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NuScale's New US460 Design Seeks NRC Approval, and NuScale Seeks to Add Subscribers as Construction Cost Estimates Rise

NuScale has admitted that they must triple its subscription level for the UAMPS project in Idaho by early 2024. [1] Only 116 MWe of the planned 462 MWe are subscribed by the Utah Associated Municipal Power Systems (UAMPS) Carbon Free Power Project (CFPP). The city municipalities in UAMPS, are a consortium of members from Arizona, California, Idaho, Nevada, New Mexico, Utah and Wyoming. Subscribers are still needed for 254 MW, yet the tendency has been for existing subscribers to drop out or reduce their subscription due to the high project cost and uncertainty.

The cost for building the NuScale US460 small modular reactor project near Idaho Falls has increased significantly, but it likely won't be the last cost increase — if the project continues.

Last January, the NuScale cost estimate increased to $89/megawatt-hour (MWh) from $58/MWh. [2] Without extremely generous government subsidies granted to NuScale, the cost would already approach $120/MWh.

Scaling down from 12 modules, the modified project slated at the Idaho National Laboratory is to deploy 6 reactor modules. The proposed power generation has been scaled up from 60 megawatt-electric (MWe) to 77 MWe each, and with all 6 modules operating could generator 462 MWe. The power level scale up for the NuScale US460 design has not been approved by the U.S. Nuclear Regulatory Commission.

The NuScale project still needs additional design work for unique equipment, licensing by the U.S. Nuclear Regulatory Commission, construction and pre-operational testing. Experience with other nuclear reactors, like the recent cost overruns at the Vogtle plant's new AP1000 reactors, indicates that further cost increases and schedule delays can be expected. [3]

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[1] Stephen Singer, *UtilityDive*, "NuScale must triple subscription level for small modular reactor in Idaho by early 2024, company says," March 17, 2023. https://www.utilitydive.com/news/nuscale-smr-uamps-funding-nrc-doe-idaho-lab/645262/

[2] David Schlissel, Institute for Energy Economics and Financial Analysis, "Eye-popping new cost estimates released for NuScale small modular reactor," January 11, 2023. https://ieefa.org/resources/eye-popping-new-cost-estimates-released-nuscale-small-modular-reactor

[3] Nick Ferris, *Energy Monitor*, "Why a new era for US nuclear looks unlikely – Evidence suggest the Inflation Reduction Act and the advent of small modular reactors is unlikely to lead to a US nuclear resurgence in the

The Vogtle AP1000 reactor construction costs are $150/MWh, natural gas combined cycle is $80/MWh and average solar cost is about $30/MWh, according to IEFFA reports. But the cost of spent nuclear fuel storage, repackaging, disposal or of highly polluting reprocessing is not included in the nuclear build construction cost figures.

The NuScale project includes some never-before-built features that are essential for operability as well as safety — like the novel helical coil steam generators which have steam generation on the tube side rather than the shell side. The piping disconnects between the reactor module and the feedwater and steam turbine side are unlike any other nuclear reactor design. And the lifting of very heavy reactor modules in a pool where other reactor modules are operating is unlike any other nuclear reactor.

The concept of having several reactor modules is clever and would allow part of the reactor modules to continue operating as one or more reactor modules are shutdown for refueling or repairs. But in practice, design or safety problems may require shutting down all the reactor modules. Dropping a reactor module during heavy load handling could cause pool leakage and pose a safety threat to all the modules.

So, while this design may provide certain improvements such as natural circulation through the core, for example, it also creates new design problems and safety problems. It can be expected to take a lot of money and time to work out these problems.

For the 2 years, NuScale insiders have been selling NuScale stock. Insiders, over the last 24 months, sold over $15 million in shares and bought less than $1000 in shares. [4] Over the last 12 months, insiders sold off about $4.5 million in shares. [5]

And what appears to be some good news for NuScale may prove ephemeral, as Poland has announced that it has applied for a decision-in-principle to construct a NuScale facility as well as six GE Hitachi Energy's BWRX-3000 nuclear plants. [6] Throwing taxpayer money at the drowning NuScale, the U.S. has recently promised to give $250 million to Romania to try to support unaffordable, unreliable, and unsafe NuScale reactor projects in Romania. [7]

Unlike what promotors want people to believe, there is no basis to expect NuScale small modular reactors to be affordable, reliable, or safe. [8] [9] [10]

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medium term," May 26, 2023. https://www.energymonitor.ai/sectors/power/why-a-new-era-for-us-nuclear-looks-unlikely/ Vogtle AP1000 reactors cost more than $30 billion, more than $16 billion over budget and more than 6 years behind schedule. In South Carolina, 2 AP1000 reactors were cancelled due to rising costs.

[4] See NuScale insider trading, accessed July 17, 2023. https://www.marketbeat.com/stocks/NYSE/SMR/insider-trades/

[5] *Simply Wall St*, "Shareholders Can't Ignore US$4.5m of Sales By NuScale Power Insiders, July 12, 2023. (NuScale Power Corporation, NYSE:SMR) https://simplywall.st/stocks/us/capital-goods/nyse-smr/nuscale-power/news/shareholders-cant-ignore-us45m-of-sales-by-nuscale-power-ins

[6] World Nuclear News, "Decision-in-principle for Polish SMR power plant," July 13, 2023. https://www.world-nuclear-news.org/Articles/Decision-in-principle-for-Polish-SMR-power-plant

[7] World Nuclear News, "Romania's NuScale SMR plan gets USD275 million boost," May 22, 2023. https://www.world-nuclear-news.org/Articles/NuScale-s-Romanian-SMR-plan-gets-USD275-million-bo

[8] David Schlissel, Institute for Energy Economics and Financial Analysis, "IEEFA U.S.: Small modular reactor 'too late, too expensive, too risky and too uncertain,' " February 2022. https://ieefa.org/articles/ieefa-us-small-modular-reactor-too-late-too-expensive-too-risky-and-too-uncertain

The Health Physics Society continues to ignore the full extent of radiation health harm – When will they ever learn?

Much has been learned about the harm of ionizing radiation on the human body over the last few decades, but the Health Physics Society, the Department of Energy and others continue to misrepresent the health harm. Cancer risk continues to be underestimated and the harm to the unborn and to children remains downplayed or simply ignored.

The Health Physics Society continues to claim, still in 2023, despite diverse evidence to the contrary, that no detectable cancer increase would occur from radiation doses below 10 rem (whole body dose). [11]

Furthermore, the HPS states: "According to the conclusions of the National Research Council … it takes significant doses ([greater than]10 rem) to measurably increase the risk."

This statement by the Health Physics Society is wrong and has been wrong for decades. Measurable increases in health harm have long been found at doses below 1 rem and are found, especially in studies of the developing child, at doses below 100 millirem.

"[G]enetic effects have not been observed in human populations exposed to ionizing radiation."

This statement by the Health Physics Society is wrong and detailed studies following the Chernobyl catastrophe have provided evidence of elevated birth defects, as will be discussed below.

