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Earth Day and Just How Many of DOE's Cleanup Sites Will Require "Forever" Institutional Controls

In honor of Earth Day, it is fitting to better understand the environmental consequences of nuclear weapons and energy work that the public is being told have been "remediated."

The Environmental Protection Agency mandated cleanup of various Department of Energy sites around the country have been completed for many sites and is considered substantially complete at the Idaho National Laboratory. The EPA likes to wax eloquent about its stringent cleanup standards. While the EPA's cleanup standards pose a much higher risk of cancer than they claim because they have not kept up with radiation health protection findings, the problem is that when the mess is large, there is no attempt to meet the cleanup standards.

Instead, "institutional controls" are said to prevent humans from getting exposed to the radioactive material. What people don't understand is the length of time that these institutional controls will be needed at places like the Idaho National Laboratory.

The INL has numerous areas of shallow and deep underground soil and water that will require, by DOE's documents, institutional control for hundreds of thousands of years and more. The DOE's term for this is "indefinite." These sites will require, for example, maintaining soil caps, signs and a prohibition on well drilling. And this was all just from a few decades of waste generation.

Few people understand the number of areas around the country and at the INL that were left a radioactively and chemically contaminated mess that will require "institutional controls" such as a sign or a fence or soil cap in order to keep people out and keep people from drinking the water.

See the long list of the INL's sites that will be contaminated "forever" despite what is claimed as "cleanup" or "remediation." [1]

[1] INL Waste Area Group Institutional Controls Report. Dated February 16, 2016. https://cleanup.icp.doe.gov/ics/ic_report.pdf from the EPA page: https://cleanup.icp.doe.gov/ics/

Chernobyl Thirty Year Anniversary — What Lessons Apply to Idaho's Past and Future Nuclear Ventures?

The estimated radiological releases from the April 1986 Chernobyl nuclear reactor accident range from 50 million curies to about half of its 9000 million curie core. [2] [3] There are nuclear booster websites that continue to claim that the health effects from the Chernobyl accident were relatively minor and limited to two dozen or so accident responders who died from acute radiation syndrome. They continue to claim that other than elevated thyroid cancers, adverse health effects were modest and much of the ill health stemmed largely from "radio-phobia." The human health consequences of Chernobyl extended far beyond early accident responders. It extended to citizens living near the accident, children in-utero at the time of the accident both near and far from the accident, and citizens of other countries affected by contamination as far away as Sweden.

Cancer rates in Sweden were unexpectedly found to be 11 percent higher in regions having a modest cesium-137 contamination level of 100 kBq/m^2. [4] And importantly, underlying the cesium-137 contamination levels that were determined by aerial survey is a host of other radioactive fallout contaminants in varying amounts that are given less attention.

There are important lessons from the Chernobyl accident. One lesson evidently not learned by the 2011 Fukushima accident is that conducting an evacuation, permanent or temporary, is nearly impossible. Predicting where the radioactive fallout plume will blow depends on changeable wind patterns. Hospital patients are nearly impossible to evacuate. And you don't have to be a rocket scientist to guess what would happen when folks get in their car on clogged highways to evacuate from a melting nuclear reactor in a highly populated area. But the problem in Idaho will be the lack of adequate radiation monitoring and failure to inform people that they need to evacuate. Think the releases won't blow offsite? The protection action distance for the INL's Advanced Test Reactor is 65 miles. Idaho still does not heed the straightforward lesson that people near nuclear reactors need access to iodine immediately to reduce the uptake of radioactive iodine-131— that is prevalent in fresh fuel from the Advanced Test Reactor.

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[2] http://www.wiseinternational.org/nuclear-monitor/641/how-much-radiation-was-released-chernobyl

[3] C. C. Busby and A. V. Yablokov, European Committee on Radiation Risk (ECRR), "Chernobyl: 20 Years On. Health Effects of the Chernobyl Accident," 2006. http://www.ratical.org/radiation/Chernobyl/chernobylebook.pdf

[4] Martin Tondel et al, Increase of regional total cancer incidence in north Sweden due to the Chernobyl accident? J. Epidemiol Community Health 2004;58 1011-1016. www.ncbi.nlm.nih.gov/pmc/articles/PMC1732641/pdf/v058p01011.pdf 1 Bq (Becquerel) is 1 disintegration per second. 1 Curie is 3.7E10 Bq.

