Radiation: The Facts

Robert Hargraves - Radiation Risks

Radiation is safe within limits. *Nuclear power is a green environmental solution. It generates no CO_2. The fuel is cheap and inexhaustible. Green nuclear power can solve the global crises of air pollution deaths and climate change. Cheap energy can help developing nations escape poverty and let industrialized nations improve economic growth.*
Is it safe? The primary obstacle to nuclear power is misunderstanding of radiation safety.
These are Misunderstandings:

- There is no safe level of radiation.
- Radiation effects are cumulative.
- Chernobyl killed nearly a million people.
- Nuclear waste is deadly for a million years.

These misunderstandings create public fear, so regulators adopted unnecessary rules to isolate the public from radiation. The excess costs and delays make nuclear power more expensive and impede its benefits to people.
Radiation is safe - within limits

RADIATION

Radioactive materials have atoms that decay at random. Half of them decay within their half-life. Some examples are:-

Atom	*Half-life*
potassium-40	1.2 billion years
americium-241	432 years
cobalt-60	5 years
iodine-131	8 days

Radiation results from each atom's decay.
- Alpha particles (two protons + two neutrons) cannot penetrate skin.
- Beta particles (electrons ejected from nuclei) do not penetrate metal foil.
- Gamma radiation (energetic photons) is partly absorbed by bone to make X-ray images.

Radioactivity of a source is reckoned as a count of atom decays. One count per second is one Becquerel (Bq). A banana has beta radioactivity of about 15 Bq from its potassium-40. Smoke detectors have americium-241 - made in nuclear reactors - with alpha radioactivity of about 30,000 Bq.

Ionising radiation **dose** is the energy transferred from radiation to body tissue. A one milliSievert (mSv) dose is 0.001 watt-second of energy per kilogram of tissue (x20 for alpha particles). One mammogram[1] exposure, for example, may be 2 mSv. **Natural background** radiation comes from cosmic rays, from breathing radon, from ingestion of food and water, and from proximity to rocks such as granite. Natural radiation **dose rates** vary, averaging 3 mSv/year in the US, 4 mSv/y in Denver, and 7 mSv/y in Finland.

(Other units are also in common use. For details see, for instance, http://orise.orau.gov/reacts/guide/measure.htm)

DOSE RATES AND HEALTH

A massive, single, whole-body radiation dose severely injures blood cell production and the digestive and nervous systems. A dose over 5,000 mSv is usually fatal. Spread over a lifetime it is harmless. Why? At low dose rates cells have time to recover. Cancer is not observed[2] at dose rates below 100 mSv/y.

Linear response. Radiation can break a chemical bond in a DNA molecule and create a slight chance it might recombine improperly to propagate cancerous cells. Linear no threshold theory (LNT) says the chance is proportionate just to radiation dose, even at low dose rates over long times. It's wrong.

Hermann Muller received the Nobel prize in 1946 for LNT theory. He used fruit flies exposed[3] to 2,750 mSv and up. But to heighten public fear of atomic bomb fallout during the Cold War, he extrapolated his results down to below 100 mSv, despite contrary evidence. The flaw in old LNT theory is that it considered only radiation dose, not dose rate. LNT theory ignored life's adaptive response.

Adaptive response. Radiation can be safe. We now know that DNA strands break and repair frequently, about 10,000 times per day per cell. Double strand breaks also occur naturally, about once per week per cell. MIT researchers observed[4] that 100 mSv/y radiation dose rates increased this number. The overwhelming majority of breaks are caused by ionized oxygen molecules from metabolism within the cell. Because DNA is a double helix, the duplicate information in one strand lets enzymes readily repair any single-strand break. Double strand breaks also occur naturally, about once per week per cell. Most such breaks are due to intracellular oxygen, with natural background radiation increasing the break rate[5] by about 0.1%. Specialized repair centers within cells fix these breaks, as observed by scientists at Lawrence Berkeley Labs[5].

Adaptive response continues at the cellular, tissue, and organism levels. This protection[5] peaks near 100 mSv exposure and persists for a year or so. The process is similar to immune response to vaccinations against smallpox, polio, or influenza.

RADIATION SAFETY EVIDENCE

The examples given below show that radiation is safe below 100 mSv/y and that LNT is wrong.

