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A Certified Health Physicist's Reflections on a 40-Year Career in Radiation Protection

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Abstract

This is a reflection from a certified health physicist regarding his becoming aware, during his 40-year career, that the linear no-threshold (LNT) model and the associated As Low As Reasonably Achievable concept have no scientific basis and make no positive contribution to radiation safety. They should be replaced by an alternative, scientifically based model that includes a threshold, below which there is no harm, and recognition of hormesis and the adaptive response, which reflect the benefits of low-dose and low-dose-rate radiation exposure. Continued use of the unscientific LNT model is not conservative, as most regulators complacently claim but actually harmful. Examples of these harmful impacts in the areas of nuclear power, nuclear medicine, and environmental management are included.

Keywords

LNT model, radiation hormesis, adaptive response, low-dose radiation

Introduction

The appropriate use of nuclear technology worldwide is an essential part of enhancing everyone's happy, healthy, and prosperous futures. My career has led me to associations with professionals from around the world who belong to groups such as the International Dose-Response Society, Scientists for Accurate Radiation Information (SARI), the Health Physics Society, the American Nuclear Society, and Go-Nuclear, to name just a few. The marvelous interdisciplinary professional association with health physicists, nuclear medicine specialists, biologists, nuclear engineers, and others that is evolving through SARI has initiated long, overdue actions that will result in beneficial changes to the understanding and acceptance of low-dose radiation. The Outstanding Leadership Award that I recently received from the Dose-Response Society (along with my colleagues, Drs Carol Marcus and Mohan Doss on behalf of SARI) is the high point of my career, and I am thankful to the Society for this recognition.

As my colleagues and I asserted in our petitions[1] to the Nuclear Regulatory Commission (NRC), the continued use of the unscientific linear no-threshold (LNT; Note 1) model on which to base regulations is counterproductive and even harmful. It leads to misperceptions and fear of the hypothetical risks of low-dose and low-dose-rate radiation, which we refer to as "radiophobia." As a well-intentioned but flawed follow-on attempt to calm the public's fear of radiation, the NRC coined the term As Low As Reasonably Achievable (ALARA, a completely subjective concept) and mandated its use in their regulations. Adoption of this acronym actually made the perception of radiation risk worse, not better. I ask myself, "If minimal radiation is not harmful (even beneficial), then why should we reduce it ALARA at every opportunity?"

Discussion

Forty years ago, when I was just beginning my career, I diligently studied and learned the concepts of radiation interaction with matter and biological tissue. I did not question the paradigm of the time that subscribed to the LNT model nor to the theory that there was a genetic risk component to radiation exposures that would manifest itself in future generations. Although the issue of radiation-induced genetic damage has been generally abandoned, continued use of the LNT model persists, even though no statistically significant data have ever been shown to support it.[4] It appears to me that studies have always focused on attempts to statistically prove a lower level of harm (down to zero dose). Perhaps they should rather search

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for a statistically meaningful threshold above which harm can be statistically demonstrated. Regulators default to this administratively simple model, defending it as the ''conservatively safe'' assumption based on the precautionary principle. The precautionary ''approach'' makes some sense, but the precautionary ''principle'' is a rigid, dogmatic position. Not only is it not always safe, it can be harmful! This fact must repeatedly be used to remind regulators that use of the LNT model is actually contrary to their responsibilities as protectors of public health.[5]

About 20 years ago, I began to question the conventional wisdom of the simplistic LNT model. It made intuitive sense that there was a linear relationship with high-dose and high-dose-rate radiation exposure. However, when these data were extrapolated several orders of magnitude down from very high exposure data to zero, without data to support it, scientific support of the approach simply cannot withstand objective scrutiny. A junior high school science fair project would be thrown out if it attempted to draw conclusions with no supporting data! Thus, the foundation of the LNT was based on misrepresentations, intending to mislead regulatory agencies and others.[6] However, there was peer pressure (as there still is) to continue to ''drink the Kool-Aid'' and maintain the status quo. Even I, for many years, went ''along with the flow'' because most of the radiation protection activities that I was involved in still made sense, and I didn't think that it was that completely unreasonable to adhere to the simplistic, default LNT model. Nonetheless, I witnessed millions of dollars being squandered on excessive environmental cleanup standards[7] and remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah FEIS, Yucca Mountain FEIS, unnecessary power plant overdesign requirements (ALARA, emergency plans, and operating plans), and nuclear medicine application obstacles (both physician and patient's unfounded concerns). These excesses and obstacles were also occurring (and continue) worldwide.