Fallout deposition can be very uneven because of wind and rain patterns. Access to long term and independent radioactivity monitoring of food will be needed as food crops are radioactively contaminated and the food and soil contamination will remain problematic for many years, as has also been learned by the Fukushima accident.

There is no convenient place for disposing of everything that gets contaminated. So in addition to having no place to put the contaminated reactor fuel and cooling water—a problem so untenable that we just leave it to the scientists in their infinite wisdom to solve—there is the problem of lacking access to a place to dispose of the radioactively contaminated crops, vegetation, playground soil, building materials, etc. Japan didn't have a place to dispose of bagged contaminated leaves or playground soil so these lay in streets for years. After Chernobyl, hastily buried wastes likely contaminated water supplies. Of course, there is still the problem of stabilizing the spent nuclear fuel still at the facility, stabilizing and storing spent nuclear fuel in pools. Oh, and the broken national economy caused by the nuclear reactor incident and the inadequate or non-existent compensation for people who have lost homes, livelihoods and health.

Anyway, back to the radiation health issues: elevated levels of illness and early deaths are described in ECRR 2006 [5] for "liquidators" who participated in cleanup efforts after Chernobyl and the citizens living near Chernobyl. Analysis of biomarkers in the blood of liquidators showed little correlation to the doses they were recorded as having received that were as acknowledged as being a high as 50 rem but averaging 9 rem. Within 16 years of work as a "liquidator" "only 1-2 percent of those remaining alive were considered healthy. [6]

There are too few radiation detectors to monitor actual levels of radiation reaching people and a tendency of the nuclear community to underestimate the radiation doses received. Children were allowed to continue playing outside the day of the Chernobyl accident as officials downplayed the seriousness of the accident and delayed the decision to evacuate. Radiation detection capability in some neighboring countries is enough to detect the plumes, but the radiation doses estimated for by neighboring countries have also turned out to be seriously underestimated based on biomarker analysis of blood years later. According the ECRR 2006, dicentric levels were indicative of doses above 1 rem even though estimates had been made that the public far from the accident received doses less than 100 or 200 mrem.

Elevated levels of disease have also been found in children exposed in utero to the Chernobyl plume as far away as Sweden and Norway. Reduced cognitive function has been found in children in these regions as well. In the most contaminated areas near the accident, elevated levels of congenital malformations continue to be found, as great as 83 percent higher than

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[5] C. C. Busby and A. V. Yablokov, European Committee on Radiation Risk (ECRR), "Chernobyl: 20 Years On. Health Effects of the Chernobyl Accident," 2006. http://www.ratical.org/radiation/Chernobyl/chernobylebook.pdf

[6] ECRR 2006. p. 145

normal for areas with greater than 15 Curie/km^2 (or 555 kBq/m^2). [7] Not only are the children in-utero at the time of the accident affected, trans-generational effects are also found as mutated cells are passed on to children from the pre-conceptual exposure of the parent.

State officials in the Ukraine deliberately withheld medical records of the true harm for the first four years. After the economic and political collapse brought on by the Chernobyl nuclear accident, records were released. Thousands of studies of the disease and illnesses brought by the radioactive release of the accident and living in radioactively contaminated areas have been conducted that are written in Russian but remain largely ignored by the world nuclear community that prefers the earlier incorrect underestimates of harm.

An important lesson is of the inadequacy of the current radiation model, the International Commission on Radiological Protection (ICRP) model, [8] that underestimates the human health harm, especially to the developing embryo or young child. When the US NRC cancelled what would have been the first meaningful epidemiology study of health effects near US nuclear reactors, I wrote last March about the German epidemiology study of children living near nuclear plants have roughly double the incidence of cancer and leukemia. [9] [10] Similar findings resulted from ECRR's study of clusters of childhood leukemia near nuclear sites including Sellafield, Dounreay and La Hague where an excess of 300-fold infant leukemia were found. [11]

Several studies in countries affected by Chernobyl fallout also found elevated childhood leukemia despite official predictions that there would be none. The elevated level of childhood leukemia have been estimated as 150 percent higher than predicted by the ICRP model. [12] These studies are diverse and many. Yet the nuclear community of officialdom fails to act responsibly: in fact they continue to deny that the illnesses were caused by radiation because the estimated doses were too low to have caused the illnesses.