" [Zero to] 5 rem received in a short period or over a long period is safe – we don't expect observable health effects … 5-10 rem received in a short time or over a long period is safe – we don't expect observable health effects. At this level, an effect is either nonexistent or too small to observe."

This statement by the Health Physics Society is wrong. The study of over 300,000 nuclear workers in three countries shows elevated cancer rates due to radiation exposures despite cumulative doses generally significantly below 10 rem total dose, exposures being from a "low dose rate" from exposures spread over time.

The Health Physics Society refuses to learn or to acknowledge the truth of the serious harm at low doses of ionizing radiation. Generally, a low dose is considered to be near or under 10

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[9] Environmental Working Group, "Questions for NuScale VOYGR Reactor Certification: When Will It Be Done? And then, Will It Be Safe"," May 2023. Posted on the Institute for Energy and Environmental Research (IEER.org) website. https://ieer.org/resource/reports/questions-for-nuscale-voygr-reactor-certification-when-will-it-be-done-and-then-will-it-be-safe/

[10] Dave Williams, *Capitol Beat News Service, The Augusta Chronicle*, "PSC expert: Plant Vogtle expansion bad deal for Georgia Power customers," July 27, 2023. https://www.augustachronicle.com/story/news/environment/2023/07/27/psc-expert-calls-plant-vogtle-expansion-a-bad-deal-for-georgia-power-ratepayers/70480878007/

[11] See Health Physics Society, "Radiation Benefit and Risk Assessment" at https://hps.org. Accessed July 17, 2023.

rem. But harm to the unborn has been known for decades to occur at doses below 0.5 rem (or 500 millirem).

In fact, in the mid-1950s, Dr. Alice Stewart reported significant increases in the rates of cancer and leukemia in children exposed in utero to one or two pelvic x-rays of their mothers. This 1957 finding shocked nuclear weapons making promoters and medical professionals promoting x-rays who could not believe an effect could be caused by such small doses, less than about 500 millirem. Numerous studies were later conducted that verified the vulnerability of the unborn to external radiation that came from medical x-rays. [12]

External radiation exposure in utero can occur from medical or occupational radiation exposure. Radiation exposure to the child in utero can also occur from internal radiation due to airborne radioactivity inhaled by the mother or ingested from contaminated food, especially milk or water. But cancer and leukemia are not the only adverse health effects to children from ionizing radiation.

In fact, the spread of airborne radioactive contamination from nuclear weapons testing has been found in independent studies to increase infant mortality and other adverse health effects in addition to increasing cancer or leukemia rates.

Modest increases in radioactivity in milk following nuclear weapons testing that contaminated the U.S. or releases from nuclear reactor facilities, spread a variety of radionuclides into the atmosphere to blow in the wind. Rain would enhance the amount of radioactive fallout. Contaminated grass consumed by cows created radioactively-contaminated milk that was consumed by pregnant mothers as well as young children.

The radioactive contamination would often include tritium, strontium-90, cesium-137 and iodine-131 along with other radionuclides. The iodine-131 was most often monitored but that does not mean that other radionuclides were not present.

Radioactive milk, at levels permitted in the U.S, have also been linked to low-birth-weight babies and decreased intelligence.

Preconception radiation doses to either the mother or father can also increase the risk of birth defects. The radiation exposure to the mother's eggs or the father's sperm can occur from external or internal radiation.

It is well documented that congenital malformations increased after the 1986 Chernobyl reactor accident. [13] [14] [15] [16] [17] [18] While elevated rates of birth defects have been observed to occur

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[12] Abel Russ, Casey Burns, Seth Tuler, and Octavia Taylor, *Health Risks of Ionizing Radiation: An Overview of Epidemiological Studies*, A Report by the Community-Based Hazard Management Program, George Perkins Marsh Institute, Clark University, March 2006.

[13] Tom Pacific, *The Medicine Correspondence Blog*, "Authors' reply: Letter to the Editor by Noboru Takamura et al.: Increases in perinatal mortality in prefectures contaminated by the Fukushima nuclear power plant accident," January 12, 2017. https://journals.lww.com/md-journal/Blog/MedicineCorrespondenceBlog/pages/post.aspx?PostID=49

8 to 9 months after the Chernobyl radiation plume passage occurred, closer to the site of the Chernobyl accident, significantly elevated rates of microcephaly, neural tube defects, and microphthalmia were observed in selected regions of Ukraine more than fourteen years after the Chernobyl accident. [19]

Down Syndrome in a common congenital malformation and is a trisomy of the chromosome 21. It is one of the most common chromosome number anomalies. **An increased number of cases of Down Syndrome was observed across Europe 9 months after Chernobyl far from the site of the disaster.** [20] [21] Even in areas of natural radiation from thorium, the rate of Down Syndrome has been found to be elevated. [22] [23] [24]

While the studies of genetic injury to the Japan bombing survivors declared that they found no evidence of genetic damage, other researchers have found those studies to have been highly flawed. A report published in 2016 by Schmitz-Feuerhake, Busby and Pfugbeil summarizes numerous human epidemiology studies of congenital malformations due to radiation exposure. [25]

The 2016 report disputes the International Commission of Radiological Protection (ICRP) genetic risk estimate and finds that diverse human epidemiological evidence supports a far

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[14] G. I. Lazjuk et al., Stem Cells, "Changes in registered congenital anomalies in the Republic of Belarus after the Chernobyl accident, 1997.

[15] V. Zieglowski et al., Mund Kiefer Gesichtschir, [Facial cleft birth rate in former East Germany before and after the reactor accident in Chernobyl], 1999.

[16] H. Scherb et al., *Environmental Science and Pollution Research*, Special Issue, "Congenital Malformation and Stillbirth in Germany and Europe Before and After the Chernobyl Nuclear Power Plant Accident," 2003.

[17] H. Scherb et al., *Mund Kiefer Gesichtschir*, [Cleft lip and cleft palate birth rate in Bavaria before and after the Chernobyl nuclear power plant accident], 2004.

[18] W. Wertelecki, Pediatrics, "Malformations in a Chornobyl-Impacted Region, 2010.

[19] W. Wertelecki et al., *European Journal of Medical Genetics*, "Chornobyl 30 Years Later: Radiation, Pregnancies, and Developmental Anomalies in Rivne, Ukraine," 2017. (See also https://ncjs.us/twin-impacts-of-the-chernobyl-disaster-birth-defects-and-mental-health/)

[20] K. Sperling et al., *Genetic Epidemiology*, "Evidence for an increase in trisomy 21 (Down syndrome) in Europe after the Chernobyl reactor accident, 2012. https://www.unboundmedicine.com/medline/citation/22162022/Evidence_for_an_increase_in_trisomy_21__Down_syndrome__in_Europe_after_the_Chernobyl_reactor_accident_

[21] I. Zatsepin et al., *Reproductive Toxicol.*, "Down syndrome time-clustering in January 1987 in Belarus: link with the Chernobyl accident?" 2007.

