

The linear no-threshold theory: Readers weigh in

Should low-dose nuclear radiation be feared? Jeffry Siegel, Charles Pennington, and Bill Sacks (PHYSICS TODAY, January 2016, page 12) pose that question and answer “no.” Siegel and coauthors discuss effects of radiation on fruit flies. But what matters to me and to most others is the effects of radiation on people. I believe there is strong evidence that the linear hypothesis is valid for effects of radiation from 0.05 Gy to a lethal dose of 10 Gy on people. Indeed, references 1–3 below have a different answer from the one by Siegel and company: They say, “very likely yes.”

Yukiko Shimizu and coauthors report on the correlation of radiation exposure and circulatory disease risk from 1950 to 2003 for survivors of the atomic bombs that devastated Hiroshima and Nagasaki.¹ Their figures 1 and 2 show good linear fits of disease risk and radiation dose from 0.1 Gy to 2.5 Gy. There is no indication of a threshold in either figure.

Zbigniew Jaworowski (PHYSICS TODAY, September 1999, page 24) argued that the radiation effects are much smaller if the radiation is received over a long time rather than instantaneously. Jan Beyea considers such prolonged exposures at the radioactive Techa River² in the Soviet Union from 1949 to 1956. Figure 2 in his report shows a linear response for exposures from 0.05 Gy to 0.4 Gy. Again, there is no evidence of a threshold.

A 2009 review of the 1986 Chernobyl disaster presented a detailed analysis of the resulting radiation deaths.³ It finds that the earlier estimate of 50 000 deaths should be doubled to 100 000. Again, it confirms the linear hypothesis. The review article is of special importance since

it lists many deaths—about half of them, in fact—that were not related to cancer. Siegel and coauthors discuss only cancer.

I urge physicists to examine this and other recent research to determine the validity of the linear hypothesis, with no threshold. We can anticipate informative studies in the next 15 years on effects of the Fukushima disaster, but we should not wait. Fifty years ago we had a vigorous (even rancorous) controversy on possible dangers from radiation in atmospheric tests of atomic and hydrogen bombs. The main antagonists in the US were Linus Pauling and Edward Teller. In the Soviet Union, Andrei Sakharov said that if the linear hypothesis were correct, then each megaton tested in the atmosphere resulted in 10 000 deaths. Today we should be able to discuss those issues as scientists and determine the truth of the linear hypothesis. What is the evidence? Has the linear hypothesis risen from “proven untrue” or “not proven true” to “probably true” or “true”?

Once we know the science on possible dangers of low doses of nuclear radiation, we must go further and look at problems caused by the use of nuclear power. If the linear hypothesis is indeed “probably true,” then we must develop procedures for the safe disposal of nuclear waste. At present we are creating more and more nuclear waste without any plans in the US for its disposal.

References

1. Y. Shimizu et al., *BMJ* **340**, b5349 (2010).
2. J. Beyea, *Bull. At. Sci.* **68**, 13 (2012).

3. A. V. Yablokov, V. B. Nesterenko, A. V. Nesterenko, special issue: “Chernobyl: Consequences of the Catastrophe for People and the Environment,” *Ann. NY Acad. Sci.* **1181** (2009).

J. S. Levinger

(levinj@rpi.edu)

Rensselaer Polytechnic Institute
Troy, New York



We write to correct inaccuracies in “Low-dose radiation exposure should not be feared,” by Jeffry Siegel, Charles Pennington, and Bill Sacks. In their comments on the invalidity of the linear no-threshold (LNT) model for low-dose radiation risk they assert that the current LNT model is based only on the efforts of Hermann Muller and his colleagues. They fail to mention other studies that validated the model.

The 2006 report *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2* from the National Academy of Sciences was based on studies of atomic-bomb survivors from Hiroshima and Nagasaki; it concluded that “the balance of scientific evidence at low doses tends to weigh in favor of a simple proportionate relationship between radiation dose and cancer risk.”¹

The dose response for most cancer sites in atomic-bomb survivors is well described linearly, without a threshold. Breast cancer data are most consistent with linearity.² When all solid cancers are analyzed together, there is no evidence of departure from the LNT scenario.

