ALARA is a Show Stopper

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Through 1951, the International Commission on Radiological Protection (ICRP) dose rate limit for the general public was 2 mSv/d. However, in 1951, the ICRP changed the recommended limit to 3 mSv/week. This was based on claims of genetic mutations at low doses which turned out to have no foundation.[1] In 1957, the American counterpart of the ICRP, the National Council for Radiation Protection(NCRP), added a limit of 50 mSv/y for nuclear workers and 5 mSv/y for the public. As the NCRP itself acknowledged, this humongous change, a reduction of 30, was not based on any new data.

> The changes in the accumulated MPD [Maximum Permissible Dose] are not the result of positive evidence of damage due to use of earlier permissible dose levels but rather are based on the desire to bring the MPD into accord with the trends of scientific opinion.[14, page 1]

Opinion trends that are not based on data are hardly scientific.

Lauriston Taylor's first hand history, reference [19], makes it clear that the "opinion trends" at the time were still dominated by Muller's theory of genetic hazard, a hypothesis already contradicted by Caspari's fruit fly results and Neel's 70,000 pregnancy bomb victim data.

Taylor points out that, before issuing the new recommendations, the NCRP checked with the AEC to find out what dose rates the AEC workers were actually receiving.[19][p 47] They were told the workers rarely exceeded 15 mSv/y.

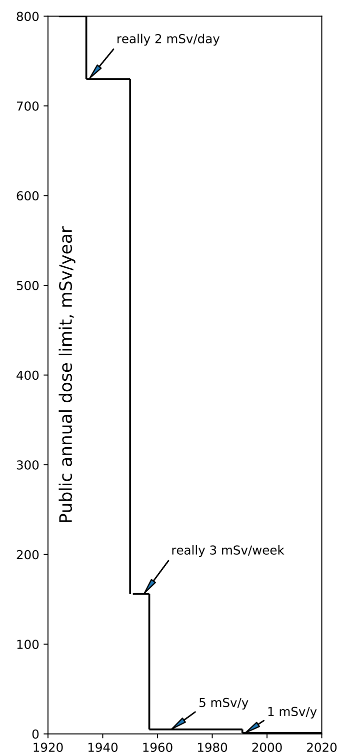

Figure 1: US Dose Limits

Taylor does not explain the reasoning for the shift from a daily limit, to a weekly limit, and then to an annual limit, which is inconsistent with radiotherapy and everything we know about the repair period. But he does say the Committee was worried about 'overruns'. If the NCRP had asked the AEC what the daily maximums were, they would have gotten back numbers in the 1 mSv and higher range. Most of the annual dose was received in far shorter periods. By pushing the regulatory limit period out, they were able to push the dose limit down without interfering with AEC operations. But I do not have documentary evidence that this was the motivation. Whatever the motivation, annual limits make no sense biologically, and could be dangerous. We must go back to daily limits.

In 1980, Taylor said.

> Collectively, there exists a vast array of facts and general knowledge about ionizing radiation effects on animal and man. It cannot be disputed that the depth and extent of this knowledge is unmatched by that for most of the myriads of other toxic agents know to man. No one has been identifiably injured by radiation while working within the first numerical standards first set by the NCRP and then the ICRP in 1934. [2 mSv/day]

Table1 shows that this is still the case. To see detectable harm — get out of the green — requires dose rates of 20 mSv/d or more. Taylor's 2 mSv/d provides a factor of 10 margin. It's a good rule.

Single acute dose above top horizontal line; repeated doses below. Belarus/Ukraine kids: thyroid dose