Part of the problem involves the underestimation of damage due to radionuclides ingested and assimilated by the body that is not adequately reflected by the Japan Atomic bomb studies of external dose upon which the ICRP model is based. The BEIR VII report [13] which acknowledges

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[7] Janette D. Sherman, M.D., and Alexey V. Yablokov, Ph.D., Chernobyl: Consequence of the catastrophe 25 years later," April 27, 2011. http://www.ratical.org/radiation/Chernobyl/CCofC25YL.html

[8] International Commission on Radiological Protection, "Compendium of Dose Coefficients Based on ICRP Publication 60," ICRP Publication 119, Volume 41 Supplement 1 2012. http://www.icrp.org/docs/P%20119%20JAICRP%2041%28s%29%20Compendium%20of%20Dose%20Coefficients%20based%20on%20ICRP%20Publication%2060.pdf

[9] P Kaatsch et al., Int J Cancer, "Leukaemia in young children living in the vicinity of German nuclear power plants," 2008 Feb 15;122(4):721-6. http://www.ncbi.nlm.nih.gov/pubmed/18067131

[10] Spix C, Schmiedel S., Kaatsch P, Schulze-Rath R, Blettner M., Eur J Cancer, "Case-control study on childhood cancer in the vicinity of nuclear power plants in Germany 1980-2003." 2008 Jan;44(2):275-84.Epub 2007 Dec 21. http://www.ncbi.nlm.nih.gov/pubmed/18082395

[11] ECRR 2006 p. 141

[12] ECRR 2006 p. 3

[13] "Health Risks from Exposure to Low Levels of Ionizing Radiation BEIR VII – Phase 2, The National Academies Press, 2006, http://www.nap.edu/catalog.php?record_id=11340 The BEIR VII report reaffirmed the conclusion of the prior report that every exposure to radiation produces a corresponding increase in cancer risk. The BEIR

higher levels of vulnerability of women and children to radioactivity has not evaluated the growing evidence concerning elevated childhood leukemia from Chernobyl fallout and from other nuclear facilities. [14]

The focus on monitoring cesium-137 because it can be surveyed in a plane aerially tends to lead to ignoring the abundant mix of radionuclides that were spread from the accident, especially the beta and alpha emitters. Strontium-90 is a beta emitter that bioaccumulates in food and is utilized like calcium when taken into the body. Long-lived alpha emitters such as plutonium, uranium, curium and americium are also spread by reactor accidents but tend to be ignored. The internal exposures to elevated levels of alpha emitters in people living there has been proven around Chernobyl by testing for chromosomal damage distinctive to alpha emitters.

In Idaho, often the whole gamut of radionuclides were also released to air or soil, but only a single radionuclide would be monitored. Officials claimed that the 1961 SL-1 accident released mainly iodine-131. [15] Yet this fuel was highly enriched and had high burnup: it contained and subsequently released a whole gamut of radionuclides to the winds that were not monitored or mentioned. Idaho was being inundated with fallout from the DOE's weapons testing in Nevada in the 1950s and 60s as well. [16]

These findings suggest the inadequacy of past studies of radiological releases from the Idaho National Laboratory [17] because of (1) inadequate monitoring of radiological releases including the tendency to ignore many very important radionuclides and (2) the underestimation of health risk from the radiation doses. The decision to not study the epidemiology around the Idaho lab from 1950s through 1970s fallout was based on inadequate radiation health models.