[22] N. Kochupillai et al., *Nature* **262,** 60–61, "Down's syndrome and related abnormalities in an area of high background radiation in coastal Kerala," 1976. https://doi.org/10.1038/262060a0 or https://www.nature.com/articles/262060a0#citeas

[23] G. Jaikrishan et al., *Journal of Community Genetics*, "Study of stillbirth and major congenital anomaly among newborns in the high-level natural radiation areas of Kerala, India," August 2012. https://link.springer.com/article/10.1007/s12687-012-0113-1

[24] T. S. Krishnan et al., *Economic & Political Weekly*, "Understanding the Debate – Impact of Natural Background Radiation on Health," September 12, 2020. https://www.epw.in/journal/2020/37/insight/impact-natural-background-radiation-health.html

[25] Inge Schmitz-Feurerhake, Christopher Busby, and Sebastian Pflugbeil, *Environmental Health and Toxicology, Genetic radiation risks: a neglected topic in the low dose debate*, January 20, 2016. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4870760/ The 2016 report found the "excess relative risk for congenital malformations of 0.5 per mSv at 1 mSv falling to 0.1 per mSv at 10 mSv exposure and thereafter remaining roughly constant."

higher genetic risk for congenital malformations. **Nearly all types of hereditary defects were found at doses as low as 100 mrem.** The pregnancies are less viable at higher doses and so the rate of birth defects appears to stay steady or falls off at doses above 1000 mrem or 1 rem. The 2016 report found the excess relative risk for congenital malformations of 0.5 per 100 mrem at 100 mrem falling to 0.1 per 100 mrem at 1000 mrem.

The 2016 report's result for excess relative risk of congenital malformations of 5.0 per rem is 250,000-fold higher than the ICRP estimate of 0.2E-4 per rem which ICRP appears to assume has a linear dose response. (See the August 2021 and July 2023 Environmental Defense Institute newsletters.)

A 2021 study of children in Switzerland found a significant excess of childhood cancer tumors and leukemia from external background radiation. The median radiation dose was under 1 rem, at 0.82 rem (with doses ranging from 0 to 3.12 rem). [26] The earlier study of background radiation effects on children (age 0 to 15) in Switzerland was published in 2015. [27] Exposure to terrestrial and cosmic radiation at the children's place of residence was estimated using aerial gamma measurements. Cesium-137 deposition after the Chernobyl accident was also estimated and included. Excess rates were found for leukemia, central nervous system (CNS) cancer, and all cancers combined. The overall cancer rate excess for Switzerland was estimated for leukemia and CNS tumors due to external background radiation was 32 percent and 34 percent, respectively.

A study of breast cancer in women in the U.S. has consistently shown increases in breast cancer near commercial nuclear power plants or Department of Energy nuclear reactors. [28] The study by Jay M. Gould compared the rate of breast cancer mortality for counties within 50 miles of 51 nuclear reactors from 1950 to 1954 to the rates from 1980 to 1984 and also to 1985 to 1989.

At the Idaho National Laboratory, the breast cancer mortality increase was the highest in the country, an increase of 333 percent for counties within 50 miles of the INL for 1980-84 compared to 1950-54. For three counties near the INL, the increase was 433 percent for these years. The INL had higher breast cancer, using age-adjusted mortality rates, than Hanford or Oak Ridge. Also, near the INL, according to the Idaho Cancer Registry, men also get breast cancer.

Gould found that in the U.S., the risk of dying of breast cancer is significantly greater for women living within 50 miles of a nuclear reactor.

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[26] A. Mazzei-Abba et al., "External background ionizing radiation and childhood cancer: Update of a nationwide cohort analysis," *J Environ Radioact*, November 2021. PMID: 34521026.

[27] Spycher et al, "Background ionizing radiation and the risk of childhood cancer: a census-based nationwide cohort study," *Environ Health Perspect.* 123(6):622-8, 2015. http://pubmed.gov/25707026

[28] Jay M. Gould with members of the Radiation and Public Health Project, Ernest J. Sternglass, Joseph U. Mangano, and William McDonnell, *The Enemy Within – The High Cost of Living Near Nuclear Reactors – Breast Cancer, Aids, Low Birthweights, and Other Radiation-Induced Immune Deficiency Effects*, Four Walls Eight Windows, 1996. ISBN 1-56858-066-5. See pages 131 and 281.

When the nuclear industry depicts what it considers a "safe dose" it usually is not pointed out that public radiation standards do not protect women, children or the unborn developing child. It is long known that women are more vulnerable to radiation health harm than men. And female children are more vulnerable than male children. The studies of the developing child in utero show harm, a doubling of leukemia or cancer rates, from medical radiation doses less than about 500 millirem.

Epidemiology studies of radiation workers is discussed in the next article.

Radiation Worker Epidemiology Findings Still Not Being Heeded

Cancer deaths among radiation workers have been studied over the years and continue to show significantly higher cancer rates than official radiation protection assumptions used in the nuclear industry.

The most recent study of radiation workers is the 2015 INWORKS study of 308,297 radiation workers in the nuclear industry in the United States, France and the United Kingdom. [29] [30] The INWORKS study by Richardson found that the cancer rate was much higher than is typically presumed by the Department of Energy and others. It is important to understand that these workers were adults and were predominantly male. Women (and children) have cancer incidence and cancer fatality rates from radiation exposure exceeding the rates for adult males.

Radiation workers in the U.S. are individually monitored and generally have both low doses (generally less than 10 rem cumulative dose) and low dose rate (meaning that the exposure is spread out over time).

Epidemiology of radiation workers by Richardson remains ignored by the Idaho National Laboratory and the Department of Energy. Epidemiology by Richardson of thousands of nuclear workers in general would find that annual radiation doses for workers averaging about 400 millirem per year showed increased rates of cancer. Excuses have been given for ignoring this study of a large population of radiation workers since this study came out in 2015.

The INWORKS study found the cancer fatality rate for radiation workers to be 47E-4 fatal cancers per rem. The median colon dose was only 410 mrem. The whole-body dose from radiation badges were evaluated for gamma penetration in order to estimate the colon dose. An

[29] David B. Richardson et al., "Risk of cancer from occupational exposure to ionizing radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS), BMJ, v. 351 (October 15, 2015), at http://www.bmj.com/content/351/bmj.h5359 Richardson et al 2015] doi: 10.1136/bmj.h5359. (This cohort study included 308,297 workers in the nuclear industry. Also, please note that studies of high leukemia risk in radiation workers and of ongoing studies to assess health effects of high and low-linear energy transfer internal radiation must also be studied in addition to this one on external radiation.)

[30] David B. Richardson et al. Department of Epidemiology, University of North Carolina, Chapel Hill, North Carolina, "Site-specific Solid Cancer Mortality After Exposure to Ionizing Cohort Study of Workers (INWORKS)," *Epidemiology*, January 2018. PMC 2019 January 01.

earlier study of radiation workers from 15 countries found an even higher result of 97E-4 fatal cancers per rem. [31]

In recent Department of Energy environmental impact statements, the cancer rate (for solid cancer and leukemia combined) used was 6.0E-4 fatal cancers per rem, although the Department of Energy has used lower estimates such as 1.2E-4 fatal cancers per rem. Furthermore, these official dose rates used by DOE have been divided in half based on the hopeful assumption and despite the lack of human evidence that low dose and low dose rate would reduce the risk derived from acute radiation doses, predominantly based on the study of atomic bombing survivors from the 1945 bombing of Hiroshima and Nagasaki.