Group	Size	Period	Cumulative dose mSv	Dose rate mSv/day	Result
Atom bomb survivors					
Leuk 5-150[21]	33,459	seconds	5 to 150	5 to 150	Insignificant decrease in leukemia
Leuk 150-300[21]	5,463	seconds	150 to 300	150 - 300	Insignificant increase in leukemia.
Leuk 300+[21]	6,793	seconds	300-5000+	300-5000+	Significant increase in leukemia.
Solid 5-20[3]	14,555	seconds	5 to 20	5 to 20	Insignificant decrease in solid cancers.
Solid 20-40[3]	6,411	seconds	20 to 40	20 to 40	Solid cancers same as control
Solid 40-125[3]	10,970	seconds	40 to 125	40 to 125	Insignificant increase in solid cancers.
Solid 125+[3]	16,166	seconds	125+	125+	Significant increase in solid cancers.
Louis Slotin[12]	1	seconds	21000	21000	Died in 9 days
H. Daghlian[12]	1	seconds	5900	5900	Died in 25 days
Norway tech[6]	1	< hour	38500	38500	Died in 13 days
Tokaimura[12]	3	seconds	3000-17000	3000-17000	>10,000 mSv died
Goiania[8]	≈46	hrs or less	1000-6000	1000-6000	50% mortality abv 4000 mSv
Thai scrap[9]	≈10	hrs or less	1000-6000	1000-6000	100% mortality abv 6000 mSv
Chern firemen+[22]	134	<2 hrs	1000-16000	1000-16000	Sigmoid mortality, 50% mortality at 6000 mSv.
Chernobyl liquidators[10]	220,000	2 min to 90 days	1-1500	nil to 1500 most < 2	Low/high dose rate mushed together. 6% increase in cancer. Decrease in mortality.
Litvinenko[5]	1	3 weeks	96,000	4,000	Died in 23 days
Belarus kids[27]	13,127	2-3 weeks	ave 780 max 48k	39-2400	45 thyroid cancer, eventual 50? deaths
Ukraine kids[20]	11,611	2-3 weeks	ave 560 max 33k	28-1600	87 thyroid cancer, eventual 50? deaths
Eben Byers[11]	1	2 years	366,000	300	Horrible bone cancer. Died in 3 years.
Evans radium hi[4]	127	10 years	>80000	80+	Cancers. Hi mortality >200 mSv/d
Dial painters hi[18]	273	up to 15 yrs	190000-440000	35 to 80+	96 bone cancers
Evans radium mid[4]	17	10 years	20000-80000	20 to 80	Abnormalities. Nil clinical symptoms.
Dial painters lo[18]	2,110	up to 15 yrs	200 - 160000	up to 30	Zero bone cancers.
Evans radium lo[4]	59	10 years	up to 20000	max 20	Nil abnormalities.
Albert Stevens[16]	1	20 years	61,000	8	Died at age 79 of heart failure.
UPPU Club[24]	26	≈10y	up to 7200	0.03-2	Lower mortality than coworkers.
Taipei Apt hi[2, 7]	1,100	18 years	up to 4000	up to 3	Decrease in cancer, maybe non-rad.
Taipei Apt mid[2, 7]	900	18 years	ave 420	up to .160	Decrease in cancer, maybe non-rad.
Taipei Apt low[2, 7]	8,000	18 years	ave 120	up to .050	Decrease in cancer, maybe non-rad.
Keralans[13]	69,956	10-15 yrs	50-650	.016 to .160	Insignificant decrease in cancer
NRX Clean Up[26]	≈1000	90s jumps	up to 200	up to 150	Insignificant decrease in cancer

Table 1: Populations who have received very large doses

The current regulations are rife with contradictions:

1. The EPA tritium drinking water limit is 740 Bq/L. It is based on an allowable dose of 0.04 mSv/y, and drinking 2 liters per day of this water every day of the year. National tritium limits range from 100 Bq/L (EU) to 76,000 Bq/L (Australia), a preposterous factor of 760.
2. The EPA requires that a nuclear power plant show that it will not expose any member of the public to more than 0.25 mSv/y.
3. The NRC level for nuclear plants is 1 mSv/year for the general public.
4. But for indoor radon, the EPA action level is set at 8 mSv/y.
5. Low level radiation from a coal plant can easily be an order of magnitude higher than that from a nuclear plant, but it is completely unregulated.
6. The Norwegian limit for Cesium-137 in human food is 3000 Bq/kg; the Japanese limit is 500 Bq/kg; the USA limit is 100 Bq/kg.
7. Nuclear workers are allowed 50 mSv/y, a factor of 50 over the general public.
8. The DOE limit for "contact handled" material, meaning no shielding required, is a surface dose rate of no more than 2 mSv/h. This is based on assuming that a worker will be in close contact with the material for no more than a half-hour, and thus will receive no more than 1 mSv/day.[17][p 9]
9. The NASA limit for astronauts is 500 mSv/y with career limits of 1000 to 4000 mSv, depending on age and gender.

