WORLD NUCLEAR ASSOCIATION

Reviewing the Question of Low-Dose Radiation

World Nuclear Association would like to thank the members of its Radiological Protection Working Group for their collaboration in producing this paper.

World Nuclear Association is the international organization that represents the global nuclear industry. Its mission is to promote a wider understanding of nuclear energy among key international influencers by producing authoritative information, developing common industry positions, and contributing to the energy debate.

Executive summary

The latest scientific studies show that any risk associated with low doses and low dose rates of radiation is extremely low, if it exists at all. Any cancer risk from low-dose radiation is too small to be distinguishable from the natural cancer rate. In fact, the very low risks associated with such dose levels make it very difficult to measure any health impacts, despite long-term radiation health effects having been extensively studied for over 100 years.

However, there is dissonance between the very low, if any, health risks of low-dose radiation, and the health risks perceived by the general public. History has shown that the socio-economic and psychological impacts of the fear of radiation far surpass any radiological impacts from low-dose radiation. Any actions taken during a radiological event (*e.g.* sheltering, evacuation, or relocation) should therefore be considered holistically, with the health and safety risks associated with the countermeasures themselves weighed against the radiological risk.

The regulatory burden from unnecessarily low release criteria and low radiation dose limits – achieving, at best, minor decreases in exposure levels, and negligible or no health benefits – imposes a significant cost to companies and governments alike. This is especially evident when comparing regulatory limits for radioactive material release from nuclear power plants with those from other human activities responsible for significantly higher dose levels to the general public, most notably coal power plants.

Further stringency in regulation, coupled with misconceptions about radiation, would directly affect the extent to which nuclear power can be used to provide clean, affordable, and low-carbon electricity. While no human activity is totally risk free, the very low risks from nuclear power are greatly outweighed by the benefits it provides.

The current radiation protection system needs careful review using the latest scientific knowledge and risk-based considerations to ensure it reflects the actual risks. Therefore, World Nuclear Association calls for:

1. Regulations to be aligned with the latest scientific knowledge on low-dose radiation and the (re) calibration of the ALARA principle, by considering them as part of a wider “all-hazards approach”, including long-term socio-economic impacts.
2. No new reduction in regulatory radiation dose limits and release criteria, unless proven to result in a measurable reduction of health risks proportionate to the associated cost.
3. The radiation protection community to communicate about the absence of any discernible effects associated with low-dose radiation.

Introduction

Radiation is a natural phenomenon and surrounds all life on a constant basis. It emanates from numerous sources, be it from within our own bodies, the ground and even outer space. Globally, the average radiation dose to a person is 2.4 millisieverts (mSv) per year, 99.99% of which is derived from radioactive sources not related to the nuclear industry [1]. Depending on the specific location, the dose can vary drastically (*i.e.*, by a factor of 100) as background radiation levels vary as a result of elevation or naturally occurring radioactive elements in the soil. Furthermore, individual lifestyle choices (*e.g.*, frequency of air travel; number of medical procedures) also contribute to substantial variations in radiation dose.

Shortly after its discovery in 1895, people began using radiation in many applications, including various medical treatments. Soon after, the international scientific and medical communities recognized the potential negative health consequences caused by exposure to high doses of radiation. This brought together medical professionals, scientists, industry and policymakers to develop a radiation protection framework to ensure that the many benefits offered by radiation could be realised safely. Over the following decades, the international radiological protection community[1] and national regulators chose to adopt conservative regulations for radiation protection based on the knowledge available at the time.

In aiming for operational excellence, the nuclear industry has continuously reduced radiation exposure to the public, workers, and the environment to levels well below internationally accepted standards and national regulatory requirements. On the other hand, communication about radiation has been inadequate, resulting in a significant gap between perceived and actual radiation risk. This is especially evident when discussing the health effects of low doses of radiation, where public perception and the often-misused concept of 'collective dose' have resulted in even the lowest of doses being considered to be harmful. This has resulted in a deeply held fear of radiation which has, in turn, led to fear and mistrust of nuclear energy.

Low-dose radiation

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)[2] defines low doses of radiation as those below 100 mSv. The scientific evidence indicates that cancer risks increase proportionally with doses above about 100 mSv, when received in a short time period. Predictions of radiation health effects for exposed individuals or populations are primarily based on studies of Japanese atomic bomb survivors and other populations exposed to high doses over a short time period.

