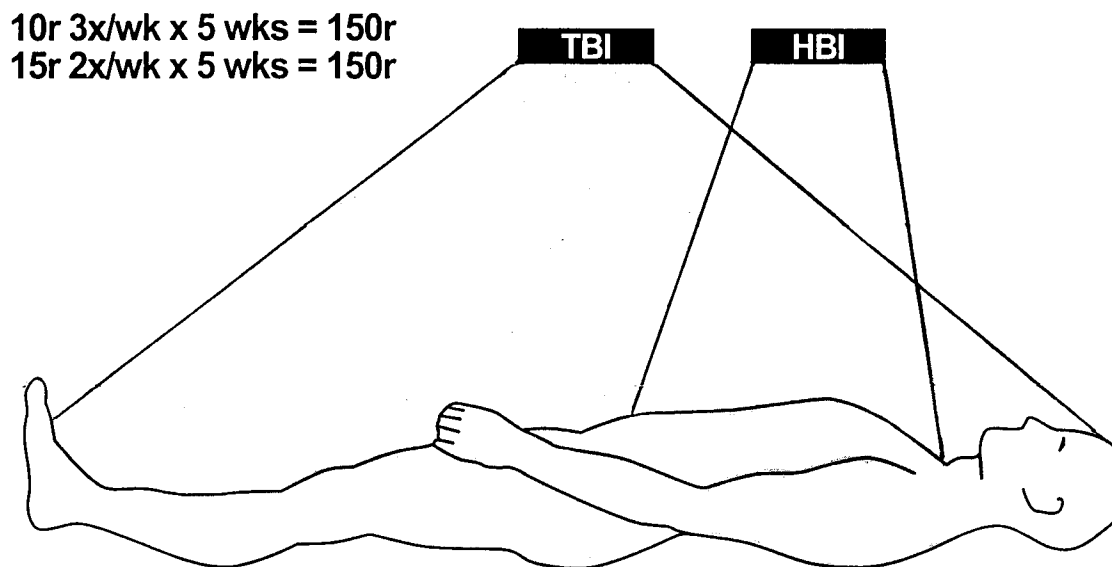


Figure 5. Low dose irradiation (LDI) therapy, Pollycove and Feinendegen<sup>[11]</sup>



Figure 6. Suppression of cancer in upper nasal cavity by half-body LDI therapy, Takai et al<sup>[21]</sup>

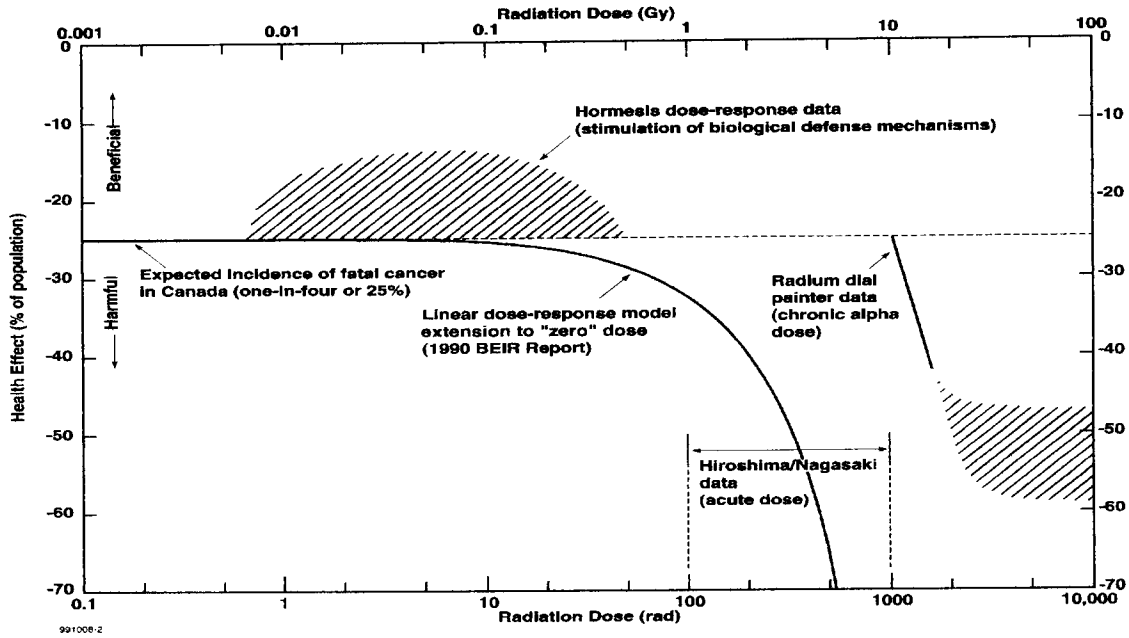


Figure 7. The linear model with radiation dose on a logarithmic scale, Cuttler<sup>[22]</sup>

