Overcoming the fear of radiation: the key to the golden age of nuclear technology

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Abstract

Canadian nuclear technology is threatened by radiophobia. It stems from the misuse of the linear dose-response model to label radiation as a carcinogen and to predict the number of excess fatal cancers to be expected from exposures to low-level radiation. Ironically, the actual response seems to be a beneficial effect due to the stimulation of the defense mechanisms that deal with both spontaneous and externally-induced cell damage. The scientific community should act to discourage improper use of the linear model and to inform Canadians of the safety of low-level radiation, to safeguard our nuclear heritage.

Impact of radiophobia on Canadian nuclear technology

Are we aware that Canada's nuclear technology and its greatest technical achievement - the CANDU reactor - are in jeopardy?

Why do I believe this is so?

It's because most Canadians have the paradigm that "nuclear radiation is a carcinogen", and they are just terrified of the big C - cancer. This response is understandable on an emotional level. As a cause of death, cancer has risen to an incidence of approximately 20 percent of the population. Teachers and the media are communicating to the next generation that nuclear technology involves radiation - a carcinogen. Today's youth will form tomorrow's governments. Would we expect them to cherish and foster our nuclear heritage?

Are we aware that one of every three patients admitted to a modern hospital receives diagnosis or treatment involving nuclear medicine techniques?[1] Are we aware that nuclear energy supplied two-thirds of Ontario's electricity in 1994?

Yes, it's a tremendous benefit to humanity, but because of radiophobia - the fear of radiation, we have great difficulty using nuclear technologies and transporting, storing and disposing radioactive wastes.

At this time, we should be celebrating the centennial of the discovery of X-rays by Röntgen. Have you heard about it? Did you know that 100 years ago, on March 1st, Becquerel discovered radioactivity? "Except, perhaps, for the Bible and Shakespeare, there is scarcely a subject that has been more closely studied than the effects of radiation on living things....

Yet most people in Canada, whether they are well educated or not so well educated, know very little, if anything at all, about radiation."[2]

We have mountains of data on the effects of radiation on health, but we behave as if it's all a big mystery. The effects are classified as deterministic and probabilistic. Deterministic ones cause harm (e.g. burns) to all people above certain dose thresholds, while probabilistic ones are assumed to cause delayed cancer and harmful genetic effects in some people, at any dose.[3] It is these probabilistic effects at low radiation doses that are controversial.

Origin of radiophobia

What do people generally think of first when nuclear technology is mentioned? Is it electricity or medicine or food processing? No! It is nuclear weapons, proliferation, Hiroshima, Chernobyl, radiation, cancer, etc. - negative ideas that inspire fearful images.

Why is that? Where did the paradigm (label) "radiation is a carcinogen" come from?

You don't need a university degree to understand it. High school mathematics is sufficient to explain it, and I apologize for being too mathematical.

Figure 1 is the linear, no-threshold dose-response model, taken from the 1990 BEIR Report,[4] that was developed 37 years ago by the ICRP.[5] Scientists observed delayed cancer fatalities among the survivors of the bombing of Hiroshima and Nagasaki that they could attribute to the radiation. They fitted a straight line to the cancer data for survivors who received an instantaneous exposure in the high dose range from 1 to 10 gray (100 to 1000 rad). Then they made the assumption to extend this line ~10 percent beyond the range of the data, from 1 to "zero" gray (100 to 0 rad), to the incidence of spontaneous cancer fatalities. Enhancements, such as dose and dose rate effectiveness factors, were added to reduce the postulated cancer fatalities at low doses and dose rates, but these are often overlooked.

The radiation measurement and protection community understood that this linear extension overpredicted the expected incidence of fatal cancers in the low dose range, but they justified it as a conservative hypothesis, suitable for protecting the health of radiation workers. Some rationalized the hypothesis by simply postulating that a constant fraction of a dose would initiate tumours, assuming that the organism's defense mechanisms, that cope with cell damage, function in proportion to the dose.

