Nuclear For Climate Australia

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Health Impacts on Workers within the Nuclear Power Industry and Health Risks from Low Dose Radiation

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This article grew from a submission made to the Victorian Parliament – Environment and Planning Committee "Inquiry into the Nuclear Activities (Prohibitions) Act 1983".

It presents conclusions drawn from references for the health impacts on workers operating nuclear power plants and addresses concerns regarding leukaemia in children living near those plants. Throughout this document the measurement of radiation is the millisievert (mSv). Its impact upon us is shown in the following two images.

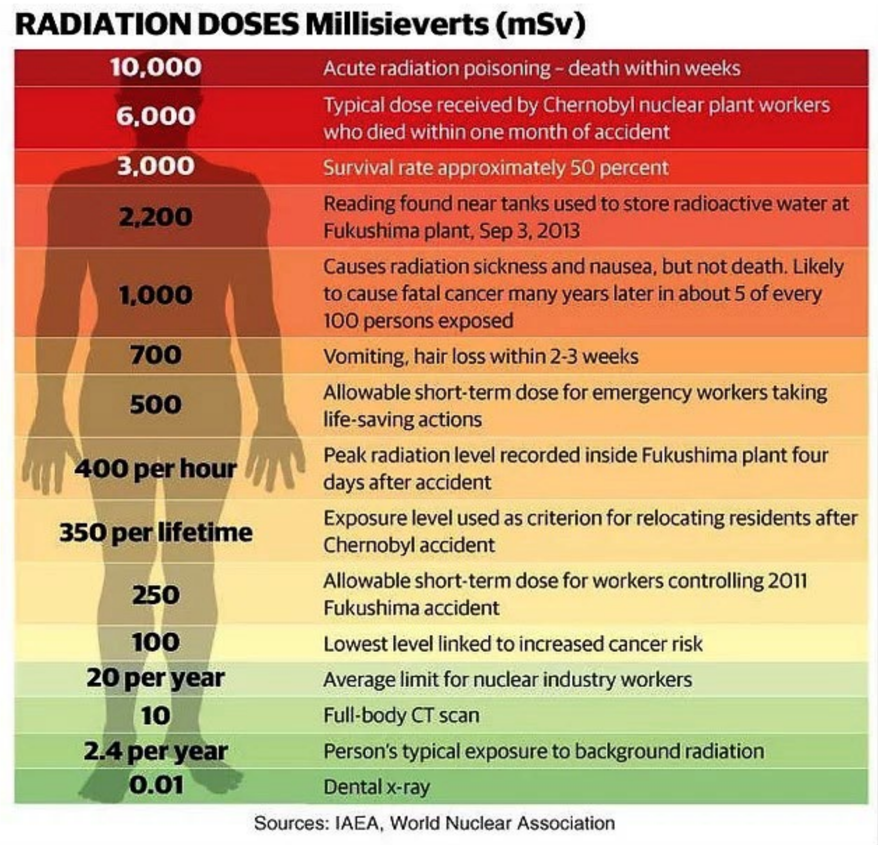

Figure 1 - Comparison of the effects of varying levels of ionising radiation in mSv