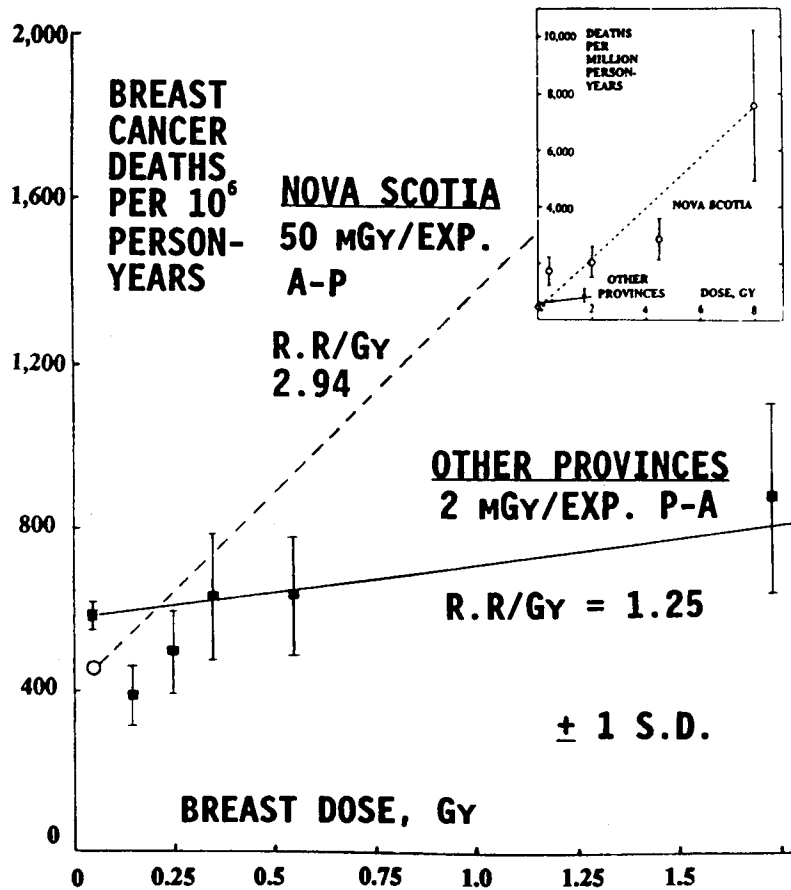


Figure 8. Canadian breast cancer study following fluoroscopy examinations for tuberculosis, Webster<sup>[24]</sup>

