Radiation: The Facts

Opening eyes to the facts

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.

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 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.

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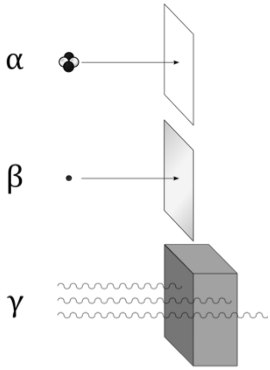
RADIATION 101

Radioactive materials have atoms that decay at random. Half decay within their half-life.

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) can not 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 is 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.

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 exposure[1] may be 2 mSv.

Natural background radiation comes from cosmic rays, breathing radon, ingestion of food and water, and 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.

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. MIT researchers observed[4] that 100 mSv/y radiation dose rates increased this number by only 12 per day. 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 also 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[6].

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

These examples show that radiation is safe below 100 mSv/y and 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[7] 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[9], not up 30% as LNT predicted. Instead the adaptive response to low-level radiation seemed to confer health benefits.

Notes[1-16] at http://Radiation-Safety-Limits.info

Chernobyl

Doses up to 8,000 mSv killed 28 emergency workers 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 > 20 mSv/y exposure. (IAEA[14] recommends > 220 mSv/y.) A UN panel of expert scientists concluded[15] that radiation caused no attributable health effects and likely none in the future. Radiation killed no one, but the evacuation stress did kill[16] hundreds. Most refugees could have safely returned home.

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 health effects. LNT and ALARA ratchet limits lower and increase costs and fear.

Radiation is safe within limits.

An evidence-based radiation safety limit would be 100 mSv/y. Ending LNT and ALARA rules will enable the full environmental and economic benefits of green nuclear power.

Ask your senators and representatives to require NRC and EPA to adopt new, scientific, evidence-based radiation safety limits.