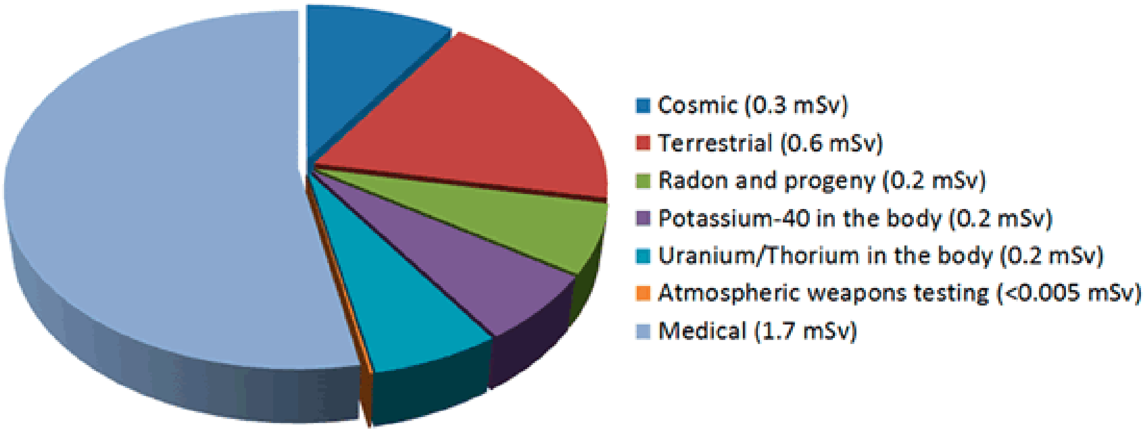

Figure 2 - Average background radiation dose per year in Australia 1.5mSv excluding medical.

1. High background radiation and rates of cancer

Most studies into the impacts of high background radiation on resident populations have found no evidence of any increased rate of cancer incidence or mortality.

Possibly the strongest evidence supporting our ability to tolerate low dose radiation is the absence of health impacts to populations living in High Natural Background Radiation Areas (HNBRA). On average, Australians are exposed to about 1.5 mSv each year from natural sources[1]. Internationally some areas are much higher. Examples are[2] Yangjiang, China with average annual internal effective doses of 4.27mSv, parts of Kerala in India with 15mSv, Brazil with 3.5 to 15mSv and Ramsar in Iran with 2.4 to 71.74mSv. A number of epidemiological studies have been conducted to analyse the risk of cancer incidence in the world's HNBRAs.

Most of these studies have concluded that there is no link between exposure to high background natural radiation and an increased rate of cancer or mortality.[2,3]

2. Current models for radiation dose response are challenged by many scientists

BEIR VII[4] is the latest reference from the National Research Council in the US which addresses the effects of exposure to low dose ionizing radiation on human health. It sets the policy for the US EPA and radiation guidelines for the nuclear industry in the USA.

Central to its policy is the “Linear No Threshold” (LNT) hypothesis, which holds that there is a linear relationship between radiation exposure and radiation risks, without any “safe” dose level – See Figure 3.

Many scientists are calling for a review of the LNT model. Levels of this support are shown in Table 1. In their publications many advocates such as Calabrese and O’Connor[5], Sacks, Meyerson and Siegel[6,7], Cardarelli and Ulsh[8] and Tubiana, Aurengo, Averbeck and Masse[9] have outlined their cases in detail.

A variety of plausible dose-response models exist and are shown in Figure 3. The vertical axis shows risk to health with harm occurring above the horizontal axis and benefits existing below the axis.

These response models are:

1. A **Linear Threshold Model** where below a recognised Threshold dose of say, 100mSv no damage occurs or,
2. An **Hormesis Model** where benefits such as cancer protection and improved immune responses actually exist at low radiation levels – below the horizontal axis or,
3. **Supra-linear** and **linear quadratic** relationships exist which do not have significant support.

The initial data upon which the LNT concept is an extrapolation to low doses of acute exposure[10] at very high doses such as studies on the atomic bomb survivors at the end of World War II. Some have argued that in some cases Japanese survivors who received low doses of radiation had fewer cancers than unirradiated populations.[11]