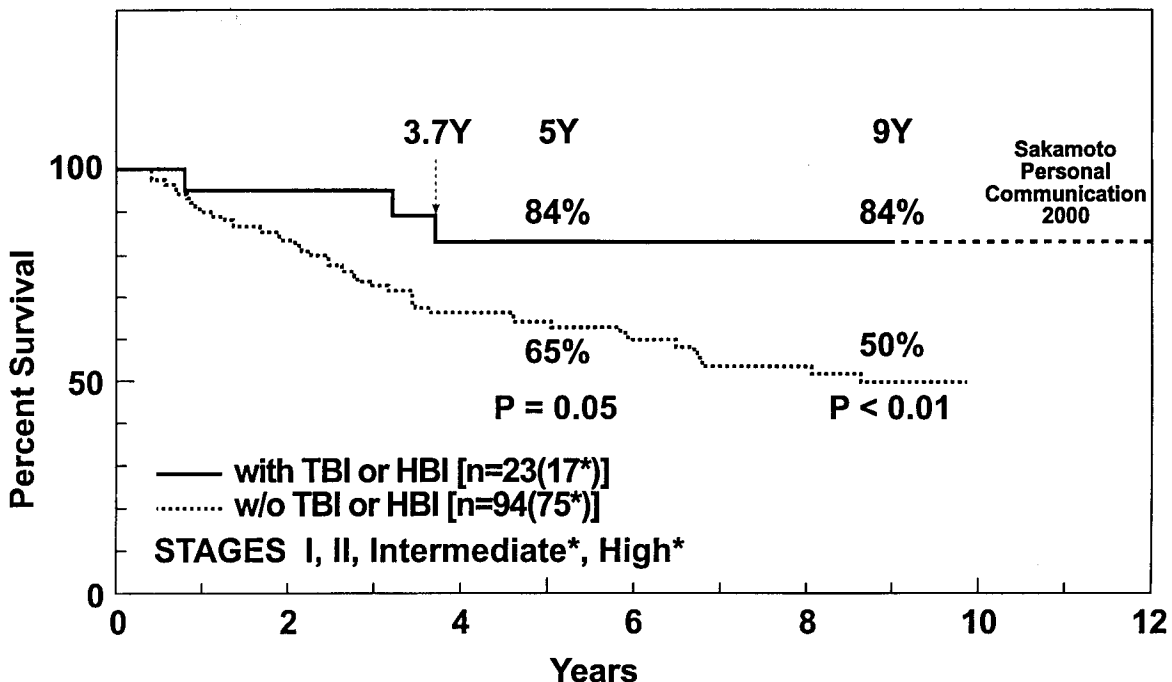


Figure 9. Survival of non-Hodgkin's lymphoma patients with and without LDI therapy (Both groups received chemotherapy and localized high-dose radiation), Sakamoto et al<sup>[26]</sup>

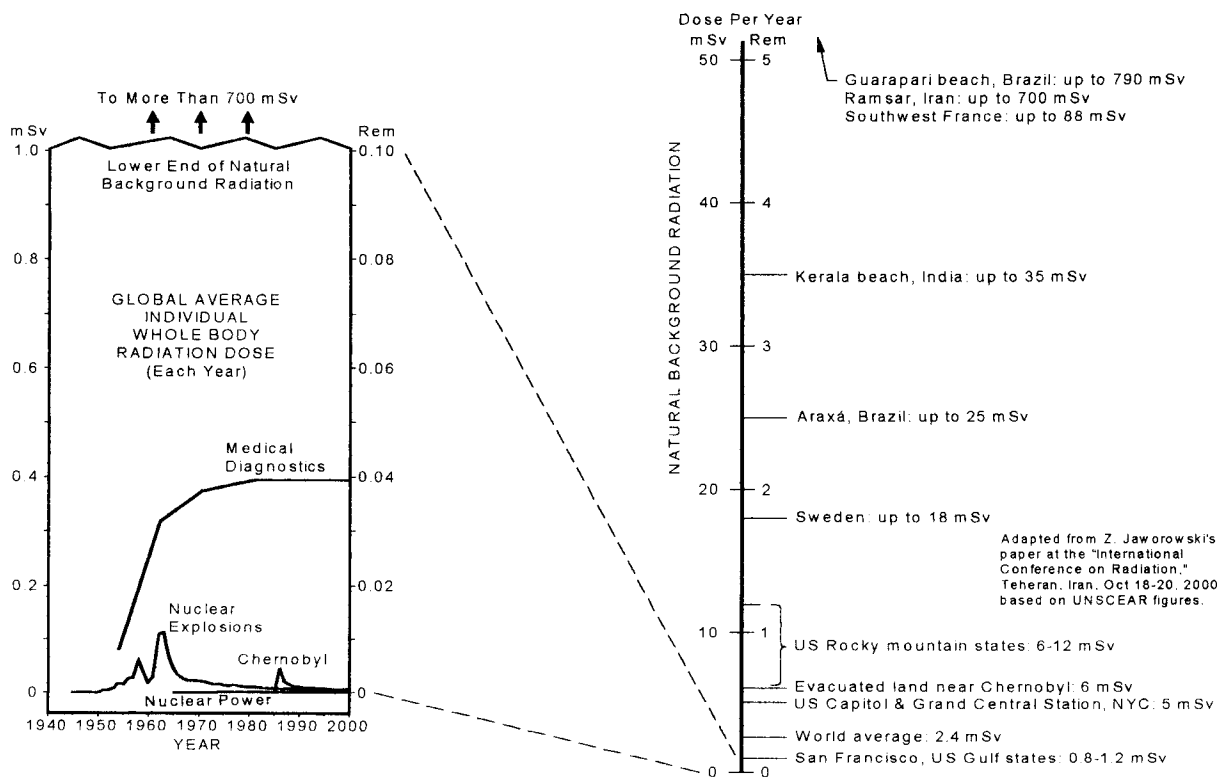


Figure 10. Comparing average annual dose: natural vs human-made radiation, Rockwell<sup>[39]</sup>