Linear No Threshold (LNT) Model of Radiation Risk

The linear no threshold (LNT)[1] hypothesis of radiation risk postulates that the theoretical incremental lifetime cancer incidence risk (ILCR) is directly proportional to the dose or exposure to ionizing radiation. Although the relationship is based on cancers induced in the Japanese A-bomb survivors who were exposed to 10s to 100s of rem of radiation, LNT theorizes that no matter how small a radiation dose, there is an associated low risk of cancer. There is a continued debate among health physicists about the validity of LNT at low doses of radiation especially at low levels at or below background levels of radiation[2].

In 2006, the U.S. National Academy of Sciences (NAS) issued the 7th in a series of studies on the Biological Effects of Ionizing Radiation (BEIR VII) in which it recommended continued use of LNT and recommend a radiation risk correlation of approximately 0.001 cancer incidences per person-rem[3,4].

The average US natural background radiation is approximately 300 millirem[5] per year (mrem/y) from cosmic rays, soil and rock, the food we eat and indoor radon[6]. The average US exposure from medical procedures is approximately an additional 300 mrem/y. Since cosmic ray exposure increases with elevation, one round trip LA to NY airline trip exposes passengers to 5 millirem (1 millirem from every 1,000 miles)[7].

LNT leads to some odd paradoxes that are conveniently igmored by LNT proponents and medical practitioners.

- LNT is a cumulative risk model. Lifetime background exposure is 300 x 85 / 1000 = 26 rem. Therefore, lifetime radiation cancer risk from background radiation is 0.001 x 26 = 0.026 = 2.6%

[1] Linear No Threshold Model of Radiation Risk. September 10, 2007. https://www.etec.energy.gov/Library/Main/Radiation_Risk_LNT_Rev_A.pdf

[2] Radiation Risk. Phil Rutherford Consulting. http://www.philrutherford.com/radiation_risk.html

[3] BEIR VII: Health Risks from Exposure to Low Levels of Ionizing Radiation. Report in Brief. 2006. http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/beir_vii_final.pdf

[4] BEIR VII. Health Risks from Exposure to Low Levels of ionizing Radiation. Book. 2006. https://www.nap.edu/catalog/11340/health-risks-from-exposure-to-low-levels-of-ionizing-radiation

[5] 1 rem = 1,000 millirem (mrem). 1 Sievert (Sv) = 100 rem. 1 mrem = 0.01 mSv.

[6] EPA. Radiation Sources and Doses. Background Radiation. https://www.epa.gov/radiation/radiation-sources-and-doses

[7] EPA. Calculate Your Radiation Dose. https://www.epa.gov/radiation/calculate-your-radiation-dose

- Since LNT is a population risk model, if 1,000 people receive 1 rem exposure then 1 person is predicted to develop cancer. Or if 40 people receive 26 rem of background radiation in a lifetime, then 1 person is predicted to develop radiation induced cancer. Of the 329 million people currently alive in the US, 1 in 40 or 8.2 million are doomed to develop cancer from background radiation during their lifetime (if you believe that LNT is valid). And approximately half of those will die from this cancer. If this "epidemic" was true, the medical community and public would be shouting from the roof-tops, demanding the government supply them with lead-lined vests to protect them from killer radiation. This is not happening because the LNT hypothesis is false.
- The EPA risk assessment guidance hangs its hat on a so-called 1-in-a-million or 10^{-6} risk goal for radiological remediation of Superfund sites[8]. This equates to 0.000001 cancer incidences per person-millirem. The individual risk goal of 10^{-6} therefore translates into an incremental radiation exposure of 1 millirem over the exposure duration (typically 26 years in EPA modeling) which means 0.04 millirem/y. This incremental exposure goal is approximately 1/10,000 part of the average background radiation and certainly less that the variation of background radiation. It is also the equivalent of moving your home to a location, 20 feet higher in elevation with the associated increase in cosmic radiation exposure[9].
- Clearly, these foolish consequences of the LNT hypothesis are absurd.