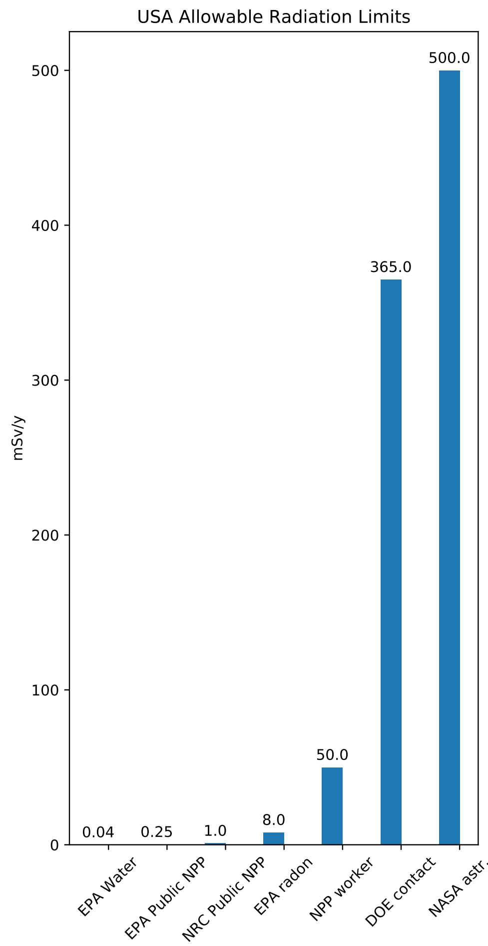

Figure 2. USA Radiation Limits

What has driven these numbers? Radon is supposedly the poster child for LNT. Why is the EPA allowable radon level 30 times the allowable power plant level? Why is the nuclear worker level 200 times the EPA general public level? If the general public level is reasonable, then the nuclear worker level is not. And the astronaut levels would be suicidal.

The answer is ALARA. ALARA stands for As Low As Reasonably Achievable. The idea is that any limit involves some risk so, if you can go lower without undue cost, why not? Nuclear power plants don't have to do anything really special to meet the EPA general public levels, so why not set them that low? Shows how safe we bureaucrats are being. But if we set the radon levels consistently, millions of homes would have to be rehabilitated at great expense. This is politically unacceptable. So we apply a completely different standard.

Similarly, the nuclear plant worker level of 50 mSv/y is not difficult to meet, but would be just about impossible for astronauts because shielding a spacecraft is orders of magnitude more expensive. So once again we apply a different standard.

In practice, As Low As Reasonably Achievable is interpreted by NRC regulators to mandate any regulation that allows nuclear to remain competitive with alternate sources of electricity. This is a perfectly reasonable interpretation of reasonably achievable. Any requirement that still leaves a design or a plant competitive with other sources of power is manifestly reasonably achievable.

But driving the cost of all nuclear power up to say the cost of coal is a show stopper:

Technology stagnates. Under ALARA, the standard solution: a cheaper nuclear technology won't work. If any such technology really is inherently cheaper, that simply provides regulators with more room to drive costs up. There is no point in developing cheaper, safer designs if all that means is still more expensive regulation. If investors cannot benefit from taking a risk on a new technology, they will not invest. Even incremental improvements are pointless. The winners are the incumbents. They don't have to worry about some cheaper provider of nuclear power coming in and undercutting them. They become both comfortable and sloppy. Then they embrace the system because it protects them.

One problem with driving the cost of nuclear power up to the cost of other sources is the cost of other sources changes. In the 1970's, the cost of fossil fuel skyrocketed. Under ALARA, the cost of nuclear rose in lock step with the cost of coal. Then from 1980 on the real cost of coal power started declining and is now as low as it has ever been. But the regulatory ratchet only works one way. Nuclear was left high and dry. New plant construction abruptly halted.