The current theoretical cornerstone of radiation protection regulation is the linear no-threshold (LNT) model. The model hypothesizes that all exposure to radiation results in health consequences and that health effects are proportional to dose at all dose levels. In other words, the LNT model says that even the smallest exposure to radiation (*i.e.* a few mSv) results in a small risk of cancer. A 2018 review of available epidemiologic data undertaken by the National Council of Radiation Protection (NCRP), calls attention to the importance of recognizing that *"the risk of cancer at low doses is small and might contribute only a very small, nondetectable fraction to an individual's overall risk"* [3]. The UNSCEAR concluded that no increase in the incidence of health effects can be attributed reliably to chronic exposure to radiation at levels that are typical of the global average background levels of radiation [11]. In fact, scientific evidence indicates that people living in areas

1 The leading international radiological protection bodies – the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the International Atomic Energy Agency (IAEA), and the International Commission on Radiological Protection (ICRP) – provide recommended standards of radiation protection principles that are generally promulgated into national regulations.

2 The United Nation Scientific Committee on the Effects of Atomic Radiation was established in 1955. Its committee regroups scientists from 27 countries providing authoritative information on the effect of ionising radiation. Their reports are used throughout the world as a scientific basis for the evaluation of radiation risk. UNSCEAR is an independent body and a non-interested party.

of significantly elevated natural background radiation who are exposed to high levels of radiation over their lifespans do not show elevated cancer rates [2]. While the use of the LNT model is therefore scientifically questionable at low doses, it is a simple and pragmatic regulatory approach given the lack of certainty of the risks at low doses. Unfortunately, this simple approach has led to a continuous debate around LNT that negatively impacts public trust in science. It also reinforces the belief that the risks associated with low-dose radiation are high, when in reality any health effects would be very small

The international radiation protection approach is based on the 'ALARA' (as low as reasonably achievable) principle to ensure the measures taken are proportionate to the risk. ALARA is derived from the principle of optimisation of protection, which the ICRP defines as *"the likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors"*. However, ALARA is often misinterpreted to mean 'as low as possible'. This misapplication of the ALARA principle incurs significant unnecessary financial costs for society as a whole, for negligible benefit. A recalibration of activities to the ALARA principle is therefore needed to align the expected benefits with the required investment.

The trend seen in Figure 1 – showcasing the decrease in radiation exposure of workers in the nuclear industry (uranium mining, milling, enrichment, fuel fabrication, reactor operation and reprocessing) worldwide over time – is a good representation of the improvement of radiation protection practices across the global nuclear industry. This is the result of considerable efforts by the nuclear industry to reduce the already low average doses in the 1970's to even lower levels by the 2010's. The average level of exposure of radiation workers in the nuclear industry (1 mSv) is now lower than the average background radiation level (2.4 mSv). It is worth noting, nevertheless, that this came at a significant cost to the nuclear industry, with no measurable health benefit. Any requirement to reduce exposure levels even further would be unjustified scientifically, would achieve no measurable reduction in health consequences, and would result in further unnecessary cost to industry and society.