The Department of Energy and other nuclear boosters continue to disbelieve the higher fatal cancer rate from INWORKS, of 47E-4 fatal cancers per rem, that is nearly 8 times higher than what DOE has assumed, of 6.0E-4 fatal cancers per rem.

Neither the INWORKS study of nuclear workers in the US, France and UK nor the earlier 15-country study has been accepted by the Department of Energy.

Likely there is some degree of understated radiation doses to these workers, which would have the affect of inflating the cancer rate per rem. But the nuclear industry has always claimed and continues to claim that its radiation dose monitoring is adequate.

Radiation monitoring of workers requires radiation badge readers to be calibrated for the actual energy levels of gamma and beta exposure. For facilities that have a variety of operations that vary from day to day, this is problematic and could cause the underestimation of radiation doses based on TLD badges. Facilities can also easily bias the badge readers downward, to make doses all appear smaller. In addition, the occasional higher radiation doses can be deleted in order to make the operation appear compliant even when it wasn't.

Unmonitored internal dose from elevated airborne contamination could also be part of the effect. At Idaho National Laboratory facilities, the radioactivity of the drinking water has also been elevated, more so prior to the late 1990s.

But official dose estimate modeling would likely predict that these internal radiation exposures contributed only a small amount to the worker's radiation dose and can be neglected. However, the actual harm from internal radiation in humans may be larger than official models predict.

Also ignored is that radiation workers also tend to live near the nuclear facilities and so they are getting airborne radionuclide contamination at their homes and in their food and water, which is not accounted for. The assumption that the chronic doses from air, water and food are insignificant has not actually been tested in humans and still remains an assumption, even now in 2023.

[31] E. Cardis et al., *Radiat Res.*, "The 15 country collaborative study of cancer risk among radiation workers in the nuclear industry: estimates of radiation-related cancer risks," 2007;167(4):396-416. PubMed 17388693.

The meta-analysis of excess cancer rates from a 2020 study, for solid cancers in adults, estimated 29E-4 to 55E-4 fatal cancers per rem. [32] [33] This is in line with the INWORKS study result for solid cancer rate of 47E-4 fatal cancers per rem.

The 2020 meta-analysis study also compared its results for cancer to the study of atomic bomb survivors of Hiroshima and Nagasaki, stating cancer rates from the Life Span Studies for males as 27E-4/rem and for females as 64E-4/rem. (These values were slightly higher than the estimates from a 2007 study of atomic bomb survivors for solid cancer incidence. [34])

Studies from recent decades find higher cancer rates than currently being used by the Department of Energy in their environmental impact statements. The Department of Energy has recently used the cancer rate of 6.0E-4/rem cancer fatality risk, that appears nearly 10-fold too low. In addition, women, children and the unborn are disproportionately harmed.

The Department of Energy continues to assume that doses below 10 rem are half of the risk of doses above 10 rem despite growing evidence of how wrong this assumption is.

The fact is, the Department of Energy, the U.S. Nuclear Regulatory Commission and others continue to underestimate the cancer risk to radiation workers and the public (as well as ignore the wider range of adverse health effects).

During the period 1950 to 2003, 58 percent of the 86,611 Life Span Study (LSS) have died. There were 58 percent more cancer deaths in those who were under 10 years of age during the bombing. A 2012 study found that the gender-averaged excess risk was 42E-4 per rad. **Significant excess solid cancer risk was found for estimated radiation doses between 0 and 20 rad, and the study concluded that a formal dose-threshold analysis indicated no threshold. A dose of zero was the best estimate of the threshold.** [35]

The incidence of leukemia, lymphoma, and multiple myeloma among atomic bomb survivors was reported in a 2013 study. [36] Although the leukemia excess risks generally declined with time since exposure, there was evidence that radiation-associated excess leukemia risks, especially for acute myeloid leukemia, had persisted throughout the follow-up period, 55 years after the bombings. The LSS leukemia risk at 10 rem, for males and females combined, was 80E-4 leukemia fatality per rem from the 2013 LSS study.

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[32] Amy Berrington de Gonzalez et al., *J. Natl Cancer Inst Monogr.*, "Epidemiological Studies of Low-Dose Ionizing Radiation and Cancer: Rationale and Framework for the Monograph and Overview of Eligible Studies," July 2020 (56): 97-113. PMID: 32657348. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7610154/

[33] Ethel S. Gilbert PhD, et al., *J. Natl Cancer Inst Monogr.*, "Issues in Interpreting Epidemiologic Studies of Populations Exposed to Low-Dose, High-Energy Photon Radiation," 2020. Doi: 10.1093/jncimonographs/Igaa004.

[34] D. L. Preston et al., *Radiat Res.*, "Solid cancer incidence in atomic bomb survivors: 1958-1998." 2007. https://pubmed.ncbi.nlm.nih.gov/17722996/ For adults exposed at age 30, the solid cancer incidence rate was 35E-4 per rad for men and 58E-4 per rad for women.

[35] Kotaro Ozasa et al, *Radiat Res.*, "Studies of the mortality of atomic bomb survivors, Report 14, 1950-2003; an overview of cancer and noncancer diseases," 2012. https://pubmed.ncbi.nlm.nih.gov/22171960/

[36] Wan-Ling Hsu et al., *Radiat Res.*, "The incidence of leukemia, lymphoma, and multiple myeloma among atomic bomb survivors: 1950-2001." 2013. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3875218/

The meta-analysis from 2020 [37] predicted twice that rate, 160E-4 leukemia fatality per rem. These leukemia excess relative rates are higher than the estimates from the 2006 BEIR report that have been widely used by the nuclear industry.

INWORKS study of radiation workers in three countries found the excess risk of leukemia mortality (excluding chronic lymphocytic leukemia) was 296E-4 fatal leukemias per rad, lagged 2 years. This is higher than the 2020 meta-analysis result (160E-4 leukemia fatality per rem) and almost 4 times higher than the LSS result of 80E-4. The 2015 INWORKS study stated: This study provides strong evidence of positive associations between protracted low-dose radiation exposure and leukemia. [38]

There has been no valid reason for the Health Physics Society, the Department of Energy or the Nuclear Regulatory Commission to ignore the higher cancer rates predicted by the 2015 INWORKS study and by other studies.

The 2020 meta-analysis is a main-stream study conducted with support from the National Cancer Institute, National Institutes of Health and by the Department of Energy. This study refutes many of the claims by the Health Physics Society.

The early expectation that low doses, delivered over time instead of all at once, would significantly reduce the health harm. The Health Physics Society still clings to that mistaken belief. It just doesn't happen to be true and Dr. John Gofman recognized that back in 1981. [39]

The fact is that radiation health harm is detected at doses below 10 rem even for doses received in increments. Little human evidence has been found for a threshold radiation dose even for doses as low as 100 millirem.