ALARA was not through. Nuclear power is an inherently low marginal cost source. For ALARA that's just means here's an opportunity, nay, a requirement, for more regulation. ALARA now went after nuclear power's operating costs, driving them up toward the operating costs of coal, for which fuel alone is about 3 cents per kWh. The easiest way to do this is paperwork requirements that add people. In the US a typical 1 gigawatt nuclear plant will have a staff of 700 people or more. But such a plant can be operated by fewer than 20 people per shift.

This was recently demonstrated in Spain. Spain has three 1 GW nuclear plants on two sites near Barcelona. Normally the three plants employ 850 people, far less than USA practice. When COVID-19 came along, the plants were instructed to keep all non-essential employees home. Turns out only 120 people were needed to operate the three plants. Not surprising. The 450 MW Riverbend coal plant in North Carolina operated with a total of 14 people per shift. Coal plants are far more maintenance intensive than nuclear plants.

Nuclear survived these bloated operating costs for a while. But then fracking came along; and the real cost of gas dropped by a factor of three. We now have the nonsensical situation where a fully depreciated nuclear plant which should have a marginal cost of well below a penny a kWh cannot compete with natural gas, a high marginal cost source of electricity. ***That's the power of ALARA.***

ALARA is biased against new technologies, even if they are inherently safer. A case in point is tritium. Tritium is a weak beta emitter. It has to be ingested to do any damage, and then you need to drink a lot of it. Over time the allowable tritium levels in water have dropped by several orders of magnitude. The current USA EPA level for water is 740 Bq/L which is 13 times lower than the WHO level of 10,000 Bq/L.[1] Not surprisingly, the current EPA level is at just about the level which a Pressurized Water Reactor (PWR) can meet without doing anything really special.

Molten salt reactors which have inherent safety advantages over PWR's (low pressure, no phase change, passive drain, most fission products, including the all-important cesium and strontium, tied up as fluorides) produce about 60 times as much tritium as a PWR. To meet the USA tritium requirement they are forced to employ an expensive extra loop cutting their economic advantage over the PWR and creating another set of fault points.

Conversely, molten salt reactors produce an order of magnitude less tritium than a heavy water moderated reactor. Canada is the home of the CANDU heavy water moderated reactor. Recently Terrestrial Energy presented their molten salt design to Canadian regulators. The designs easily met the CANDU-based tritium requirements, which according to the regulators more than adequately protect the public. The regulators, invoking ALARA, said not good enough, and ended up requiring much lower tritium emissions from the Terrestrial design than from a CANDU.

ALARA stoked fear is exploited by pigs feasting at the public trough ALARA says we should spend substantial resources reducing radiation exposure, even if the exposure is already far below the dose rates which have resulted in detectable harm. There is no dose rate below which it does not make sense to reduce the dose rate further. ALARA says to one and all, any radiation is perilous.

A large portion of the nuclear establishment regards this as a feature, not a bug. ALARA can be used to funnel immense amounts of other people's money to nuclear clean up, spent fuel disposal, and nuclear regulation. Under the right circumstances, an accomplished bureaucrat can turn ALARA based fears into a ***half-trillion dollar*** project to shift slightly contaminated dirt from one place to another, as has happened at Hanford.

[1] The WHO level is based on limiting the cumulative "committed effective" dose to someone who drank 2 liters of this water per day for 365 days to 0.1 mSv. If EPA has done the calculations the same way, the EPA limit is 0.008 mSv/y, All these numbers are a small to very small fraction of background radiation. Tritium has a biological half life of 7 to 14 days, It does not bioaccumulate.

Hanford is fitted with about 120 permanent radiation monitors clustered around the old plutonium processing and storage facilities. Most of the measured dose rates are around 1 mSv/y, essentially background, Table 2. In 2011 and 2012, the highest dose rate measured by these sensors was less than 6 mSv/y. So we are going to spend about 10 billion dollars per year for 50 years to attempt to reduce dose rates, which are already lower than the dose rate that the EPA says is fine for your basement.