Another important lesson for the public is that often it requires substantial anecdotal evidence of increases in ill health before a study is conducted, even in such an obvious catastrophe as the Chernobyl accident. In sparsely populated communities of Idaho, this has offered considerable concealment of disease although state disease records to point to problems. Official

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VII report found increased sensitivity to radiation in children and women. Cancer risk incidence figures for solid tumors for women are about double those for men. And the same radiation in the first year of life for boys produces three to four times the cancer risk as exposure between the ages of 20 and 50. Female infants have almost double the risk as male infants.

[14] ECRR 2006 p. 3

[15] Atomic Energy Commission report, Idaho Field Office, IDO-19313, "Additional Analysis of the SL-1 Excursion: Final Report of Progress July through October 1962. Flight Propulsion Laboratory Department, General Electric Co., November 1962. Various DOE reports released by Freedom of Information Act request about SL-1 are at http://www.id.doe.gov/foia/archive.htm

[16] Records of weapons test fallout that reached a particular county can be found by using the Center for Disease Control's interactive iodine-131 fallout map. By entering a birth date prior to 1971, state and county and milk drinking habits, you can obtain potential I-131 dose and the results will present the estimated dose by individual weapons test name and date. https://ntsi131.nci.nih.gov/

[17] US Department of Energy Idaho Operations Office, "Idaho National Engineering Laboratory Historical Dose Evaluation," DOE-ID-12119, August 1991. See Table E-5 on p. E-36 for mystery milk and see Table C-21 for the public annual dose summary. Volumes 1 and 2 can be found at https://www.iaea.org/inis/inis-collection/index.html

organizations influenced by promoters of nuclear energy have proven unable to provide adequate and unbiased studies of adverse health effects following Chernobyl. Likewise, the Department of Energy has time and again withheld known epidemiology results, cancelled funding for studies when unfavorable results began to surface, or argued that epidemiology was not needed. The DOE has refused to track the level of congenital malformations occurring to highly exposed radiation workers who have children and has continued to ignore the BEIR VII findings that women and children are many times more vulnerable to radiation induced illnesses than adult men.

The health effects of exposures of cleanup workers at INL are based on inadequate health models. And cleanup standards, although in the short term are depicted in terms of more stringent EPA standards, after 10,000 years, the very permissive Department of Energy radiation protection standards have been applied to the largest buried waste at INL, the Radioactive Waste Management Complex, and the predicted 30 to 100 mrem/yr doses are based on the inadequate ICRP model. Ingested doses of 100 mrem/yr will not be protective of children or embryos.

The EPA cleanup standards are more stringent than DOE regulations but even if the EPA standards weren't being ignored wherever the radioactivity is too high at INL, the actual risk of the contamination appears to be roughly 10 times higher than estimated by the EPA because human epidemiology of about 1 million people exposed in Sweden to a modest Cs-137 soil contamination (plus unmentioned other radionuclides) of 100 kBq/m^2 caused an 11 percent cancer increase. By my estimated conversion to grams of soil, the EPA model would predict instead , roughly, only about a 1 in 1000 chance of cancer from this.

"Cleanup" at INL means consolidate waste, sprinkle soil on top, maybe a soil cap, put up a sign, monitor the aquifer, and call it protective of human health because you're assuming no one will be exposed for the more than hundreds of thousands of years the material will remain in high concentrations in soil and water.

The Department of Energy practice of "report sanitation" and inadequate aquifer monitoring continues the long-standing practice of largely ignoring past alpha emissions and the true extent of perched water, soil and aquifer alpha contamination at the INL's Advanced Test Reactor Complex, or formerly Test Reactor Area. This practice prevents the public from having accurate information, misinforms CERCLA cleanup, and prevents accurate estimation of doses for past worker exposures there needed for the Energy Employee Occupational Illness Compensation Act. [18]

[18] Department of Energy Idaho Operations Office, *Five-Year Review of CERCLA Response Actions at the Idaho National Laboratory Site,* Fiscal Years 2010-2014, DOE/ID-11513, December 2015.

Understanding Retrospective Estimate of Radiation Dose Using Biological Dosimetry Can Increase Nuclear Industry Liability

It has long been recognized that external whole body radiation doses can be estimated after exposure by testing blood levels of granulocyte, lymphocyte, leukocyte, or platelet counts within 1 to 2 days after exposure. These indicators of the absorbed doses may also be useful up to 30 days after exposure but after then these counts usually begin to rebound to normal levels. [19] [20] The lower the count, the higher the radiation exposure.

