The Physical Hazards of Nuclear Energy

Author: Associate Professor Mark Diesendorf

Date: 10 March 2025

EnergyScience Coalition
2025 Briefing Paper No 2

The EnergyScience Coalition is an independent non-governmental organisation established as a collaboration of concerned scientists, engineers and policy experts.
www.energyscience.org.au

Introduction

The four principal physical hazards of nuclear energy discussed here are the contribution of nuclear energy to the proliferation of nuclear weapons, the risk of nuclear accidents, the unprecedented task of managing nuclear wastes for 100,000 years or more, and the health hazards of low-level ionising radiation. On the latter issue, this article supplements the more detailed article by nuclear radiologist Peter Karamoskos, Number 22 in this series, which was published before the disaster at the Fukushima Daiichi nuclear power plant (NPP) in 2011.

Proliferation

The nuclear fuel 'cycle' offers two pathways to the production of nuclear explosives, reprocessing and uranium enrichment.

In the first pathway, fissile plutonium is extracted from the spent fuel of either NPPs or military reactors by a chemical process known as reprocessing. It requires remote handling of the spent fuel and is very expensive. A 1000-megawatt NPP produces annually about 200 kg of reactor-grade plutonium. Contrary to misinformation by nuclear power proponents, this can be used to make nuclear weapons, as confirmed by a Commissioner of the US Nuclear Regulatory Commission (Dr Victor Gilinsky), a former leading nuclear bomb designer (Dr Theodore Taylor), and the US Department of Energy. 200 kg of reactor-grade plutonium would provide the explosives for about 20 bombs, although they would be less 'efficient' at causing death and destruction than using weapons-grade plutonium made in military reactors. In the latter reactors, the spent fuel is extracted after a shorter period of time, so that the fissile Plutonium-239 is less 'contaminated' by the non-fissile Plutonium-238.

In the second pathway, uranium enrichment is continued beyond the 3-5% of fissile Uranium-235 used in most NPPs to a level suitable for nuclear weapons. Conventional 'wisdom' that 80–90% enrichment is necessary for a nuclear weapon is only correct for small nuclear bombs that can fit into the warheads of missiles. However, as little as 20–30% enrichment may be sufficient for a large nuclear bomb. While the logistics of delivering such a large bomb would be difficult, it could be delivered to a target by semitrailer or ship and detonated without unloading it.

Training in nuclear science and engineering for research, medical isotope production and nuclear energy provides many of the skills needed for making nuclear weapons. Beyond this, nuclear energy has directly assisted and cloaked the development of nuclear weapons by six countries: the United Kingdom, France, India, Pakistan, North Korea and South Africa.

Plutonium from the United Kingdom's first generation of NPPs was used to supplement the plutonium produced in the United Kingdom's military reactors and so expand its nuclear weapons inventory. In France, the military and civil nuclear programs are intertwined. India drew upon its experience with Canadian-designed NPPs to develop its bomb. Pakistan and North Korea were assisted in developing their nuclear weapons by metallurgist-engineer A.Q. Khan, who gained his skills in the European non-military URENCO uranium enrichment research facility. South Africa covertly used its uranium enrichment plant for both its Koeberg NPP and its bomb—incidentally, it is the only country to have dismantled a successful nuclear weapons program. Countries that commenced nuclear weapons programs disguised in nuclear energy programs, but discontinued them before fruition, were Algeria, Argentina, Australia, Brazil, Libya, South Korea and Taiwan. This summary is drawn from research published by the Institute of Science & International Security, the Nuclear Weapon Archive, and the Nautilus Institute.

An important role in Australia's attempt to develop the nuclear bomb was played by Australia's two nuclear knights, Sir Ernest Titterton, then Professor of Nuclear Physics at the Australian National University, and Sir Philip Baxter, then chair of the Australian Atomic Energy Commission. Both had worked in the US nuclear weapons program during World War II. Throughout the 1960s, they argued for Australia to develop nuclear energy and for nuclear weapons, at various times acknowledging and denying the link between these dangerous technologies. In 1970, the Australian government commenced the construction of an NPP at Jervis Bay NSW, but this was terminated at a very early stage following a change of Prime Minister. Australia's attempt is described in Richard Broinowski's book Fact or Fission: The truth about Australia's nuclear ambitions (2nd edition, 2022) and Wayne Reynolds's book Australia's Bid for the Atomic Bomb (1997).