My thinking crystallized when circumstances surrounding the Fukushima accident brought many issues into clear focus. Even though there was real fear (due to myriad uncertainties present at the time, due to the lack of data and information), it quickly became apparent to me that the releases, though measurable, were not life threatening in the near term nor in the future. Neither regulators, the public nor the media, had any reasons or perspective to appreciate the unnecessary harm that current standards or perceptions were causing. However, due to radiophobia and public pressure, massive evacuations were ordered, displacing many tens of thousands of persons. This led to over 1000 documented disaster-related deaths (DRDs), which were in no way related to any radiation exposures.[8] This was tragic, given that there were zero radiation-related deaths, either during the accident or at any time in the predicted future! In addition, most evacuated people have not been allowed to return to their slightly contaminated homes (where their families have lived for countless generations). This is because international standards (widely adopted by most countries in the world, including Japan) are so restrictive (based on the flawed LNT and the precautionary principle and decades of maintaining the status quo) that return will not be considered ''safe'' for many years, even after very expensive, extensive, and unnecessary cleanup efforts.

Unfortunately, the existing standards reinforce the erroneous perception that any radiation dose, no matter how small, bears some attendant risk (tied to the unscientific LNT). Can you blame the world's public for drawing this conclusion?

Worldwide, LNT and ALARA have resulted in nearly incalculable, unjustified increases in the cost of commercial nuclear power, nuclear medicine, and environmental management.[9] Some notable impacted areas in nuclear power (difficult to precisely quantify but intuitively obvious) include:

- Reactor component overdesign to minimize/eliminate ''risk''
- Operating procedures based on LNT and ALARA that needlessly increase costs and imply an exaggerated risk
- Radiation safety staff tasked with trivial LNT and ALARA engagements that detract from ''real'' radiation safety practices
- Increased insurance premiums as well as bonds and reserves for decommissioning to zero contamination
- Emergency plans that are highly overconservative and costly—which reinforces the implied message to the public—''Be afraid!''

These are just a few examples of things that have kept and continue to hamper acceptance of nuclear power as a viable contributor to the world's energy portfolio. The LNT and ALARA are 2 major obstacles strangling the public's perception and acceptance of nuclear power. Not until radiation risk is properly understood and put into perspective that can widespread acceptance of anything radiation-related happen. Furthermore, the engineering designs and associated costs would become affordable, further enhancing the attractiveness of the nuclear power option. Unfortunately, the nuclear power industry doesn't realize this simple fact! Instead, being single-minded engineers, they wrongly assume that if they ''engineer a fix'' (to a risk that doesn't even exist or is significantly less than they are told) that the public will rush to accept their solution. WRONG!

In nuclear medicine, gross misunderstanding of the actual radiation risks (minimal) and the enormous benefits from using nuclear medicine techniques for diagnostic and therapeutic purposes results in considerable unrealized health benefits worldwide.[5]

- The LNT and ALARA have resulted in some patients or parents declining recommended scans and physicians not ordering the appropriate scans because of misguided perceptions of risk associated with low-dose and low-dose-rate radiation. Also, scans are being performed with poor diagnostic quality because of radiation dose concerns, potentially placing patients at risk.
- There are many exciting potential applications of low-dose and low-dose-rate radiation that are just beginning to be explored.[10]

In the field of environmental management, LNT and ALARA have resulted in disastrous unintended consequences and exorbitant cleanup costs. Some examples include:

- How the United States spent US$1.45 billion to prevent 1290 theoretical (based on the LNT model) cancer deaths from mill tailings on the Uranium Mill Tailings Remedial Action project.[7]
- Billions overspent on EPA Superfund cleanups. While some level of cleanup is indeed justified, the ''how clean is clean enough'' issue generally isn't addressed. Instead, cleanups (both radiological and chemical) are based on simplistic LNT model logic.
- How Japan's prompt and hastily conceived evacuations resulted in over 1000 documented DRDs,[8]
- Where, post-Fukushima, there are continued unscientifically based delays in reoccupying slightly contaminated properties (many of which have radiation levels far lower than natural background radiation in many parts of the world) and
- Spending billions of dollars in Japan to burn hydrocarbon fuels to replace the power lost when they shut down over 50 operating nuclear plants (only 3 have restarted so far) because of radiophobia.