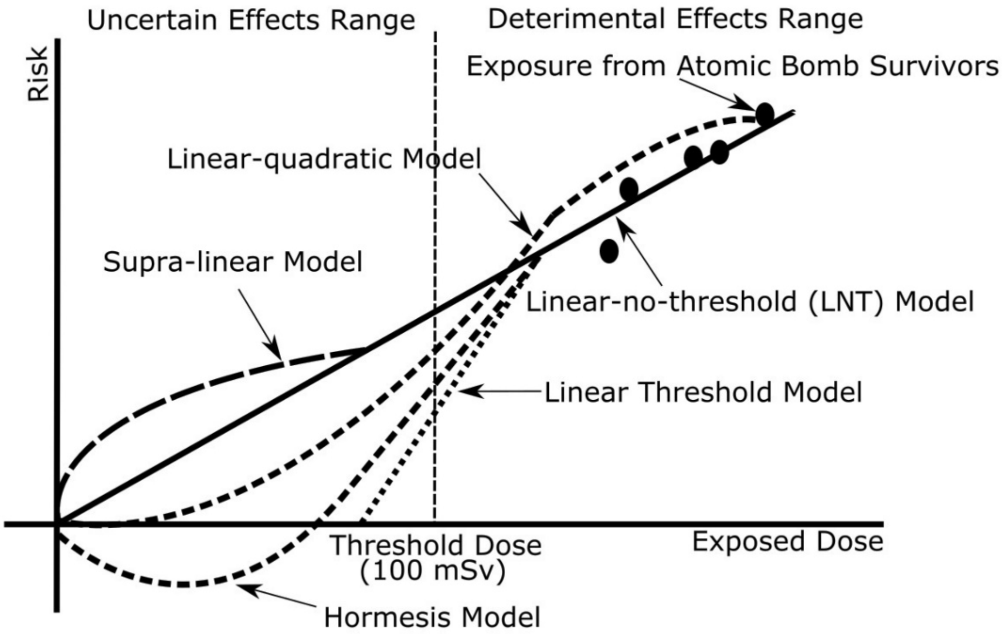

Figure 3 - Dose-response models to estimate the risk of low-dose radiation from medical imaging based on high-dose radiation exposure.[12]

Table 1 – Survey of Scientists Regarding the Most Accurate Radiation Dose–Response Model for Cancer.[13,14]

Surveys	Respondents	Percent Supporting LNT Model	Percent Supporting Threshold Model	Other
United States	National Labs	12	70	18[a]
	Union of Concerned Scientists	21	48	31[a]
Subscribers to Science	United States	19	75	6[b]
	Britain	21	71	8[b]
	France	18	70	13[b]
	Germany	22	64	13[b]
	Other European Union	23	69	8[b]

Abbreviation: LNT, Liner No-Threshold

[a] The “other” category includes “supralinear” and “don’t know” responses.

[b] The “other” category includes “supralinear” responses.

3. No Impact on Nuclear Power Plant Workers from Low Level Radiation – in fact their health is probably improved.

3.1. France

A French study was carried out on 22,393 workers employed over a 42 year period at EDF’s 58 nuclear power plants.[15] They received an average cumulative occupational dose of 21.5mSv. With an average age of 49 years, their background radiation from non-occupational sources would be approximately 2-4mSv/yr or 98-196mSv cumulative. This significantly dominates the workplace dose and calls into doubt the accuracy of studies which focus solely on the occupational dose.

The French study found no increase in death relative to radiation dose except for an excess of 2 deaths out of 22 linked to cerebrovascular disease. Relative risks of cancer for these nuclear workers was lower than the general population.

3.2. Canada

Review[16] by the Canadian Government’s Nuclear Safety Commission has found approximately 42,200 Nuclear Energy Workers (NEWs) from Hydro-Québec, New Brunswick Power Corporation, Ontario Hydro, and AECL, first employed since 1965, had no increase in risk of solid cancer mortality due to their occupational radiation exposures.

3.3. INWORKS

The International Nuclear Workers Study (INWORKS)[17] study examined risks in worker cohorts from the United States, France, and the United Kingdom (a subset of the larger cohort included in the 15-country study). It claimed analysis demonstrated a significant association between red bone marrow low dose radiation and the risk of leukaemia (excluding chronic lymphocytic leukaemia) and between colon dose and the risk of solid cancers.