The next step taken was very damaging for nuclear technology. The linear model was enshrined and used in the low-level range (where it is difficult to test due to statistical errors) to predict the expected number of "excess" fatal cancers that would result from calculated radiation exposures from hypothetical nuclear accidents. This is the basis for the radiophobia that later developed. This model has recently been used to frighten the public of tiny releases of tritium to drinking waters.[6]

Figure 2 is the dose-response behaviour, showing radiation dose on a logarithmic scale. The straight line of the linear dose-response model appears as a curve that approaches the likelihood of spontaneous cancer fatalities, typically one in five, or 20 percent of the population, as dose decreases. Statistical variations cloud the difference at low doses.

The Hiroshima/Nagasaki data ranges from 1 to 10 gray (100 to 1000 rad), instantaneous, but the straight line extension continues many orders of magnitude (factors of 10) to "zero" dose. (Natural background radiation is ~0.3 rad per year.) Since this line theoretically never reaches the spontaneous incidence of cancer, any analyst can always calculate a large number of excess fatal cancers, for a small dose, simply by multiplying the small difference between the lines by a very large population.

This is the source of radiophobia - the paradigm that radiation in any amount is a carcinogen.

The real response

So what is the reality of the response of living organisms to radiation?

First of all, humans genes have been exposed to background radiation for approximately two million years and, with all that accumulated dose, humanity seems to be improving with time.

Secondly, there is considerable evidence of beneficial health effects[7, 8, 9, 10, 11, 12] from short-term (acute) exposures up to ~50 rad, and long-term (chronic) exposures up to at least a thousand rad. This evidence appears to support the hypothesis that radiation exposures in these dose ranges actually stimulate defense mechanisms[13] that deal with both spontaneous and externally-induced cell damage. The rate of spontaneous DNA damage is remarkably high, ~8000 events per cell per hour, while DNA damage caused by radiation is only ~20 events per cell per rad.[14] Spontaneous events may not be equivalent to radiation-induced events, nevertheless, the defense mechanisms are very active. While small, acute doses stimulate the defense mechanisms, impairment overrides stimulation for exposures greater than 50 rad.

Thirdly, organisms can tolerate a very large dose of radiation if it is delivered gradually, in a manner that does not overwhelm the defense mechanisms. The radium dial painters accumulated considerable amounts of radium in their bones in the 1920s, yet they show no evidence of excess cancer for integrated doses up to at least 1000 rad, over their entire lives.[15, 16] As a result, the hypothesis of probabilistic harmful effects for low-level doses is being challenged.

The positive effect of subharmful doses of nuclear radiation is termed "radiation hormesis". The word hormesis is derived from the Greek word *hormaein*, which means "to excite". This is shown on Figure 2 as a beneficial effect of up to ~30 percent on the spontaneous incidence of cancer due to acute doses up to ~0.5 gray or 50 rad.

A comprehensive test of the linear model for inhaled radon decay products clearly shows that the incidence of lung cancer fatalities is <u>lower</u> in regions were the concentration of radon is higher.[17] The slope of the line is actually opposite to what the linear model predicts!

Unfortunately, members of the radiation measurement and protection community do not acknowledge data which indicate beneficial effects of radiation because the idea of hormesis is not compatible with the paradigm that all radiation is harmful. Scientists are reluctant to endorse the evidence on radiation hormesis for fear of ridicule and admonishment by the radiation protection establishment who support the extension of the linear model to zero dose.

The real effect of radiation on health was known to scientists when the Chernobyl accident occurred in 1986. They also knew the lifetime dose to the local population would be less than ~35 rad.[18] Nevertheless, radiophobia prevailed, and added the fear of impending cancer to the emotional stress of evacuation from homes.[19] Many thousands of abortions were performed needlessly.

The data[20, 21] demonstrate that the incidence of cancer fatalities does not exceed the incidence of fatalities in neighbouring regions, where there was much less fallout - except for thyroid cancer in children. Of the ~70,000 children who received relatively high doses (to thousands of rad each) to their thyroid glands from the uptake of iodine-131, ~600 children contracted thyroid cancer. They were treated, but three of them died of their disease.

Aside from the emotional stress, this is the effect of the radiation from the worst imaginable accident of a nuclear power plant.