The concept of LNT applied to radiation exposure is perhaps a little hard for the lay person to comprehend. So, let's try something more understandable to illustrate the foolishness of LNT theory applied to another toxin.

You go into a bar and the bartender asks you "What's your poison?" This is an appropriate question because alcohol is considered a poison. Medical opinion says that if you drink 30 shots of 80 proof liquor (about 1 liter), you are dead[10]. Not maybe. Not dead in 20 or 30 years, but dead immediately if you don't get a stomach pump. We are not talking about long-term effects of alcohol abuse, but short-term immediate poisoning.

- If EPA regulated alcohol, and applied the LNT model, it would say the fatal risk is 1 (100%) per 30 shots.
- That means the fatal risk is 0.03 per shot. So, every drink you take, you are rolling the dice with a 3% chance of dying.

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[8] EPA. Preliminary Remediation Goals for Radionuclides (PRG). https://epa-prgs.ornl.gov/radionuclides/

[9] EPA. Calculate Your Radiation Dose. Cosmic radiation increases by 2 millirem/year from sea level to 1,000 ft elevation. https://www.epa.gov/radiation/calculate-your-radiation-dose

[10] Alcohol Poisoning. https://www.alcohol.org.nz/alcohol-its-effects/health-effects/alcohol-poisoning

- Furthermore, since alcohol risk is cumulative, and if you have 1 drink each day for a month, you are dead.
- Or since the LNT is a population risk model, if 30 of your friends at a party have 1 shot of tequila each, then 1 will keel over dead.

This humorous analogy is, of cause, flawed. Radiation risk is stochastic[11], meaning it is statistical. It also deals with chronic low-level exposures and chronic effects, i.e. long-term cancer effects. For instance, it does not apply to non-stochastic or deterministic[12], short-term effects due to high-level radiation exposures that result in immediate effects, sometimes referred to as “radiation poisoning.”

The same cannot be said of the alcohol risk analogy. It is not a population model. It is not a stochastic, statistical process. It is more akin to deterministic short-term “radiation poisoning.”

Exposing 1,000 people to 1 rem of radiation will “theoretically” result in 1 cancer. It will also “theoretically” leave 999 of 1,000 people with no cancer. This is the population aspect of the radiation risk LNT model.

The population aspects of the LNT radiation risk model can lead to invalid conclusions as we saw in the predictions of millions of people contracting cancer from background radiation. The Health Physics Society (HPS) and American Nuclear Society (ANS) state that there is no evidence of health effects below a lifetime dose of 10 rem and caution against applying the population model and multiplying small individual risk or dose numbers by large populations to get unrealistically high numbers of cancers and subsequently high numbers of deaths[13,14].

On the other hand, in more realistic scenarios, population risk models can meaningful. For instance, if individual risk is 10^{-4} at a cleanup site and the exposed population is relatively small, e.g. 1,000, then the population risk is 0.0001 x 1,000 = 0.1 predicted cancers. Population risk in units of cancers (unlike individual risk in units of probability between 0.0 and 1.0) can only be integral, i.e. 0, 1, 2, 3 etc. 0.1 is therefore functionally equivalent to zero. In this case a 10^{-4} individual risk goal instead of a 10^{-6} individual risk goal is therefore deemed acceptable by EPA[15].

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[11] “Stochastic” means the probability of an effect is a function of (proportional to) the dose.

[12] “Non-stochastic” or “deterministic” means the severity of the effects vary with dose.

[13] Health Physics Society. Radiation Risk in Perspective. July 2010. http://hps.org/documents/risk_ps010-2.pdf

[14] American Nuclear Society. Health Effects of Low-Level Radiation. June 2001. http://www.ans.org/pi/ps/docs/ps41.pdf

[15] EPA. Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination. OSWER 9200.4-18. August 22, 1997. http://www.philrutherford.com/Radiation_Cleanup_Standards/OSWER_9200-4-18.pdf