Another method considered to be the classical method of cytogenetic analysis is based on the comparison of unstable chromosomal aberrations, such as dicentrics or rings, which can be detected 1.5 to 2 years after radiation exposure for doses above 1 rem. This method is based on the comparison of the number of aberrations in exposed and unexposed people. The higher the number of aberrations, the higher the radiation exposure. However, there are individual differences in radiosensitivity which may cause the same dose to result in more aberrations in some people. [21]

A third method involves painting cells and counting the aberrations in a technique called fluorescent in situ hybridization (FISH). The technique is considered applicable for doses above 25 rem. Stable translocations caused by high linear-energy-transfer alpha radiation such as from internal plutonium exposure are replicated by the body. The number of these chromosomal aberrations does not decline and may be measured many years after exposure. One study of former plutonium workers found "elevated rates of stable chromosome aberrations were found in lymphocytes of former workers decades after plutonium intakes, providing evidence that chronic irradiation of hematopoietic precursor cells in the bone marrow induces cytogenetically altered cells that persist in peripheral blood." [22]

Elevated levels of dicentrics or of stable translocations are indicators of dose and are generally indicators of cancer risk. These tests have not been widely available but tests such as these have been used in litigation to estimate radiation doses. The federal and state government stood by the story that maximum doses from the 1979 accident at the Three Mile Island nuclear plant did not exceed 100 mrem. But subsequent FISH DNA damage testing conducted later by those who were vomiting the day of the accident showed radiation doses far higher: 50 to 90 rem. [23]

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[19] Shaoen Hu et al., *Health Physics Society*, "Hemodose: A Biodosimetry Tool based on Multi-Type Blood Cell Counts," 2015. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4482456/pdf/hp-109-54.pdf or http://www.ncbi.nlm.nih.gov/pubmed/20065671

[20] Radiation Emergency Medical Management, US Department of Health and Human Services, see https://www.remm.nlm.gov/aboutlymphocytedepletion.htm

[21] Min Su Cho et al., *Journal of Radiation Research*, "Retrospective biodosimetry using translocation frequency in a stable cell of occupationally exposed to ionizing radiation," 2015. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4497401/

[22] GK Livingston et al., *Journal of Radiation Research*, "Effect of occupational radiation exposures on chromosome aberration rates in former plutonium workers," 2006. http://www.ncbi.nlm.nih.gov/pubmed/16808624

[23] Steve Wing, David Richardson, Donna Armstrong, and Douglas Crawford - Brown, A Reevaluation of Cancer Incidence Near the Three Mile Island Nuclear Plant: The Collision of Evidence and Assumptions, Volume 105, Number 1, January 1997, Environmental Health Perspectives.

The increased liability to the nuclear industry or of the Department of Energy of people exposed to accidents actually learning what their radiation doses are rather than relying on contrived estimated doses may be why you don't know about it. [24]

Small Modular Reactors (SMRs) a Nuclear Boondoggle

Commentary by Darryl Siemer, printed in the Idaho Falls Post Register on February 26, 2016.

The Dept. of Energy just announced that the Idaho National Lab's 50 megawatt "small modular reactor" will generate 1,000 "temporary" full-time jobs and 300 thereafter.

Assuming that a "full-time job" costs taxpayers $100k per year and "temporary" means two years, labor costs add up to $1.1 billion during a 30 year lifetime.

Assuming 10 percent downtime for refueling, maintenance, labor costs, etc. during that lifetime would be 9.3 cents/kWhr. Adding in fuel costs, the total comes to 10.1 cents/kWhr. Of course, its actual costs are apt to be considerably greater.

In 2014 the total cost (operation, maintenance and fuel) of generating electricity with the USA's existing reactors was only 2.76 cents/kWhr.

Idaho's electricity consumption averages about 2700 MW which means that even though it might "contribute" to Idaho's power needs, that contribution would be insignificant.

If its fuel cycle were sustainable, it would be worth "studying" anyway.