It came under criticism from Cardarelli, Ulsh[8], Pennington, Sacks, Siegel and Meyerson[6,11], Calabrese and O'Connor[5] and Scott[18] for significant methodological errors including:

1. failure to account for natural background radiation exposure, the differences in which potentially dwarf the occupational exposures of the study cohort;
2. failure to account for medical exposures experienced by the public;
3. failure to account for dose–rate effects;
4. the a priori assumption of an LNT dose response;
5. mischaracterization of the y-intercept as 0 total dose when in fact it was 0 occupational dose;
6. arbitrary exclusion of all dose responses except LNT and linear-quadratic

3.4. Nuclear shipyard worker study (1980–1988): A large cohort exposed to low-dose-rate gamma radiation

The 1991 Final Report of the Nuclear Shipyard Worker Study (NSWS)[19] was a very comprehensive study of occupational radiation exposure in the US. The NSWS compared three cohorts: a high-dose cohort of 27,872 nuclear workers, a low dose cohort of 10,348 workers, and a control cohort of 32,510 unexposed shipyard workers. The cohorts were matched by ages and job categories. Although the NSWS was designed to search for adverse effects of occupational low dose-rate gamma radiation, few risks were found. The high-dose workers demonstrated significantly lower circulatory, respiratory, and all-cause mortality than did unexposed workers. Mortality from all cancers combined was also lower in the exposed cohort.

The workers exposed to radiation had a 24% lower standardised mortality ratios (SMR) than the unexposed workers which implies a 2.8-year increase in average lifespan.

4. No evidence that radiation causes childhood leukaemia clusters.

The claim has been made by the Medical Association for Prevention of War (Australia) that there is an increase in lifetime cancer risk of an additional 10mSv. This claim is not based upon any measurable evidence but is a mere application of the LNT hypothesis, for which ANY exposure would entail additional risks. However, this is a misuse of the quantity Collective Dose and of the dose-risk relationship, as here indicated:

> *Collective effective dose is an instrument for optimisation, for comparing radiological technologies and protection procedures. Collective effective dose is not intended as a tool for epidemiological studies, and it is inappropriate to use it in risk projections. This is because the assumptions implicit in the calculation of collective effective dose (e.g., when applying the LNT model) conceal large biological and statistical uncertainties.*
>
> *"Specifically, the computation of cancer deaths based on collective effective doses involving trivial exposures to large populations is not reasonable and should be*

avoided. Such computations based on collective effective dose were never intended, are biologically and statistically very uncertain, presuppose a number of caveats that tend not to be repeated when estimates are quoted out of context, and are an incorrect use of this protection quantity".[20]

The claim has been made by the Medical Association for Prevention of War (Australia) that childhood leukaemia clusters near some nuclear power plants are caused by radiation on the grounds that "no possible cause other than radiation has been identified". Further, it is claimed that errors in radiation measurement are also a cause.

These claims are challenged. A review of the German KiKK report by COMARE[21] and reviewers from Oxford found the effective doses from discharges of between 0.0001 mSv and 0.02 mSv per year for individual NPPs, are totally dominated by doses from medical diagnostic radiation exposure per person of 1.9 mSv per year and natural background radiation exposure of 2.1 mSv per year.

A comprehensive summary of childhood leukaemia clusters in France, Germany, the UK and Finland exists in the Oxford Martin[22] "Health effects of low-level ionizing radiation" and a detailed discussion by Janiak[23].

From these studies possible explanations for the German KiKK results include:

- statistical problems with the study or
- possible causes of childhood leukaemia such as virus infection from population mixing.

For the time being, no cause for the German cancer clusters has been identified but radiation has been rejected on the basis that the amounts are too low.

It is also noteworthy that based on data from the United Nations Scientific Committee on the Effects of Atomic Radiation on the Effects of Atomic Radiation 2016 Report[24], nuclear power plants emit less radiation than coal fired power plants, especially of the brown coal variety in use in the Latrobe Valley. This is shown in the following image of Table 48 from Annex B, Radiation Exposures from Electricity Generation.