Predictions of health effects, fifty years into the future, are being made. Radiation protection practitioners calculate the increase in lifetime cancers induced in the general population to be 0.01 percent. This harmful health effect, if it occurs, will be hidden in the inherent natural statistical fluctuations of the cancer fatality data.[21] However, since radiation is known to stimulate biological defense mechanisms, beneficial health effects (lower incidence of cancer, increased life expectancy) should be expected.

April 26th will be the 10th anniversary of the Chernobyl accident. What would you expect the media to report? Will it be the good news, that the actual consequence of the radiation was much less than feared?

A need for action

We can imagine how Galileo must have felt 500 years ago when he was ordered by the priesthood of the Inquisition not to publish the theory that the planets rotate about the sun, which contradicted the established geocentric model of the universe - that the Earth is the centre of the world.

If we take no action to stop the inappropriate use of the unsubstantiated linear, no threshold dose-response hypothesis, fear of radiation will continue and the likely consequence will be the end of nuclear technology in Canada. Fear and excessive regulation will make nuclear technologies uneconomic in comparison with other, inferior options. The quality of human life will suffer.

Is it proper to inform the public of the likelihood of fatal cancer using an invalid theory?

The linear, no-threshold model is not necessary for effective regulation of radiation. It should be discarded immediately. Our policy on low-level radiation should be changed.

To preserve, enhance and fully utilize our nuclear heritage, we must abandon our restraint and silence on the issue of radiophobia. We must speak out and take action to inform all Canadians that we live in a radioactive world, that all living things can tolerate moderate exposures to radiation, that low-level radiation is quite safe and even beneficial, and that it is acceptable to use nuclear technology and dispose of radioactive wastes.

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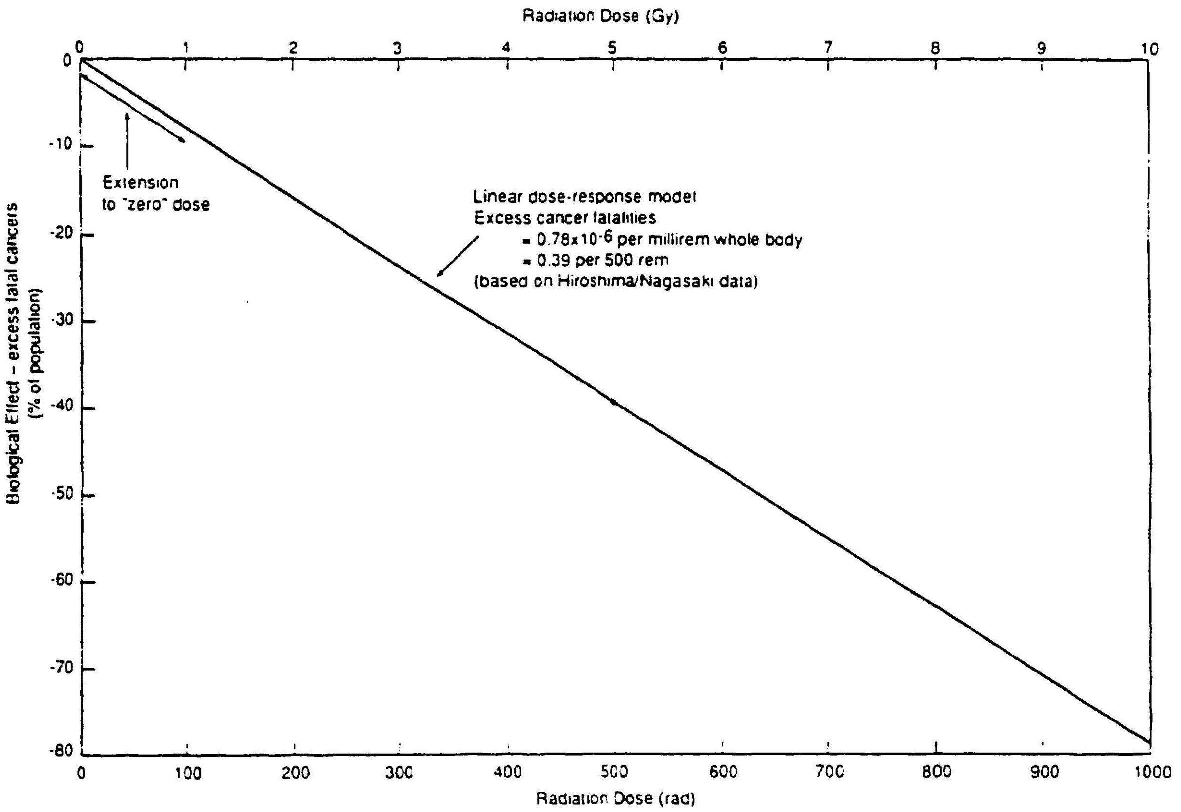