However, it's just another light water reactor (LWR) requiring the same kind and amount of fuel and generating the same kind and amount of waste/kWhr as do today's full-sized LWRs. Its sole virtue is "modularity" and the only thing it'll prove (again) is that big reactors make more sense.

Consequently, it's another long-winded, over-priced DOE nuclear boondoggle that will chew up time, tax dollars and make it more difficult to convince "outsiders" that they really could afford a "nuclear renaissance."

Worse, it'll probably turn another generation of eager young INL PhDs into cynical "good team players."

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[24] Hande, M. Prakashet al., "Complex Chromosome Aberrations Persist in Individuals Many Years After Occupational Exposure to Densely Ionizing Radiation: An MFISH Study," Genes, Chromosomes & Cancer 44:1-9, Wiley-Liss, Inc., 2005. http://onlinelibrary.wiley.com/doi/10.1002/gcc.20217/abstract;jsessionid=5E362E0AAA8D098B341D801A296640CA.d03t04

INL Director Talking to Idaho Attorney General Lawrence Wasden About Blocked Shipment of Research Fuel

Idaho Falls Post Register reported an interview with INL Director Mark Peters March 4, 2016. Peters said that “in order not to impact the scope of the project, we need to have a decision (on the latest spent fuel shipment) pretty quick.” But regarding the Integrated Waste Treatment Unit that is part of the reason the state is disallowing the shipment, Peters also stated that “We certainly don’t want them to turn this thing on unless we know it will work well and be safe.” In addition to not meeting the sodium bearing waste treatment milestone in the Idaho Settlement Agreement, shipments of transuranic waste to the struggling to reopen WIPP facility in New Mexico are also missing Idaho Settlement Agreement milestones.

Department of Energy Names WIPP Preferred Alternative for Greater-Than-Class-C Waste

The Department of Energy has issued its final Environmental Impact Statement on the disposal of greater-than-class-C radioactive waste. [25] WIPP has been named as the preferred alternative. The good news is that the preferred alternative does not include shallow land burial at DOE sites such as Hanford or Idaho.

Greater-than-class-C waste includes waste from commercial nuclear reactor decommissioning and also Department of Energy radioactive waste that cannot be disposed of in Class A, B or C radioactive low-level waste disposal facilities because the waste is radioactive far longer than 500 years. This is long-lived waste that has long been recognized as requiring deep geologic disposal and includes uranium, plutonium, americium, technetium-99 and many other radionuclides that will eventually migrate with water infiltration as the metals corrode.

The Department has determined the preferred alternative, WIPP, would satisfy the needs of the Department for the disposal of GTCC and GTCC-like waste. Prior to making a final decision on which disposal alternative to implement, DOE will submit a Report to Congress and await action by Congress. DOE will not issue a Record of Decision until its required Report to Congress has been provided appropriate action has been taken by Congress in accordance with the Energy Policy Act of 2005.

The DOE states that the second alternative would be land disposal at “generic” commercial facilities although none have been specifically identified. DOE states “These land disposal conceptual designs could be altered or enhanced, as necessary, to provide the optimal application

[25] See the Department of Energy’s Final EIS-0375 at http://energy.gov/nepa/eis-0375-disposal-greater-class-c-low-level-radioactive-waste-and-department-energy-gtcc-waste

at a given location. . . . Due to the uncertainty regarding the need for legislative changes and/or licensing or permitting changes, further analysis will be needed before a Record of Decision is announced."

On June 20, 2014 Waste Control Specialists, LLC, (WCS), filed (and resubmitted on July 21, 2014) a Petition for Rulemaking with the Texas Commission on Environmental Quality (TCEQ) requesting the State of Texas to revise certain provisions of the Texas Administrative Code to remove prohibitions on disposal of GTCC LLRW, GTCC-like waste and TRU waste at its TCEQ licensed facilities. On January 30, 2015, TCEQ sent a letter to the NRC requesting guidance on the State of Texas's authority to license disposal of GTCC LLRW, GTCC-like waste and TRU waste. This matter is under review by NRC. Should DOE identify a specific commercial facility or facilities for the disposal of GTCC LLRW and GTCC-like waste, DOE states that they will conduct site -specific NEPA reviews, as appropriate.