Major accidents

Although there have been hundreds of nuclear accidents, the most serious were the Kyshtym disaster in former USSR in 1957, the partial core meltdown at Three Mile Island in the United States in 1979, the explosion at Chernobyl in Ukraine in 1986, and the meltdown of three of the six reactors at Fukushima Daiichi in Japan in 2011. Except for Three Mile Island, which took the USA to the brink of a major disaster but not quite over it, each of these accidents resulted in the emission of vast quantities of highly radioactive materials and has likely caused many thousands of cancer deaths.

The Kyshtym disaster occurred at a reprocessing plant to extract plutonium for nuclear weapons. As reprocessing is also sometimes done for civil nuclear power – to better manage high-level nuclear wastes or to extract plutonium to use as a fuel in a NPP – this disaster is relevant to nuclear energy.

Previously, it was thought that the airborne radiation fallout from the Fukushima disaster descended only on the local area or was blown out to sea, and that only very low levels at most reached densely populated Tokyo, 240 km south of Fukushima. However, recently it was revealed that a plume of highly radioactive micro-particles rich in the radioisotope Cesium-137 blanketed Tokyo. The researcher who detected the micro-particles, Satoshi Utsunomiya, and his results were suppressed until they were mentioned in the Scientific American (11 March 2019) and reported in detail in the open-source online repository arXiv.

Nuclear proponents, who ignore the large body of scientific evidence that low levels of ionising radiation are carcinogenic, claim that only about 50 people were killed by the Chernobyl explosion. They only recognise the prompt deaths from exposure to high-level radiation. However, the experts at the International Agency for Research in Cancer estimate that the Chernobyl disaster will induce 16,000 cancer deaths in Europe alone by 2065. But, as medical doctor Helen Caldicott has pointed out, cancer does not have a flag indicating its cause. Cancer is responsible for about 25% of all deaths and so even an increase of 16,000 cancer deaths spread out over seven decades would not be statistically significant.

The large body of epidemiological evidence that low-level ionising radiation is carcinogenic comes from studying specific groups and is outlined in the next section. The most convincing studies are known as case-control studies: individuals with cancer (the cases) are matched with individuals who are similar to the case individuals except that they do not have cancer (the controls). The researcher then investigates historical factors to identify if radiation exposure is greater in the cases than the controls. When case-control studies find that the incidence of cases increases with the degree of exposure to radiation, this is strong evidence that the link between exposure and cancer is causal.

Case-control studies are more credible than so-called 'ecologic' studies that compare groups rather than individuals, because the aggregation of data results in an information loss that can lead to bias. For example, early ecologic studies compared cancer incidences in nuclear industry workers and the general population, finding that the former had lower cancer incidence than the latter, and then drew the incorrect conclusion that low-level radiation is harmless or even beneficial. However, this simplistic analysis did not take into account the 'healthy worker effect/bias' that invalidates choosing the general population as the comparison group, because it includes elderly retired people, ill people (who are less likely to be employed) and unemployed poor (who have higher morbidity and mortality rates than average). The detailed case-control studies discussed in the next section obtained the opposite results from the invalid ecologic studies.

Cancer from low-level radiation

Radiation emissions from normally operating NPPs

For many years, studies of cancer incidence in people living near NPPs have been inconclusive, due mainly to inadequate data on individual radiation exposure and on individual cancers, and inadequate methods. However, recently the German Childhood Cancer Registry conducted a case-control study of all cancers registered between 1980 and 2003 in children younger than five years living near all Germany's NPPs. Distance from a NPP was used as a proxy for radiation exposure. This is the most comprehensive study in the world.

The results, which are statistically significant, are that young children living within 5 km radius of an NPP have 2.2 times the incidence of leukaemia compared with residence outside this zone. A smaller increase is observed in solid cancers—these have longer latency periods than leukaemia and so would mostly appear in older children that were not studied. This important study has received little publicity outside Germany, although it is relevant to Australia: one of the nuclear power station sites proposed by the Coalition, Mt Piper NSW, is about 5 km from the township of Wallerawang and several smaller communities.