Atomic bomb survivors. The US exploded atomic bombs over Japan in 1945, killing 200,000 people. 93,000 survivors have since been closely monitored for health effects. In 55 years 10,423 survivors died from cancer, 573 more than the 9,850 deaths normally expected by comparison with residents away when the bombs exploded. But there were no cancer deaths[8] observed from radiation doses less than 100 mSv.

Taiwan apartment buildings. Recycled steel contaminated with cobalt-60 was used to build apartments, exposing 8,000 people to 400 mSv of radiation over 20 years. Cancer incidence was sharply down, not up 30% as LNT predicted. Instead the adaptive response to low-level radiation seemed to confer health benefits.

Chernobyl. Doses up to 8,000 mSv killed 28 emergency workers at Chenobyl in 1986. The Chernobyl Forum[10] estimated up to 8,000 children contracted thyroid cancer from milk contaminated with iodine-131, and 15 died. Relying on LNT theory, the report projected up to 4,000 future fatal cancers might occur, but these have not been observed among the 100,000 fatal cancers normally expected.

US nuclear shipyard workers. The US studied workers maintaining nuclear submarines who were exposed to low levels of gamma radiation from cobalt-60. The study compared 28,000 nuclear workers and 33,500 non-nuclear workers. People exposed to more radiation (averaging 8 mSv/y) had a death rate[11] from all causes 24% less than the others. This contradicts LNT theory.

Medical radiation. Radiation medicine exposes a US person to 3 mSv/y on average. Diagnostic radiation doses[12] are low, ranging from 0.001 mSv for a dental X-ray to 20 mSv for a CT procedure.

Therapeutic doses[13] are high. A rotating X-ray beam focused on cancer tissue delivers up to 80,000 mSv. To minimize the risk of causing cancer in nearby tissue, radiologists divide the radiation dose into fractions, administered daily rather than all at once, giving healthy tissue time to recover. If LNT were true this fractionated radiation therapy wouldn't work

Fukushima. The tsunami-flooded reactors overheated and released radioactive materials. Residents were evacuated from areas with greater than 20mSv/y exposure (IAEA[14] recommends this at greater than 220 mSv/y). A UN panel of expert scientists concluded[15] that radiation caused no attributable health effects and none likely in the future. Radiation released killed no one, but evacuation stress was reported to have killed hundreds. Most refugees could have returned home safely.

RADIATION POLITICS

Exposure limits that were set by LNT theory ignore observed low-level radiation effects. Public radiation safety limits have become more restrictive, from 150 mSv/y (1948) to 5 mSv/y (1957) to 1 mSv/y (1991).

These rules are political and inconsistent. Nuclear workers are allowed 50 mSv/y, and astronauts 500 mSv/y. EPA's limit for indoor *radon* is 8 mSv/y, but 0.04 mSv/y for *tritium* in drinking water. EPA limits Yucca Mountain exposure to < 0.1 mSv/y for 10,000 years.

The LNT fallacy that any radiation can kill you led to the ALARA principle (as low as reasonably achievable). But achievability is based on ever-changing technology capability, not on health effects. LNT and ALARA ratchet limits lower and increase costs and fear.

Notes and references

1 "mammogram exposure"
Radiation Doses and Cancer Risks from Breast Imaging Studies
by R. Edward Hendrick, PhD
http://pubs.rsna.org/doi/abs/10.1148/radiol.10100570

2 "cancer is not observed at dose rates below 100 mSv/y"
The Linear No-Threshold Relationship Is Inconsistent with Radiation Biologic and Experimental Data
by Maurice Tubiana, MD, Ludwig E. Feinendegen, MD, Chichuan Yang, MD, and Joseph M. Kaminski, MD
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2663584/

3 "fruit flies exposed"
How the US National Academy of Sciences misled the world community on cancer risk assessment: new finding challenge historical foundations of the linear dose response
by Edward J. Calabrese
http://www.ncbi.nlm.nih.gov/pubmed/23912675
See also http://www.ncbi.nlm.nih.gov/pubmed/22166484

4 "MIT researchers observed"
A new look at prolonged radiation exposure
by Anne Trafton, MIT News
http://web.mit.edu/newsoffice/2012/prolonged-radiation-exposure-0515.html

Integrated Molecular Analysis Indicates Undetectable Change in DNA Damage in Mice after Continuous Irradiation at ~ 400-fold Natural Background Radiation
by Werner Olipitz et al
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3440074/pdf/ehp.1104294.pdf