Ian Goddard Reviews Radiation Epidemiology Studies

Since the 2006 BEIR VII Report

Ian Goddard explains the "linear no-threshold" radiation health risk model and compares it to epidemiology results since 2006 in a video he created. He gave us permission to share it on our website. Please find it on our Radiation health page. [26] By reviewing recent human health epidemiology of mixed ages (adults and children) and of children only, Ian explains why the linear no-threshold model is still appropriate. Human epidemiology results show harm from radiation exposure far below 10 rem lifetime exposures.

The 2006 Biological Effects of Ionizing Radiation, or BEIR VII report found that current International Commission on Radiological Protection (ICRP) model underestimates cancer risk. The ICRP model has been found to underestimate the risk of cancer by at least a factor of 2.

As Ian Goddard points out in a related video that both the ICRP and BEIR VII radiation risk levels underestimate the health risk of low doses accumulated over time as studied by a meta analysis of radiation workers in many countries. [27] The 2009 study by Jacob showed that while there are problems with accuracy of dose estimates, doses accumulated slowly and to a level of about 10 rem total, were not less harmful than doses accumulated all at once, as the victims of the atomic bombing of Japan received. The underpinnings of the ICRP used for nuclear workers and medical radiation exposures are the study of Japan's atomic bomb survivors. Therefore, the dose reduction factors assumed based on animal studies that were applied in these models is not supported by human epidemiology. The slow dose rate reduction factor taken by ICRP (of 2) and

[26] http://www.environmental-defense-institute.org/radhealth.html
[27] P. Jacob et al., Occup Environ Med, "Is cancer risk of radiation workers larger than expected?" 2009;66:789-796 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2776242/pdf/BWC-66-12-0789.pdf

by BEIR VII (of 1.5) based on animal studies are simply not valid for humans and are one reason these models under-predict radiation harm.

The Department of Energy still uses the outdated and long proven to underestimate risk ICRP model for accident risk assessment and for its radiation protection of workers. Past studies conducted by or for the Department of Energy to assess the harm of its fallout on communities has been based on ICRP of various editions. The Department of Energy's ignoring the bad news that radiation health effects are worse at slowly accumulated doses far less than half of its 5 rem per year standard and at lifetime doses of about 10 rem hurts workers. The harm from radioactive fallout from the Department of Energy's past radiological releases in Idaho, New Mexico and Nevada has been argued based on ICRP models which underestimated to harm to embryos and children, especially female children. And the evaluation of probability of causation for former energy workers in order to qualify for compensation also use the outdated ICRP models that under predict harm by at least a factor of two for external radiation exposure as it relates to the risk of developing a solid cancer (not leukemia).

Epidemiology studies cited by Ian Goddard: [28]

Pooling of dose responses animated:

National Academy of Sciences (2006). BEIR VII. http://www.nap.edu/read/11340

Solid-Cancer Dose Responses (adult and mixed age) Post-BEIR VII

Boice JD et al (2006). Mortality among Radiation Workers at Rocketdyne (Atomics International), 1948–1999, Radiat Res. 166(1 Pt 1):98-115. http://pubmed.gov/16808626

Cardis et al (2007). The 15-Country Collaborative Study of Cancer Risk among Radiation Workers in the Nuclear Industry: estimates of radiation-related cancer risks. Radiat Res. 167(4):396-416. http://pubmed.gov/17388693

Ronckers et al (2008). Multiple diagnostic X-rays for spine deformities and risk of breast cancer. Cancer Epidemiol Biomarkers Prev. 17(3):605-13. http://pubmed.gov/18349278

[28] In reading these studies that use international units of Gray (Gy) and Sievert (Sv), it may be helpful to have conversions to units commonly used in the US of the analogous Rad and rem. Gray and Rad indicate the quantity of energy imparted. Sievert and rem indicate the dose accounting for enhanced biological harm. A multiplier may be applied to Gray (or Rad) to estimated the Sievert (or rem) dose. The greater biological harm from alpha and neutron doses is roughly accounted for by use of a multiplier on the dose. Typical background radiation of 100 to 170 mrem per year from living on Earth does not include medical radiation. The conversions shown below assume the biological effectiveness multiplier is 1.0 which would not be true of internal alpha exposure or neutron exposure.