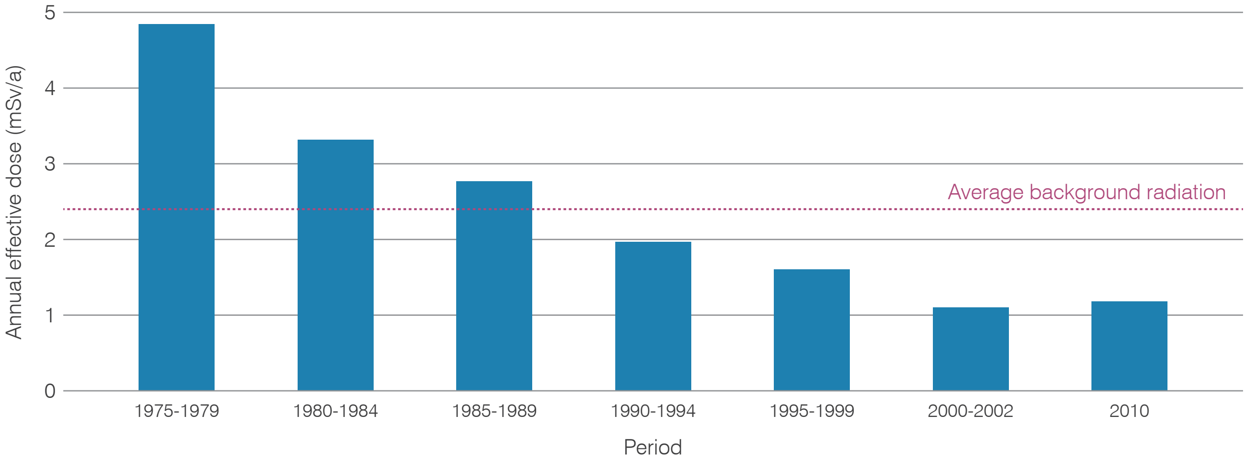

Figure 1. Estimated annual average effective dose (mSv/a) to workers[3] in the nuclear industry worldwide [7, 8]

In comparison, workers in several other sectors receive higher radiation doses than workers in the nuclear industry, as shown in Figure 2. For instance, the annual occupational dose for US airline crews is about 3 mSv [6], while radiation workers working in the nuclear fuel cycle will receive less than 1 mSv. The United Nations has also highlighted that the use of coal contributes more than half of the total radiation dose to the global public from electricity generation [8]. In fact, the radiation exposure of a person living in the vicinity of a coal-fired power plant is 30 times higher than for a person living close to a nuclear power plant[3] [9].

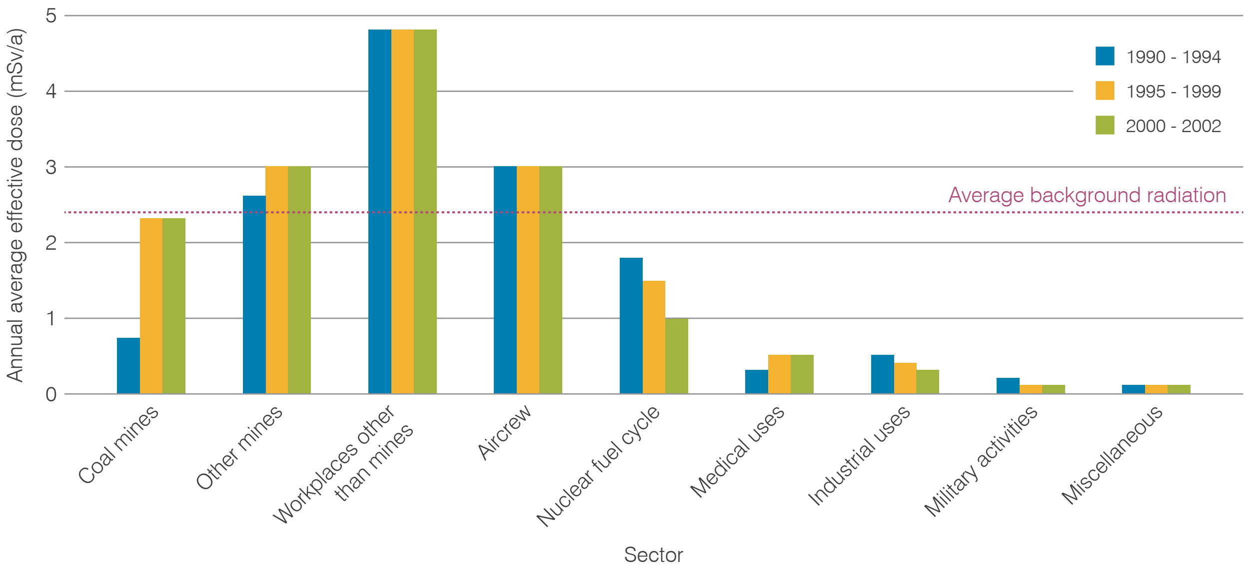

Figure 2. Occupational radiation doses in different industries[4] [8]

Collective dose and health assessments

Historically, the concept of collective dose was developed as a tool to compare different dose optimisation opportunities. Its application has, however, been inappropriately extended to imply or calculate health risks by multiplying very small average doses with the number of individuals in a large group. This practice creates phantom risks by predicting cancer deaths that are impossible to discern and are entirely theoretical as the doses in question are often below natural background radiation levels.