Conclusion

The stakes in this issue are real and considerable. It's not an academic argument about a few percentage points here and there. It's about something as obvious as factors of 10! However, this obvious information is clouded by LNT and ALARA. Their elimination from our lexicons will result in enormous benefits in our attempts to achieve science-based regulations and realistic radiation risk perceptions by the public. Only then can true radiation safety be practiced by radiation protection professionals and the health effects of low-dose and low-dose rate radiation be understood by the public.

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Note

1. Background: In 1934, the US Advisory Committee on X-ray and Radium Protection proposed the first formal standard for protecting people from radiation sources. At that time, the quantitative measurement of ionizing radiation was expressed as the ionization produced in air, in units of roentgens, and the recommended limit on dose rate for radiologists was 0.1 R/d. The LNT model assumes that the long-term, biological damage caused by ionizing radiation (essentially the cancer risk) is directly proportional to the dose (no matter how small). It was publicized in 1946 when Dr Herman Muller, a geneticist, received the Nobel Prize for the discovery of the X-ray-induced mutation of germ cells in Drosophila melanogaster fruit flies. Later, experiments demonstrated a linear relationship. However, these experiments were performed at high dose and high dose rates. When he discovered that the linear relationship did not hold at lower dose and lower dose rate exposures, there is evidence that he ignored or covered this information up.[2] Subsequently, Dr Muller served on the International Council on Radiation Protection (ICRP) in 1954. It was at this time that the Cold War was heating up and real fears of nuclear holocaust and lasting radiation genetic damage to the human species that would result were palpable. Perhaps out of concern for Cold War developments, the Genetics Panel of the National Academy of Sciences Biological Effects of Atomic Radiation I Committee in 1956 endorsed the overly restrictive and ''conservative'' exposure rate standard.[3] Its summary report made statements such as ''Even very small amounts of radiation unquestionably have the power to injure the hereditary materials'' and ''there is no such figure other than zero'' (for amount of radiation that is genetically harmless). The full report was published in the New York Times and received huge publicity initiating the fear of low-dose radiation. Dr Muller may have used his status to persuade the ICRP to adopt the LNT model to establish more restrictive occupational radiation protection standards. In 1957, the ICRP recommended an annual occupational dose limit of 5 rem (0.05 Sv) per year.

References

1. Nuclear Regulatory Commission. *Linear No-Threshold Model and Standards for Protection against Radiation: Docket Folder Summary*, Regulations.gov. 2015. https://www.regulations.gov/document?D=NRC-2015-0057-0010. Accessed October 10, 2016.
2. Calabrese EJ. On the origins of the linear no-threshold (LNT) dogma by means of untruths, artful dodges and blind faith. *Environ Res*. 2015;142:432-442.
3. National Academy of Sciences (NAS). Genetic Effects from Atomic Radiation—BEAR I Genetic Committee. *Science*. 1956; 123(3209):1157-1164. http://science.sciencemag.org/content/123/3209/1157.long. Accessed October 10, 2016.
4. National Council on Radiation Protection & Measurements. *Principles and Application of Collective Dose in Radiation Protection*. 1995. NCRP Report No. 121:45.
5. Scott BR, Dobrzyński L. Special issue introduction. *Dose-Response*. 2012;10(4):462-466.
6. Calabrese EJ. Model uncertainty via the integration of hormesis and LNT as the default in cancer risk assessment. *Dose-Response*. 2015;13(4):1-5.
7. Miller ML, Cornish R, Pomatto CB. Calculation of the number of cancer deaths prevented by the Uranium Mill Tailings Remedial Action (UMTRA) Project. *Health Phys*. 1999;76(5):544-546.
8. Saji G. A post-accident safety analysis report of the Fukushima Accident—Future Direction of Evacuation: Lessons Learned, Appendix A. *Proceedings of the ICONE 21.16526*. Chengdu, China: International Conference on Nuclear Engineering (ICONE); 2013.
9. Cohen BL. *The Nuclear Energy Option: An Alternative for the 90s*. Chapter 9. 1990 ed. Plenum Publishing Corporation; 1990.
10. Cuttler JM, Moore ER, Hosfeld VD, Nadolski DL. Treatment of Alzheimer disease with CT scans: a case report. *Dose-Response*. 2016;14(2):1-7.