5 "break rate"
Hormesis by Low Dose Radiation Effects: Low-Dose Cancer Risk Modeling Must Recognize Up-Regulation of Protection
by Ludwig E. Feinendegen, Myron Pollycove, and Ronald D. Neumann
http://dl.dropbox.com/u/119239051/Feinendegen-2012_Hormesis-by-LDR_Therapeutic-Nucl-Med.pdf

6 "observed by scientists at Berkeley Labs"
Evidence for formation of DNA repair centersand dose-response nonlinearity in human cells
by Teresa Neumaiera et al
http://www.pnas.org/content/early/2011/12/16/1117849108.full.pdf+html

7 "10,423 died"
Radiation and Reason, p 89, Table 4, p 91 Table 5
by Wade Allison
http://www.amazon.com/Radiation-Reason-Impact-Science-Culture/dp/0956275613/

http://www.jstor.org/discover/10.2307/3581199?uid=3739800&uid=2134&uid=2476504073&uid=2&uid=70&uid=3&uid=2476504063&uid=3739256&uid=60&sid=21102986258363

Table 4 (leukemia)

Dose range (mSv)	Survivors	Observed deaths	Expected deaths
<5	37,407	92	85
5 to 100	30,387	69	72
100 to 200	5,841	14	15
200 to 500	6,380	27	16
500 to 1000	3,963	20	10
1000 to 2000	1,972	39	5
> 2000	737	25	2
All	86,955	296	203

Table 5 (solid cancer)

Dose range (mSv)	Survivors	Observed deaths	Expected deaths
<5	38,507	4,270	4,282
5 to 100	29,960	3,387	3,313
100 to 200	5,949	732	691
200 to 500	6,380	815	736
500 to 1000	3,426	483	378
1000 to 2000	1,764	326	191
> 2000	625	114	56
All	86,611	10,127	9,647

8 "no cancer deaths"
Radiation and Reason pp 89, 91, Tables 4 and 5, first two rows

9 "cancer incidence was sharply down"
Effects of Cobalt-60 Exposure on Health of Taiwan Residents Suggest New Approach Needed in Radiation Protection
by W.L. Chen et al
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2477708/

Hemopoietic Response to Low Dose-Rates of Ionizing Radiation Shows Stem Cell Tolerance and Adaptation
by Theodor M. Fliedner et al
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3526333/

10 "contaminated with iodine-131, and 15 died"
Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts
by Chernobyl Forum
http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf

11 "death rate from all causes"
Nuclear shipyard worker study (1980–1988): a large cohort exposed to low-dose-rate gamma radiation
by Ruth Sponsler and John R. Cameron
http://www.probeinternational.org/low-dose-NSWS-shipyard.pdf

12 "Diagnostic radiation doses are low"
Radiation Dose in X-Ray and CT Exams
by American College of Radiology and Radiological Society of North America
http://www.radiologyinfo.org/en/safety/index.cfm?pg=sfty_xray

13 "Therapeutic doses are high"
Radiation therapy
by Wikipedia
http://en.wikipedia.org/wiki/Radiation_therapy

14 "IAEA recommends > 220 mSv/y"
Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor
by UN International Atomic Energy Agency
http://www-pub.iaea.org/MTCD/Publications/PDF/EPR-NPP_PPA_web.pdf

15 "UN panel of expert scientists"
No Immediate Health Risks from Fukushima Nuclear Accident Says UN Expert Science Panel
by United Nations Scientific Committee on the Effect of Atomic Radiation
http://www.unis.unvienna.org/unis/en/pressrels/2013/unisinf475.html

16 "Evacuation stress"
Commentary on the Appropriate Radiation Level for Evacuations
by Jerry Cuttler
http://www.ourenergypolicy.org/wp-content/uploads/2012/03/35766131k01w4103.pdf

Fukushima evacuation zone November 2013 radiation, p 3
by Japan Nuclear Regulation Authority
Evacuation boundary line radiation 20 mSv/y, outside orange area <100 mSv/y
http://radioactivity.nsr.go.jp/ja/contents/8000/7480/24/362_0513_11.pdf

This information is also available as
http://home.comcast.net/~robert.hargraves/public_html/RadiationSafety26SixPage.pdf

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