A 20-year study that followed 110 645 workers who helped clean up after the 1986 Chernobyl accident in the former Soviet territory of Ukraine shows statistically significant risks for all leukemia and for chronic lymphocytic leukemia.³ Those data show a significant linear dose response for all leukemia.

A cohort study of 308 297 workers in the nuclear industry cites, as a principal finding, “evidence of a linear increase in the excess relative rate of cancer mortality with increasing exposure to ionizing radiation at the low dose rates typically encountered in the nuclear industries in France, the UK, and the USA.”⁴

The National Council on Radiation

**CONTACT
PHYSICS
TODAY**

Letters and commentary are encouraged and should be sent by email to ptletters@aip.org (using your surname as the Subject line), or by standard mail to Letters, PHYSICS TODAY, American Center for Physics, One Physics Ellipse, College Park, MD 20740-3842. Please

include your name, work affiliation, mailing address, email address, and daytime phone number on your letter and attachments. You can also contact us online at <http://contact.physicstoday.org>. We reserve the right to edit submissions.

Protection and Measurements, the United Nations Scientific Committee on the Effects of Atomic Radiation, the UK National Radiological Protection Board, and other authoritative bodies have assembled committees of experts to review the available scientific data on health effects of low-level ionizing radiation and issued reports analyzing the scientific literature in which the LNT and other theories have been used in estimating risk.⁵ Those expert organizations have long adhered to the LNT model as the basis for their recommendations.

Numerous scientific studies support the LNT model, and there is simply no statistically valid science at present that warrants changing the model.

References

1. National Research Council, Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2*, National Academies Press (2006), p. 246.
2. M. P. Little et al., *Radiology* **251**, 6 (2009).
3. L. B. Zablotska et al., *Environ. Health Perspect.* **121**, 59 (2013).
4. D. B. Richardson et al., *BMJ* **351**, h5359 (2015).
5. K. L. Mossman, *Health Phys.* **80**, 263 (2001).

Bemnet Alemayehu
(balemayehu@nrdc.org)

Thomas Cochran
Natural Resources Defense Council
Washington, DC



Letter writers Jeffry Siegel, Charles Pennington, and Bill Sacks state that modern-day concepts of a linear dose response to ionizing radiation are based on fruit-fly data collected 70 years ago. Actually, fruit-fly data haven't been important since William Russell's Oak Ridge mice data became available in the 1960s. Today, linearity is based on fits to data for cancer incidence or mortality as a function of dose received by individuals in large exposed populations, such as the atomic-bomb survivors (125 000), the Techa River cohort in Russia (17 000), and radiation workers (300 000–600 000). A linear fit is taken as the conservative starting point for dose response, with quadratic terms turning out to be modest.¹ Widespread consensus exists that linearity holds at least down to 100 millisieverts, and there is a broad but not unanimous view that it is likely to continue to apply at lower doses—that risk

will continue to decrease in proportion to dose.

Arguments about repair and evolutionary protection are not sufficient. On occasion, repair systems can fail—for example, mismatched repairs of breaks in double-stranded DNA. Protective systems, such as tumor-suppression genes, can be damaged or turned off by ionizing radiation. Furthermore, ionizing radiation is a promoter, not just an initiator; it can affect cells already genetically damaged by other causes.

Siegel and coauthors cite a claim Siegel makes² that a graph of atomic-bomb-survivor data for cancer incidence suggests a threshold in the epidemiologic noise region of the dose response (below 100 mSv) where uncertainty of data points is great, but the comparable graph for mortality,³ suggesting a supra-linear response, is not shown. They also cite a 58-page review by the French Academy of Sciences and National Academy of Medicine,⁴ but they do not mention the more comprehensive

POWER of COLLABORATION

"Through the purchase of seven KJL deposition tools, over the course of almost 20 years, the overall experience has been terrific. The systems have performed very well and have proved to be valuable tools for thin film deposition and a big factor in completing a number of large projects making detectors for high energy physics and photon science applications. One big consideration for our research at Brookhaven National Labs is having reliable, high quality equipment with strong customer support. In my experience KJL has provided all of that and more."

BROOKHAVEN
NATIONAL LABORATORY

Brookhaven National Laboratory
Upton, NY, U.S.A.



Kurt J. Lesker
Company

Enabling Technology for a Better World
www.lesker.com