One has to wonder, when will they ever learn? Workers and the public are not being protected by the agencies responsible for these nuclear operations and the excuses made for not heeding what has been learned are revealing a scandalous disregard for human health.

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[37] Amy Berrington de Gonzalez et al., *J. Natl Cancer Inst Monogr.*, "Epidemiological Studies of Low-Dose Ionizing Radiation and Cancer: Rationale and Framework for the Monograph and Overview of Eligible Studies," July 2020 (56): 97-113. PMID: 32657348. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7610154/

[38] Klervi Leuraud et al., *Lancet Haematol*, "Ionising radiation and risk of death from leukaemia and lymphoma in radiation-monitored workers (INWORKS): an international cohort study," 2015. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4587986/

[39] John W. Gofman, M.D., Ph.D., *Radiation and Human Health*, Sierra Club Books, 1981. ISBN 087156-275-8

Radiation Worker Inhalation at the Columbia Generating Station and Other Safety Issues

An unplanned radiation worker inhalation occurred at the nuclear power plant in Washington state, the Columbia Generating Station. Multiple workers' exposure to airborne radiological contamination occurred on May 28, 2021 at Energy Northwest's Columbia Generating Station. [40]

Subsequent investigation by the U.S. Nuclear Regulatory Commission questioned whether the internal radioactive exposures were correctly measured. Urine samples were only taken once, and no fecal analysis was conducted. An adequate determination of all radionuclides that may have been inhaled was not conducted. There was no air sampling in the workers' breathing space. Importantly, alpha emitters such as plutonium were ignored.

Worker radiation exposures are typically evaluated by in-house Certified Health Physicists, trained by the Health Physics Society. The Health Physics Society, according to their website, continues to ignore the evidence of health harm at radiation doses below 10 rem.

Nuclear workers in the U.S. are permitted to receive an annual dose of 5 rem. Stated policies may be to limit planned doses to less than 2 rem annually, but this is not enforceable. The industry has refused to lower the annual radiation limits because it may be inconvenient for certain repair work on nuclear reactors.

The NRC investigation found that the procedures to address the airborne contamination were inadequate. Energy Northwest did not have the equipment or personnel available to address the contamination or assess the dose within workers' bodies, according to the NRC.

How are operations at the Columbia Generating Station overall? Well, the utility promises to lower the estimated radiation doses for the overexposed workers. And the NRC soft-petaled serious safety deficiencies in the Columbia Generating Station, including failure to understand and prevent causing the failure of the boiling water reactor's containment system. [41]

Columbia Generation Station failed to implement an existing procedure and this resulted in a challenge to primary containment. This means that had an accident occurred, the fission products would have been released to the environment from the reactor containment. "The associated pressure changes were neither monitored adequately nor established as a key parameter [for operators in the control room to follow]."

The U.S. Nuclear Regulatory Commission soft-petaled the problem, but compromising primary containment has serious implications during accident conditions and the Columbia Generating Station is supposedly a mature operation.

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[40] Annette Cary, *Tri-City Herald*, "NW nuclear plant failed to properly measure workers' radioactive exposure, report says," June 6, 2023.

[41] U.S. Nuclear Regulatory Commission letter to Robert Schuetz, Energy Northwest, Subject: Columbia Generating Station – Integrated Inspection Report 05000397/2023001, May 5, 2023. https://nrc.gov/adams/ML2312/ML23122A076

On the 78th anniversary of the U.S. atomic bombing of Hiroshima and Nagasaki, what has been learned about excess rates of leukemia from ionizing radiation?

Within just two to three years following the atomic bombing of Japan cities of Hiroshima and Nagasaki in 1945 during World War II, increases in the cases of childhood leukemia were noticed. The Leukemia Registry program was begun in the late 1940's and remained active until the late 1980's when it was supplanted by area cancer registries. The formal study of elevated cancer and leukemia rates of bombing survivors began in 1950.

Ionizing radiation is now a known cause of leukemia, based on studies of the study of the bombing survivors and certain studies of patients exposed to medical radiation.

Through the years, several studies of Japan's survivors of the 1945 atomic bombing have been published, focusing mainly on solid cancers and on leukemia. [42] A recent leukemia study of the bombing survivors by Hsu and others was published in 2013, that followed the survivors from 1950 through 2001. [43]

There are many disease types included as leukemia. Major types of hematopoietic malignancy include: acute lymphoblastic leukemia, acute myeloid leukemia, chronic myeloid leukemia — which are considered to be caused by ionizing radiation — and several varieties of leukemia lacking consensus as to whether or not radiation exposure is a cause: chronic lymphocytic leukemia, adult T-cell leukemia, Hodgkin lymphoma, non-Hodgkin lymphoma, and multiple myeloma.

Chronic lymphocytic leukemia is rare among the Japanese was not usually observed and Hodgkin lymphoma and multiple myeloma are stated as not observed in the 2013 study of bombing survivors by Hsu.

While leukemia is more rare than solid cancers, the latency for leukemia cases from radiation can occur within 2 years of exposure. The bulk of the leukemia cases tend to occur earlier, within 15 years of exposure, with fewer cases in later years. Cases of acute myeloid leukemia, however, have persisted, even 55 years after the atomic bombings of Japan.

The observation of elevated rates of leukemia, early on, is a recognized sign of radiation exposure. Excess cases of childhood leukemia were observed in Utah following Nevada Weapons Testing the commenced in the 1950s, and the Atomic Energy Commission, later to become the Department of Energy suppressed the reporting of excess childhood leukemia. While the overall number of cases of leukemia was small, leukemia is often fatal and occurs younger in life.

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[42] D. L. Preston et al., *Radiat Res.*, "Solid cancer incidence in atomic bomb survivors: 1958-1998," 2007;168(1):1-64.

[43] Wan-Ling Hsu et al., *Radiat Res.*, "The incidence of leukemia, lymphoma, and multiple myeloma among atomic bomb survivors: 1950-2001." 2013. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3875218/

The study of Japan's atomic bombing survivors who were exposed to the atomic bombings in 1945 has been called the "Gold Standard" for understanding radiation exposure. However, there have been now three different versions of the estimated radiation doses from the bombings. Experts have argued that linear extrapolation of the excess cancer risks over-estimated the risk at doses under about 10 rem. The funding for these reports has typically been from governmental support that has sought to obtain low association of rates of disease with radiation exposure so that nuclear power plants and nuclear weapons development could proceed unfettered.

John Gofman studied many of the early problems of analyzing Japan's bombing survivors and the errors being made in the early studies. [44] [45] His concern about human health and willingness to communicate his honest assessment of radiation health harm cost him his position with the Atomic Energy Commission.

There are numerous serious problems with the studies of the Japanese bombing survivors that lower the estimated radiation risks. First, the studies did not begin until 5 years after the bombings and this means that only the healthiest survivors were included in the study. The radiation dose estimates for the survivors are not based on any measurements and have been subjected to various revisions. Dose estimates were made in 1965, 1985 and again in 2002, often lowering the cancer risk from ionizing radiation.