Figure 1. The linear dose-response model for radiation-induced cancer

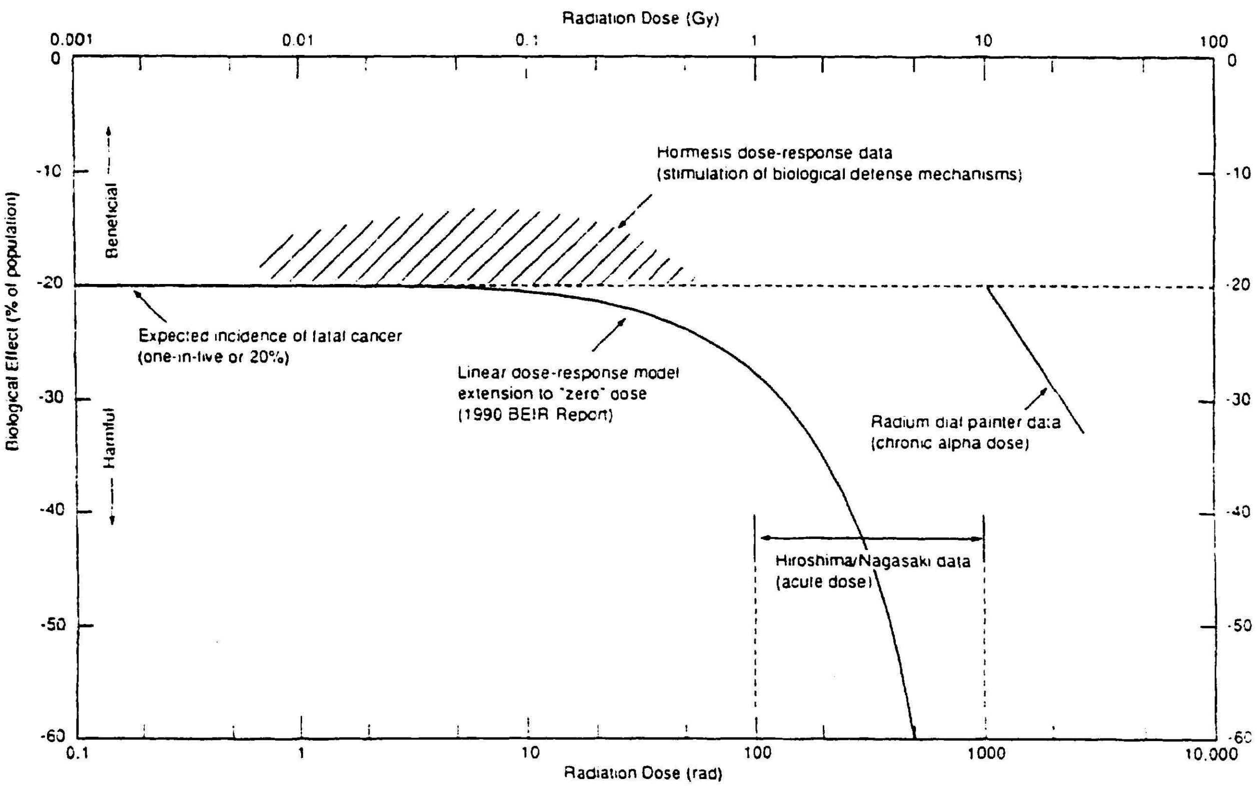

Figure 2. The linear model with radiation dose on a logarithmic scale