Resistance to this clear-cut result is based on the belief that radiation emissions from normally operating NPPs are very low, much lower than the natural background radiation we all experience from cosmic rays, radioisotopes in rocks and soil, and traces in a few foods. Yet the result that cancer incidence decreases with distance from NPPs suggests strongly that the correlation between exposure and cancer is causal.

Two explanations for this very low dose effect have been proposed: (i) the actual radioactive emissions from NPPs are higher than given by the official figures; and/or (ii) the cause of the observed increased childhood cancer risk near NPPs in Germany is the exposure of their mothers, when pregnant. The foetus is very sensitive to ionising radiation, because of its high rate of cell division, and so even very low doses can induce cancer. The evidence, that prenatal exposure to very low doses of radiation is carcinogenic, is very strong, as discussed next.

Prenatal x-rays and childhood cancers

In the bad old days before the advent of ultrasound, pregnant mothers were routinely x-rayed. The first warnings that these low-dose exposures could be carcinogenic were published by Dr Alice Stewart and colleagues at Oxford University in 1958. Their case-control studies found a higher incidence of childhood cancers following prenatal x-rays. The results, which challenged standard medical practice of the time, were initially rejected by the medical establishment including the famous epidemiologist, Sir Richard Doll. The fact that the warning came from a woman also reduced its credibility in the eyes of the male 'experts'. Despite the criticisms and her shoestring budget, Dr Stewart continued to expand her research, showing that the cancer incidence depended on the number of x-rays taken during pregnancy, i.e. was dose related. Independent research groups in other countries confirmed Stewart's results. Eventually (in 1997), even Sir Richard conceded that this was a real effect. Stewart's story is told by Gayle Greene in The Woman who Knew Too Much.

Cancer in other occupations

Peter Karamoskos's previously mentioned *Briefing paper No. 22* discusses the increased cancer incidence in underground uranium miners, a dangerous occupation. However, it is difficult to obtain statistically significant conclusions in other occupations in which there is radiation exposure, because the number of people exposed may be small and the latency period for developing cancer is often long.

To sum up the impacts of low-level ionising radiation: contrary to misinformation spread by the nuclear lobby, there is a large body of evidence that low-level radiation is carcinogenic. The best fit to the epidemiological data is that there is an approximately linear relationship between radiation dose and cancer incidence and that there is no safe threshold. Hence even the natural background radiation is likely to be responsible for a small fraction of cancer prevalence. However, this is probably impossible to prove empirically by studies that compare cancer incidence in groups living in different regions with different background radiation levels. Such groups differ in many other relevant ways, e.g. diet, type of employment, wealth and lifestyle. Furthermore, the studies would have to be ecologic.

Nuclear wastes

At the time of writing, there is no operating final repository for high-level NPP wastes anywhere is the world, although the Onkalo underground repository in Finland is close to operation. No other country has reached Finland's stage of final storage. The USA spent US$15 billion on an unsuitable site in Nevada and then abandoned it. Temporary storage at most nuclear stations around the world is in deep pools of water, which are potential terrorist targets; a small minority of temporary storage is in stainless steel casks.

Incidentally, the costs of managing nuclear wastes, including decommissioning of radioactive NPPs, have not been included in the otherwise detailed CSIRO GenCost report on energy costs.

Low-level nuclear wastes are also of concern because of their quantity and unsatisfactory management practices. For example, at Olympic Dam uranium and copper mine in South Australia, a small mountain of over 100 million tonnes of low-level radioactive waste is not covered and is blowing in the wind. Although it is expected to induce very few cancers per year in Australia, it will continue to expose people for tens of thousands of years. Summing over the long-term future gives thousands of total deaths.

Conclusion

Nuclear energy is a very dangerous, unforgiving technology, as well as being very expensive and too slow to build to address the climate crisis.

Additional refutations of myths and misinformation about nuclear (and renewable energy) are available on Dr Diesendorf's personal website.