There is evidence of substantial but never reported radiative fallout from the atomic bombing of Japan that exposed both the bombing survivors and the people studied as the "control" who were not directly exposed to the bombings (see Gofman, 1981, page 672). Chromosome aberrations, measured in cultured peripheral blood samples, in 1967-1968 found chromosome aberrations indicating higher doses than estimated for people more than 2.4 kilometers from the bombing, who had been assumed to have received less than 1 rad. This creates serious problems for the study of bomb survivors, particularly as low doses. The people presumed to be in the zero-dose category did not have zero dose. So, while many of Japan's bombing survivors were exposed to a wide range of radiation doses, from less than 5 rad to over 200 rad doses of external gamma radiation, the control case population also had radiation exposure to radiative fallout from the bombings that was not reported.

The study of Japan's atomic bombing survivors highlighted the vulnerability of women to radiation exposure, particularly due to breast cancer mortality and the elevated rates of cancer of children due to radiation exposure at early age. Some of these lessons were captured by the National Research Council BEIR VII report issued in 2006. [46] (See the Institute for Energy and

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[44] John W. Gofman, M.D., Ph.D., *Radiation and Human Health*, Sierra Club Books, 1981. ISBN 087156-275-8

[45] John W. Gofman, M.D., Ph.D., Committee for Nuclear Responsibility, Inc., *Radiation-Induced Cancer from Low-Dose Exposure: An Independent Analysis*, 1990.

[46] "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 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

Environmental Research (IEER.org) report, *Science for the Vulnerable,* for additional insight. [47] See also the August 2020 Environmental Defense Newsletter at Environmental-Defense-Institute.org.) However, the BEIR VII report advises dividing the cancer rates observed above 10 rem by a factor 1.5. The practice of dividing the health risks for doses below 10 rem has never been supported by human evidence and now further evidence has been gathered that show how wrong-headed this assumption was.

It is important to also understand that the instantaneous radiation from the bombings (an external radiation exposure) does not provide adequate data for chronic exposures to radiation or to internal radiation exposure typical of radioactive fallout from nuclear weapons tests and nuclear reactor accidents. There is evidence of serious and detectable harm to the unborn child in utero from internal radiation from contaminated air, water and/or food consumed by the mother.

There are serious shortcomings from the study of Japan's bombing survivors when trying to understand the full effects of chronic radiation exposure to parents, to the developing child in utero, and to children. The study of Japan's bombing survivors is designed to distinguish the effect of the flash of the bombing from the later effects of both the survivors and the controls living in radioactive contamination – which was never disclosed. Birth defects and preconception doses to mothers or fathers are also difficult to study and unreliable due to the study of the 1945 bombings not beginning until 1950.

The population of the bombing survivors included all ages of people and both males and females. **The doses ranged from 10 rad to 400 rad; however, more than 60 percent of the Japanese bombing survivors had radiation doses below 10 rad.** [48]

In the article by Gilbert in 2009, it was stated that, based on a report by Preston in 2004, [49] of the 87,000 people studied, there had been 204 total deaths from leukemia in survivors (by 1998) with doses of 0.5 rad of more. "Forty-six percent of the leukemia deaths were estimated to be related to radiation."

The 2009 article by Gilbert presented the leukemia excess relative rate per unit radiation dose for male atomic bombing survivors, exposed between the age of 20 and 60 years. The leukemia ERR was 150E-4/rad.

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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.

[47] Arjun Makhijani, Ph.D., Brice Smith, Ph.D., Michael C. Thorne, Ph.D., Institute for Energy and Environmental Research, *Science for the Vulnerable Setting Radiation and Multiple Exposure Environmental Health Standards to Protect Those Most at Risk*, October 19, 2006.

[48] Ethel S. Gilbert, *Int J Radiat Biol.,* "Ionizing Radiation and Cancer Risks: What Have We Learned From Epidemiology?" 2009. Doi:10.1080/09553000902883836.

[49] D. L. Preston et al., *Radiation Research*, "Solid cancer incidence in atomic bomb survivors: 1958 – 1998, 2007. PubMed:177229996

The meta-analysis conducted in 2020 [50] cited a more recent 2013 study of the atomic bombing survivors as having the leukemia excess relative rate of 80E-4/rad for males and females combined, with exposure occurring after age 30. [51] However, the 2013 study included other higher estimates: leukemia excess relative rate of 278E-4/rad for males and females exposed at age 25 with follow-up to age 60, and leukemia excess relative rate of 204E-4/rad for males exposed at age 25 with follow-up to age 50.

The INWORKS study of adult radiation workers in three countries, mostly men, found the association between radiation dose and mortality from leukemia to be 296 E-4 fatal leukemias per rad. [52] The 2015 INWORKS study stated: This study provides strong evidence of positive associations between protracted low-dose radiation exposure and leukemia.

Gofman conducted an independent analysis in 1981 of atomic bombing survivors and estimated leukemia rates higher than government funded LSS studies see Table 1.

Table 1. Comparison of excess relative rates for leukemia due to radiation, selected studies.

Study	ERR/rad for leukemia
Preston, 2004 (cited by Gilbert 2009) for males exposed between the ages of 20 and 60 years.	150 E-4/rad
Nuclear Workers in 15 countries, Cardis, 2007 (cited in Gilbert 2009)	190 E-4/rad
Hsu, 2013 (cited by 2020 meta-analysis) for males and females combined, exposure after age 30	80 E-4/rad
Hsu, 2013 for males exposed after age 25	204 E-4/rad
Hsu, 2013 for males and females combined, exposed at age 25	278 E-4/rad
INWORKS, 2015 study of nuclear workers (adults) that are predominantly male	296 E-4/rad
Gofman, 1981, page 664, males and females combined, age 20 to 34 year old at exposure	870 E-4/rad

Table notes: The unit of rad represents absorbed dose. 1 Gray is equal to 100 rad. For external radiation 1 rad may be 1 rem for an organ dose.

[50] Amy Berrington de Gonzalez et al., *J. Natl Cancer Inst Monogr.*, "Epidemiological Studies of Low-Dose Ionizing Radiation and Cancer: Rationale and Framework for the Monograph and Overview of Eligible Studies," July 2020 (56): 97-113. PMID: 32657348. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7610154/

[51] Wan-Ling Hsu et al., *Radiat Res.*, "The incidence of leukemia, lymphoma, and multiple myeloma among atomic bomb survivors: 1950-2001." 2013. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3875218/

[52] Klervi Leuraud et al., *Lancet Haematol*, "Ionising radiation and risk of death from leukaemia and lymphoma in radiation-monitored workers (INWORKS): an international cohort study," 2015. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4587986/

During World War II, many thousands of people were in an extremely high stress situation and probably alcohol consumption increased. But only in the two cities exposed to atomic bombings were elevated leukemia rates noted. This should be kept in mind when the elevated rates of leukemia cases followed the Three Mile Island nuclear reactor accident in March 1979, which were attributed to "stress." [53] [54]

Three Mile Island, Recent Meta-Analysis Inadvertently Highlights Three Mile Island Epidemiology Problems

This is Part 4 of a series about the 1979 Three Mile Island Accident. See the earlier Parts in the May, June, and July 2023 Environmental Defense Institute newsletters.