Location	No. of	2011		2012	
	Dosi-	Max	Ave	max	Ave
	meters	mSv/y	mSv/y	mSv/y	mSv/y
100-K	14	2.07	2.02	1.07	0.82
100-N	5	2.03	1.16	3.11	1.40
200-East	42	3.85	1.00	1.76	1.02
200-West	24	1.78	0.96	1.51	1.00
200-North	1	5.70	2.51	0.88	0.83
300-area	8	1.14	0.86	1.11	0.86
300-TEDF	6	0.81	0.79	0.86	0.83
400-area	7	0.89	0.79	0.91	0.82
618-10	4	0.75	0.74	0.80	0.77
CVDF	4	0.78	0.74	0.76	0.75
ERDF	3	0.89	0.81	1.01	0.76
IDF	1	0.88	0.83	0.98	0.89

Table 2: Hanford's deadly dose rates

To keep this scam going, the nuclear establishment must maintain that these less-then-Denver dose rates are so deadly that spending 500 billion dollars to attempt to reduce them is a good investment. ***The nuclear establishment is telling the public that nuclear power is unacceptably dangerous.***

Under ALARA, nuclear power can never be cheaper than coal or gas electricity. Our goal should not be to just make nuclear power as cheap as coal or gas fired power. Our goal must be to keep pushing the cost of nuclear electricity down and down, allowing us to replace fossil fuels almost everywhere, including transportation and industrial processes.

But this will only happen if the providers of nuclear power are forced to compete with each other in a truly competitive market, in which case the inherent cheapness of fission power combined with technological advances would push the real cost of nuclear power lower and lower. The real losers here are the poor and the planet.

Imagine a world in which nuclear power costs less than three cents real a kilowatt-hour as it did not so long ago. Not only would the poor be immensely richer, but the planet would be far better off. Electrification of transportation and industry would explode. Desal would take off. Synthetic fuels could become viable. Skies would be clean. All this electricity would require little land and produce almost no CO2.

ALARA creates regulatory uncertainty and volatility ALARA is by definition rubbery. It is subject to nearly automatic creep. If you set a level based on ALARA and experience reveals that level can be met, is not another factor of two reasonably achievable?[2]

Under ALARA, the only guarantee is that the rules will change.

- No engineer can design to ALARA.
- No rational investor can be at its mercy.

The regulatory uncertainties inherent in ALARA preclude or at least strongly discourage private investment in nuclear. When the AEC introduced ALARA in 1972, essentially all utilities operated as regulated monopolies. The cost of ALARA-based changes in regulations could be folded into the rate base. The plant's investors broke even or came out ahead. The losers were the rate payers. Needless to say, there was little pushback from the industry. But in deregulated markets, ALARA is a death knell for nuclear power.

ALARA creates a tragically unbalanced regulatory focus. The goal of regulation should be to balance benefits against costs. The benefits of nuclear power include a massive reduction in fossil fuel pollution, which is resulting in millions of premature deaths per year.[25] ALARA ignores those deaths. ALARA claims that a nuclear power caused death is infinitely more valuable than a fossil fuel caused death.

The public and the media interprets any breach of ALARA-based limits as a dangerous health hazard. This in turn generates all sorts of responses in a casualty which are either unnecessary or in many cases create health hazards which are worse, usually much worse, than the radiation hazard.

Under the pre-1951 allowable of 2 mSv/day, no member of the public would have had to evacuate in the Fukushima release. But the ALARA-based 1 mSv/year plant boundary limit resulted in a panicked, botched evacuation, in which fifty frail, elderly people were killed almost immediately; and at least 1600 eventually died prematurely, as a result of the psychological stress of the prolonged evacuation. The total compensation bill is approaching $60 billion dollars, for a release that has caused no detectable radiation harm to the public.[23] ALARA killed those people.

ALARA must go. If nuclear power is to live up to its remarkable promise, ALARA must be replaced by firm limits based on a balanced, comprehensive appraisal of nuclear's benefits and costs.

[2] A corollary is that it is politically infeasible to raise an ALARA limit. In 1991, EPA did a study which concluded that by its own rules the tritium concentration limit in drinking water should be 2500 Bq/L.[15] However, the limit was not changed. This is an example of the down ratchet. Regulatory changes can only go one way. If 740 Bq/L was the safe limit, then clearly 2500 Bq/L must be unsafe. Or if you don't buy that argument, the old level was obviously achievable, so it would be a violation of ALARA to raise it.

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