0.1rem	= 1 mGy	= 100 mrem	= 1 mSv
1 rem	= 10 mGy	= 1000 mrem	= 10 mSv
10 rem	= 100 mGy	= 10,000 mrem	= 100 mSv
50 rem	= 500 mGy	= 50,000 mrem	= 500 mSv

Muirhead et al (2009). Mortality and cancer incidence following occupational radiation exposure: third analysis of the National Registry for Radiation Workers. Br J Cancer. 13; 100(1): 206–212. http://pubmed.gov/19127272

Ozasa et al (2012). Studies of the Mortality of Atomic Bomb Survivors, Report 14, 1950–2003: An Overview of Cancer and Noncancer Diseases. Radiat Res. 177(3):229-43. http://pubmed.gov/22171960

Schonfeld et al (2013). Solid Cancer Mortality in the Techa River Cohort (1950–2007). Radiat Res. 179(2):183-9. http://pubmed.gov/23289384

Metz-Flemant et al (2013). Mortality associated with chronic external radiation exposure in the French combined cohort of nuclear workers. Occupational Environ Med. 70(9):630-8. http://pubmed.gov/23716722

Kashcheev et al (2015). Incidence and mortality of solid cancer among emergency workers of the Chernobyl accident: assessment of radiation risks for the follow-up period of 1992–2009. Radiat Environ Biophys. 54(1):13-23. http://pubmed.gov/25315643

Davis et al (2015). Solid Cancer Incidence in the Techa River Incidence Cohort: 1956–2007. Radiat Res. 184(1):56-65. http://pubmed.gov/26121228

Sokolnikov et al (2015). Radiation Effects on Mortality from Solid Cancers Other than Lung, Liver, and Bone Cancer in the Mayak Worker Cohort: 1948–2008. PLoS One. 26;10(2):e0117784. http://pubmed.gov/25719381

Richardson et al (2015). Risk of cancer from occupational exposure to ionising radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS). BMJ. 351:h5359. http://pubmed.gov/26487649.

Solid-Cancer Dose Responses (children) Post-BEIR VII

Spycher et al (2015). Background ionizing radiation and the risk of childhood cancer: a census-based nationwide cohort study. Environ Health Perspect. 123(6):622-8. Shown @ 6:20 but not included in the pooled graph due to x axis being dose rate, not cumulative dose. http://pubmed.gov/25707026

Pearce et al (2012). Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet. 380(9840):499-505. http://pubmed.gov/22681860

Mathews et al (2013). Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians. BMJ. 21;346:f2360. http://pubmed.gov/23694687

Kendall et al (2013). A record-based case–control study of natural background radiation and the incidence of childhood leukaemia and other cancers in Great Britain during 1980–2006. Leukemia. 27(1):3-9. http://pubmed.gov/22766784

Child-only leukemia graphs shown after 6:55 are from Pearce and Kendall above.

Pooled solid-cancer studies animation:

Note: the pooled graphs use the Excess Relative Risk (ERR) standard where baseline risk is valued @ 0.

Included graphs using the Relative Risk (RR) standard, where baseline risk is valued @ 1, are fit into the pooled graph by the standard definition: ERR = RR – 1

In the case of Mathews et al (2013) (fitted @ 3:21), the y axis is Incidence Rate Ratio (IRR), which is equivalent to RR. Additionally, the x axis in Mathews is a count of CT scans. As per Table 8, the average scan in the 5-year-lag group whose graph I used (given it is between the 1- and 10-year lag groups) was 4.5 mSv, with the maximum data point representing a sub-group with an average of 3.5 scans, hence 15.75 mSv is the x-axis value for the highest-dose data point (see Mathews Fig 2 for the 1-year lag and Appendix Figures A(a,b) for the 5- and 10-year lag graphs http://bmj.com/content/bmj/suppl/2013... , of which I used the 5-year lag).

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