The inappropriate use of the concept has been widely condemned by radiation protection professionals. The ICRP notes that it is inappropriate to use collective dose calculations for theoretical health impacts of radiation exposure as "collective effective dose is not intended as a tool for epidemiological risk assessment, and it is inappropriate to use it in risk projections" [10].

Most recently, in 2016, UNSCEAR recommended that collective dose should not be used to estimate potential health effects:

> *Collective dose is not intended as a tool for epidemiological risk assessment. Moreover, the aggregation of very low individual doses over extended time periods is inappropriate for use in risk projections and, in particular, the calculation of numbers of cancer deaths from collective doses based on individual doses that are well within the variation in background exposure should be avoided [7].*

[3] Annual average exposure from a coal-fired power plant is 0.0003 mSv/year, and 0.000009 mSv/year from a nuclear power plant.

[4] "Workplaces other than mines" includes work groups uncategorized in this graph (*e.g.*, food industries, subways and tunnels), and is the biggest dose-contributor.[3]

Socio-economic impacts

Despite the increasing number of peer-reviewed scientific studies [4, 5] contesting the validity of the LNT model for low doses, some individuals and interest groups continue to actively misrepresent the effects of low doses, leading to unnecessary fears of radiation and nuclear energy.

Risks posed by radiation exposures should always be put into context by regulators and practitioners as one of the many risks that people and the environment are exposed to. A holistic "all-hazards approach" should be used, with all health detriments, both short and long term, weighed – regardless of their source.

The consequences of not adopting such an approach have been demonstrated during radiological incidents and accidents where the fear of radiation, coupled with decision-making disproportionate to the actual levels of radiological risk, have resulted in a detrimental impact on people. This has manifested itself in several different ways. In the short-term, there have been a significant number of fatalities directly connected to decisions to enact evacuations based on overly conservative radiation exposure predictions, where radiation doses would have been too low to cause any harm. In the case of the Fukushima Daiichi accident, there have been more than 2200 deaths resulting from evacuation stress and interruption to medical care [12]. The long-term effects include stigmatization and fatalistic behavior of affected populations, mental health problems (including alcohol abuse, depression, suicide, abortions), and other long-term socioeconomic impacts, seen among both evacuees and on-site clean-up workers.

Improved communication about the low health risks associated with exposure to low levels of radiation will play a role in preventing future health detriments associated with the fear of radiation. The fear of radiation also hinders the fact-based assessment of the beneficial role that nuclear energy can play in creating a modern and sustainable society. This has the indirect consequence of encouraging countries and policymakers to disregard nuclear energy as one of the tools to achieve simultaneously economic development and decarbonization. This, in turn, has negative socio-economic and health consequences for the whole society, as the deployment of nuclear energy can help combat air pollution, energy poverty and climate change.

Conclusions

The latest scientific studies show any risk associated with low doses of radiation (*i.e.* doses less than 100 mSv) is extremely low, if it exists at all. However, misconceptions about radiation directly affect the utilisation of nuclear energy to provide clean, affordable and low-carbon electricity. While no action or practice is without risk, the benefits provided by the use of nuclear energy greatly outweigh the very low risks associated with nuclear power generation.

Disproportionate fears regarding low-dose radiation have led to questionable policy decisions limiting – or stopping completely – nuclear energy activities. World Nuclear Association believes that the ALARA principle is often misused and needs to be recalibrated to consider both costs and benefits. Similarly, the application of collective dose in health-risk assessment has no scientific validity and therefore should not provide a basis for public policy.

The regulatory burden from excessive regulation imposes needless costs upon the global nuclear power industry, achieving – at most – minor decreases in exposure levels, but without delivering any measurable health benefits.

Additional constraints on radiation emissions would also impair the many other beneficial uses of nuclear technology. Non-power nuclear radiation applications improve standards of living. For example, advanced diagnostic and treatment methods have saved millions of lives. Furthermore, the use of nuclear energy provides clean, affordable and low-carbon electricity for many millions of people around the world, ensuring that people can live fulfilling modern lives, with as small a footprint as possible.

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