I came across a 2020 meta-analysis of low dose and low dose rate epidemiology that included a new 2011 Three Mile Island epidemiology study. [55] The 2020 meta-analysis is a main-stream study conducted with support from the National Cancer Institute, National Institutes of Health and by the Department of Energy. The 2011 TMI study is not publicly available without charge, and so I did not obtain full access to the study. [56]

However, the results of the 2011 TMI epidemiology cited in the 2020 meta-analysis, when compared to other radiation studies reveals obvious problems, particularly with the leukemia risk.

Using an earlier study of TMI epidemiology, some raw figures on the cancer and leukemia rates within a 10-mile radius of the accident are provided in Table 2.

For five years before the March 1979 accident (1975 through March 1979) and for five years after the accident (1981 through 1985), the numbers of cancer and leukemia cases are provided below in Table 2. Just look at how case numbers increased after the TMI accident.

The number of cases in the five years before the accident compared to the number of cases from 1981 through 1985, that included a 2-year lag time, reveal significantly elevated numbers of cancers and leukemias.

The 1990 and 1991 study of the Three Mile Island epidemiology studied a 10-mile radius around the reactor. It subdivided regions according the weather patterns, topography and elevation to estimate where the highest radioactive fallout from the accident would be received

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[53] Maureen C. Hatch, PhD, Sylvan Wallenstein, PhD, Jan Beyea, PhD, Jeri W. Nieves, MS, and Mervyn Susser, MB, BCh, American Journal of Public Health, "Cancer Rates after the Three Mile Island Nuclear Accident and Proximity of Residence to the Plant," June 1991.

[54] Maureen C. Hatch, PhD, Jan Beyea, Jeri W. Neives and Mervyn Susser, MB, BCh, American Journal of Epidemiology, "Cancer Rates after the Three Mile Island Nuclear Accident: Radiation Emissions," September 1990.

[55] Amy Berrington de Gonzalez et al., *J. Natl Cancer Inst Monogr.*, "Epidemiological Studies of Low-Dose Ionizing Radiation and Cancer: Rationale and Framework for the Monograph and Overview of Eligible Studies," July 2020 (56): 97-113. PMID: 32657348. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7610154/

[56] YY Han, AO Youk, H Sasser, et al., Environ Res., "Cancer incidence among residents of the Three Mile Island accident area: 1982-1995," 2011;111(8):1230-1235.

by wind patterns following the accident. The studies, while acknowledging the lack of reliable monitoring of radioactivity, the authors fully accepted the statements that the releases had been minimal and that the maximum dose had been below 100 millirem external dose. The stated the average radiation exposure was just 10 millirem (page 403 of Hatch, 1990).

Table 2. Selected cancer and leukemia case numbers five years before and five years after the March 1979 Three Mile Island nuclear accident.

Grouping	1 - Lowest fallout	2 - Next to lowest fallout	3 - Next to highest fallout	4 - Highest fallout	
Age, 0-24 years	Childhood Cancers				Total cases
1975-1979	17	1.3	8.7	6	31.83
1981-1985	17	13	12	5	47
Age, 0-24 years	Childhood Leukemia				
1975-1979	1	0	0	0	1
1981-1985	1	0	2	1	4
Age, 25 years or above	Adult Leukemia				
1975-1979	7.8	11.2	6	2	27
1975-1979	14.1	16.3	11.6	7	49
Age, 0-24 years	All Cancers				
1975-1979	538.6	525.5	403.8	254.1	1722
1981-1985	845.9	874.8	707.4	401.8	2829.9
Age, 0-24 years	Lung Cancer				
1975-1979	45.1	63.2	50.7	35	194
1981-1985	88.2	137.4	120.5	93.9	440

Table notes: Data based on Maureen C. Hatch, PhD, Jan Beyea, Jeri W. Neives and Mervyn Susser, MB, BCh, American Journal of Epidemiology, “Cancer Rates after the Three Mile Island Nuclear Accident: Radiation Emissions,” September 1990. Fractional case numbers are from splitting a case into different study tracts when the correct tract was not known. Cases in 1975 known to be undercounted in hospital records. The “all cancers” data include the lung cancers presented here.

The more recent 2011 TMI epidemiology study has raised the maximum dose to the public to 210 millirem, but retains the 10 millirem mean dose.

The study of Three Mile Island epidemiology funded by the Three Mile Island Public Health Fund, a court-supervised fund, made a number of biased decisions in how it treated the data and arrived at its conclusions. The improperly low 1975 case numbers, from hospital data problems, were improperly utilized to create a rate change that would minimize the effect of the 1979 accident. The study authors in the 1991 TMI study by Hatch [57] noticed the steep rise in cancer cases in 1982 in regions receiving the highest radiation doses from the accident. The study noted that the cancer rates by 1982 were clearly elevated, nearby the plant. But by 1984, the cancer rates had fallen to preaccident levels. The elevated cancers and leukemias were then attributed to "stress" and many statements were made asserting that stress might be a plausible cause of the elevated cancers and leukemias. Radiation was soundly dismissed as a cause of the elevated rates of cancer and leukemia cases.

The 1990 and 1991 epidemiology studies ruled out radiation as a possible cause of elevated rates of leukemia and cancer near the Three Mile Island plant.

The BEIR VII report from 2006 estimated the leukemia incidence rate from ionizing radiation for adult males as 1.0E-4/rem, and for the 0.01 rem average dose, this would yield less than one excess leukemia case.

0.01 rem * 160,000 people living within 10 miles of TMI * 1.0E-4/rem = 0.16 leukemias.

So, experts may not have expected an increase in leukemia cases from the 1979 Three Mile Island accident.

But higher excess rates for leukemia have been found in various studies, including the studies of adult, predominantly male, nuclear workers. Healthy adults are less vulnerable to ionizing radiation than children and the elderly. The meta-analysis from 2020 [58] estimated ionizing radiation to cause 160E-4 leukemia fatalities per rem for adult exposure. This is 160 times higher than the 2006 BEIR VII report for leukemia in adult males.

0.01 rem * 160,000 people living within 10 miles of TMI * 160E-4 leukemia/rem = 25.6 leukemia cases. (Here leukemia incidence and mortality are mixed but most leukemias are fatal.)

Interestingly, during the brief follow-up 1981-1985 around TMI, the excess cases of adult leukemia was 22 cases. So, the experts who were claiming that no elevated rates of cancer would be expected following the TMI accident not only did not have a reliable radiation dose estimate, they also had low estimated rates of leukemia from radiation exposure.

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[57] Maureen C. Hatch, PhD, Sylvan Wallenstein, PhD, Jan Beyea, PhD, Jeri W. Nieves, MS, and Mervyn Susser, MB, BCh, American Journal of Public Health, "Cancer Rates after the Three Mile Island Nuclear Accident and Proximity of Residence to the Plant," June 1991.