Table 48. Comparison of collective doses to the public, and collective doses normalized to electricity generation in 2010, integrated to 100 years, to the world-average population within a 1,500 km radius of each source for the electricity-generating technologies based on the coal cycle and the nuclear fuel cycle

Coal			*Nuclear*		
Source	*Collective dose (man Sv)*	*Normalized collective dose (man Sv/(Gw a))*	*Source*	*Collective dose (man Sv)*	*Normalized collective dose (man Sv/(Gw a))*
Coal mining	370	0.4	Uranium mining[a] and milling	53	0.2
Older coal plants	780	0.8	NPP generation	68	0.2
Modern coal plants	60	0.1			
From coal ash deposits	240	0.2	Reprocessing	7.6	0.03

[a] Of the 53 man Sv for uranium mining and milling, 40 man Sv is from mining only.

5. Nuclear Power Protects Lives and Our Environment

This final group of references addresses the benefits of nuclear energy in terms of reduced mortality per unit of output compared to other generating sources and also a reduction in carbon emissions.

Pushker Kharecha and James Hansen outlined in their paper “Prevented Mortality and Greenhouse Gas Emissions”[25] that global nuclear power has prevented an average of 1.84 million air pollution-related deaths and 64 gigatonnes of CO2-equivalent (GtCO2-eq) greenhouse gas (GHG) emissions that would have resulted from fossil fuel burning.

They calculate that nuclear power could additionally prevent an average of 420 000−7.04 million deaths and 80−240 GtCO2-eq emissions due to fossil fuels by mid-century, depending on which fuel it replaces.

In the following table from Electricity Generation and Health[26] by Anil Markandya, Paul Wilkinson outlines the very low mortality of nuclear energy compared to fossil fuel use. References included[27], Power generation and the environment—a UK perspective, vol 1.[28] and European Commission report EUR 16524, Vol 5. Brussels: EC,1995[29].

	Deaths from accidents		Air pollution-related effects		
	Among the public	Occupational	Deaths*	Serious illness†	Minor illness‡
Lignite[30]	0·02 (0·005–0·08)	0·10 (0·025–0·4)	32·6 (8·2–130)	298 (74·6–1193)	17 676 (4419–70 704)
Coal[31]	0·02 (0·005–0·08)	0·10 (0·025–0·4)	24·5 (6·1–98·0)	225 (56·2–899)	13 288 (3322–53 150)
Gas[31]	0·02 (0·005–0·08)	0·001 (0·0003–0·004)	2·8 (0·70–11·2)	30 (7·48–120)	703 (176–2813)
Oil[31]	0·03 (0·008–0·12)	··	18·4 (4·6–73·6)	161 (40·4–645·6)	9551 (2388–38 204)
Biomass[31]	··	··	4·63 (1·16–18·5)	43 (10·8–172·6)	2276 (569–9104)
Nuclear[31,32]	0·003	0·019	0·052	0·22	··

Data are mean estimate (95% CI). *Includes acute and chronic effects. Chronic effect deaths are between 88% and 99% of total. For nuclear power, they include all cancer-related deaths. †Includes respiratory and cerebrovascular hospital admissions, congestive heart failure, and chronic bronchitis. For nuclear power, they include all non-fatal cancers and hereditary effects. ‡Includes restricted activity days, bronchodilator use cases, cough, and lower-respiratory symptom days in patients with asthma, and chronic cough episodes. TWh=10^{12} Watt hours.

Table 2: Health effects of electricity generation in Europe by primary energy source (deaths/cases per TWh)

The benefits of nuclear energy were outlined in an Economic Analysis of Various Options of Electricity Generation - Taking into Account Health and Environmental Effects by Nils Starfelt Carl-Erik Wikdahl[30]

Final Comment

Thirty-one references have been provided which give a snapshot of the contested issues surrounding the safety of nuclear energy. Many hundreds of additional papers and studies no doubt exist. From the body of evidence that we have examined the introduction of nuclear energy provides improved health outcomes, increased community wealth and stability and a greatly improved environment.

Robert Parker

Founder of Nuclear For Climate Australia and

Vice President, Australian Nuclear Association

https://nuclearforclimate.com.au/

www.nuclearaustralia.org.au

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