[58] Amy Berrington de Gonzalez et al., *J. Natl Cancer Inst Monogr.*, "Epidemiological Studies of Low-Dose Ionizing Radiation and Cancer: Rationale and Framework for the Monograph and Overview of Eligible Studies," July 2020 (56): 97-113. PMID: 32657348. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7610154/

The 2020 meta-analysis of the excess relative risk (ERR) for leukemia for adults based on exposures near 10 rad (or 100 mGy) is depicted (very roughly) below, and is converted to ERR per rem, (see Figure 2 from the meta-analysis). **The 2020 meta-analysis estimate for excess leukemia rates for adults is 160E-4/rad. The 2020 meta-analysis estimate of excess leukemia rates for children based on exposures near 10 rad is 2840E-4 per rad.**

What was obscured by the presentation in the 2020 meta-analysis is just how oddly high the ERR for Three Mile Island is for leukemia. **The excess relative risk (ERR) per rad for Three Mile Island is 19,000E-4 per rad, over 6 times greater than the 2020 meta-analysis [59] value and the values for radiation workers, see Table 3.**

Table 3. Selected excess relative rates values for leukemia from the 2020 meta-analysis.

Selected ERR Values per rad	0	1.0	2.0
Three Mile Island, ERR 1.9 (-0.3, 4.5)	XXXXXXXXXXXXXXXXXXXXXX		
United Kingdom NRRW (nuclear workers), ERR 0.05 (-.0006, 0.05)	X		
US nuclear workers, ERR 0.017 (-0.002, 0.047)	X		
French nuclear workers, ERR 0.035 (0.000, 0.16)	X		
Meta-analysis for leukemia (adults) ERR = 0.016 (0.007, 0.025)/rad	X		
Meta-analysis for leukemia (children) ERR = 0.284 (0.037, 0.532)	XX		

Table notes: Excess relative rate (ERR). The confidence interval is given in parentheses. For comparison to other ERRs, the ERR of 1.9/rad is equivalent to 19,000E-4/rad. The ERR of 0.016/rad is equivalent to 160E-4/rad. The ERR of 0.284/rad is equivalent to 2840E-4/rad.

The 2020 meta-analysis estimate of excess leukemia rates for children exposed to about 10 rem or less is 2840E-4 per rad. **Yet, the ERR for leukemia for the public exposed to the Three Mile Island radiological releases was 19,000 E-4 leukemia cases per rad. The 2020 meta-analysis is silent on the disparity.**

[59] Amy Berrington de Gonzalez et al., *J. Natl Cancer Inst Monogr.*, "Epidemiological Studies of Low-Dose Ionizing Radiation and Cancer: Rationale and Framework for the Monograph and Overview of Eligible Studies," July 2020 (56): 97-113. PMID: 32657348. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7610154/

The 2020 meta-analysis mixes leukemia incidence and fatality, but this is less of a problem for leukemia than for cancers because leukemia is often fatal. The mixing of adult populations with all age populations is more problematic.

The doses for the radiation workers were modest, and the overall mean red bone marrow dose to radiation workers was only 1.59 rad. The dose at skin surface would be higher, perhaps twice as high, or 3 rad. The median dose for nuclear workers was only 0.21 rad red bone marrow dose, so the median dose was roughly 0.42 rad. This is in contract to the stated very low average dose of 10 millirem (or 0.01 rem) for Three Mile Island.

Nuclear promotors have said that no leukemia excess would occur from the Three Mile Island accident. Nuclear promotors are still claiming that despite the elevated cases of cancers and leukemias that occurred, that "no one died from TMI."

The 2020 meta-analysis also shows an oddly high the ERR for Three Mile Island solid cancer data from the 2011 TMI epidemiology. The ERR was negative but the upper bound was very high. Just how the 2011 TMI epidemiology lowered the cancer ERR isn't clear. It is very unfortunate that the 2020 meta-analysis excluded relevant studies of childhood cancer, some of which were published prior to the arbitrary cutoff date used in the meta-analysis.

The 1979 Three Mile Island accident released airborne radioactivity and the biased "guesstimated" estimated doses were only based on the assumption of external (shine) doses and not inhalation of radioactive particles, as may have actually been the case due to the low cloud ceiling and slow wind speeds during part of the release.

During World War II, many thousands of people were in an extremely high stress situation and probably alcohol consumption increased. Cigarette use was also high. But following World War II, only in the two cities exposed to atomic bombings were elevated leukemia rates noted and this was noted before 1950. This should be kept in mind when the elevated rates of leukemia cases followed the Three Mile Island nuclear reactor accident in March 1979, were suggested to be attributed to "stress" and elevated use of alcohol and cigarette smoking. [60] [61]

Based on the 2020 meta-analysis, whatever was released from the Three Mile Island nuclear accident packed a leukemia-causing impact far higher than what nuclear workers are exposed to and far higher than the meta-analysis estimate for leukemia cases from childhood exposure. The Three Mile Island case included both genders and all ages, unlike the nuclear workers which were adults and predominantly male.

[60] Maureen C. Hatch, PhD, Sylvan Wallenstein, PhD, Jan Beyea, PhD, Jeri W. Nieves, MS, and Mervyn Susser, MB, BCh, American Journal of Public Health, "Cancer Rates after the Three Mile Island Nuclear Accident and Proximity of Residence to the Plant," June 1991.

[61] Maureen C. Hatch, PhD, Jan Beyea, Jeri W. Neives and Mervyn Susser, MB, BCh, American Journal of Epidemiology, "Cancer Rates after the Three Mile Island Nuclear Accident: Radiation Emissions," September 1990.

Subsequent FISH DNA damage testing conducted 15 years after the accident for 29 people who were vomiting the day of the accident suggested radiation doses far higher: 50 to 90 rem. [62] However, determination of the accident dose via the FISH DNA is likely complicated by the need for calibration for living in contaminated areas and receiving chronic radiation doses. The update of plutonium and/or americium into bone tissue is highly retained and is providing a life-long chronic dose even from a single intake. The alpha radiation damage is ongoing and there was no monitoring of the alpha radiation release from Three Mile Island or from other nuclear weapons testing that affected Pennsylvania.

Steve Wing's 1997 study found that the most highly contaminated regions near Three Mile Island consistently had the highest increases in cancer and leukemia rates. These regions were not previously identified prior to or during the accident and were unique to the wind dispersion patterns during the accident. The stress levels for people living near the plant were certainly elevated, but there was no way for the residents to know which geographical areas were to be the hardest hit.

The leukemia uptick being due to stress as asserted in lengthy conjecture by epidemiology funded by the TMI Health Fund is an example of how not to conduct epidemiology. Honest assessment of cancer and leukemia increases around Three Mile Island should never have ruled out radiation from the accident as being the cause of the elevated rates of cancer and leukemia.

With the excess leukemia rate for Three Mile Island's 1979 accident far above that of any other radiation epidemiology study, it would indicate that if stress was the cause as asserted in previous studies, it was stress unlike anything humans have experienced in the last 80 years.

Or, could it be that the utility and the Nuclear Regulatory Commission low-balled the guesstimates of the radiological release from the accident that they failed to prevent.

Articles by Tami Thatcher for August 2023.

[62] 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.