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THE AUSTRALASIAN RADIATION PROTECTION SOCIETY'S POSITION STATEMENT ON RISKS FROM LOW LEVELS OF IONIZING RADIATION

Donald Higson □ Paddington, NSW, Australia

□ Controversy continues on whether or not ionizing radiation is harmful at low doses, with unresolved scientific uncertainty about effects below a few tens of millisieverts. To settle what regulatory controls should apply in this dose region, an assumption has to be made relating dose to the possibility of harm or benefit. The position of the Australasian Radiation Protection Society on this matter is set out in a statement adopted by the Society in 2005. Its salient features are:

- There is insufficient evidence to establish a dose-effect relationship for doses that are less than a few tens of millisieverts in a year. A linear extrapolation from higher dose levels should be assumed only for the purpose of applying regulatory controls.
- Estimates of collective dose arising from individual doses that are less than some tens of millisieverts in a year should not be used to predict numbers of fatal cancers.
- The risk to an individual of doses significantly less than 100 microsieverts in a year is so small, if it exists at all, that regulatory requirements to control exposure at this level are not warranted.

Keywords: Radiation, risk, hormesis, protection, regulation

INTRODUCTION

At its Annual General Meeting in 2004, the Australasian Radiation Protection Society (ARPS) set up a Working Group to draft a statement of the Society's position on risks from exposure to low level radiation. To carry out this task, the ARPS Executive Committee established the membership of this Working Group, as follows:

Dr Riaz Akber,
Mr Peter Burns,
Dr Donald Higson,
Dr Ches Mason,
Dr Andrew McEwan and
Dr Pamela Sykes

The Working Group was assisted by two of the office bearers of the Society:

Dr Ron Cameron and
Dr Joe Young.

Address correspondence to Donald Higson, 260 Glenmore Road, Paddington, NSW 2001, Australia. Tel: +612 9360 4225; e-mail: higsond@bigpond.net.au

All those who participated in this work did so as private individuals and not as representatives of any organisation other than ARPS.

The Position Statement is appended (Appendix 1). It does not purport to be a comprehensive review of the scientific literature. Rather, it represents a consensus of the expert views of members of the group. Nevertheless, it is considered to be consistent with scientifically based information on the biological effects of ionising radiation. A list is provided of references to some of the key publications considered by the group.

KEY FEATURES OF THE SCIENTIFIC LITERATURE

A number of key features of the scientific literature were noted, as follows:

1. Experiments in radiation biology have shown that damage caused by radiation to DNA in living cells could be an initiating event in the development of cancer in exposed persons and hereditary effects in their descendants. This observation, and the assumption that the risk of radiation induced cancer is proportional to dose without a threshold (the LNT model), underpin current radiation protection practice and reflect the considered views of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the International Commission on Radiological Protection (ICRP).
2. Radiation exposure can also induce or activate cellular DNA protective capacity involving damage prevention, repair and removal, additional to that which would otherwise exist. This “adaptive response” to radiation may reduce the effects of damage from radiation or from other causes.
3. The effects and responses, described in 1 and 2 above, are not necessarily confined to the cell which is hit by a radiation track. A cell which is hit can interact with neighbouring cells by intercellular communication systems, thus involving *inter alia* defence mechanisms in the tissue and organ as well as in the cell.
4. Experiments with irradiation of animals have shown that the enhancement of protective capacity, described in 2 above, can predominate over detrimental effects at low levels of radiation exposure. Such an effect, sometimes called “radiation hormesis”, has been observed in cells from virtually all types of organisms, in whole plants and animal species other than humans, and in human cells. For doses greater than about 100 mSv in animals, it has been observed that detrimental effects may dominate.
5. Hence, both bio-positive and bio-negative effects of radiation might be expected in humans. At low levels of exposure, the net effect may be either positive or negative or too small to be of any practical significance.

6. The human race (as it now exists) represents only the small, successful part of all the trials and errors of evolution, which has occurred in the presence of ionizing radiation and many other agents that are harmful at high levels of exposure, including sunlight, heavy metals in food and water, arsenic and various naturally-occurring chemical compounds. Levels of these agents in our environment have varied from place to place and from time to time during the evolution of life on earth. It is a fundamental tenet of evolutionary biology that organisms adapt to their environment. Hence, it might be expected that a normal level of exposure to these agents would be necessary for life and normal health; that small increases above the normal level might be beneficial although large increases would be harmful. The beneficial effect from small increases in exposure to environmental agents occurs widely in nature and is called “hormesis”. There is no such thing as a toxic agent – only toxic doses. Calabrese and Baldwin (2003) have concluded that “the hormetic model is not the exception to the rule – it is the rule”.
7. Human epidemiology has shown that acute doses greater than about 100 mSv can cause increases in the incidence of cancer. For acute doses less than a few tens of millisieverts and for low dose rates, there is often a lack of statistical significance to any health effect of radiation. Studies are confounded by many factors including diet and smoking, which can have much greater effects on the incidences of cancer than radiation. Smoking is a powerful confounding factor in epidemiology related to many forms of cancer, not just lung cancer.
8. There is no significant discernable effect of natural background radiation on the incidences of cancer or genetic damage, although the background dose rate ranges around the world from less than 1 mSv per year to more than 100 mSv per year in a few areas. Lifetime doses from natural radiation range up to thousands of millisieverts. Populations exposed to very high dose rates for long periods, and for many generations, may be too small for reliable statistically based conclusions to be drawn. Nevertheless, it can reasonably be said that harm has not been found to result from exposures to chronic dose rates up to at least a few tens of millisieverts per year.
9. Many studies have been conducted of the possible risk of lung cancer due to radon in homes. Results range from positive to negative correlations, possibly *inter alia* because of the confounding effect of smoking. Recent studies of pooled data suggest a linear relation between excess relative risk and radon exposure down to less than 5 mSv/y, with significant uncertainties. A conclusion which can be drawn from one such study, by Darby *et al* (2005), is that the absolute risk of lung cancer from radon is predominantly a risk to smokers, apparently compounded by the synergistic effect of radon. Without

smoking, the reported risk from radon (up to at least 20 mSv/y) is small compared with other causes.

10. The effects of low dose exposure to external radiation have been estimated in several cohorts of workers in the nuclear industry, but the sample sizes have limited the significance of these estimates. Estimates from these analyses are compatible with a range of possibilities, from a reduction of risk to risks higher than those underlying current radiation protection recommendations. Again, smoking is a powerful confounding factor. The study of pooled data by Cardis *et al* (2005) has concluded that “a small excess risk of cancer exists, even at the low doses typically received by nuclear industry workers in this study”. However, a careful examination of the published report leaves room for some doubt on the inferences that may be drawn from it. For example, without the inclusion of Canadian data, which show unusually high (and unexplained) cancer mortality, the findings of Cardis *et al* appear to be statistically insignificant.
11. The only confirmed health effects of radiation from the Chernobyl reactor accident in 1986 have been associated with very high doses to workers, who were at the plant at the time and immediately following the accident, and to the thyroids of children in some districts around Chernobyl. About 100,000 workers and many members of the public were exposed to doses in excess of 100 mSv. There has been no discernible increase in the incidence of cancers, other than child thyroid cancer, but it may be too early to draw firm conclusions about the development of solid tumours with minimum latency periods of 10-20 years. The incidence of leukaemia was one of the main concerns, due to its short latency period (5-10 years after radiation exposure in adults). No increase has been observed in the incidence of leukaemia in any of the exposed groups.
12. Major reviews of literature on the biological effects of radiation, published by Brenner *et al* (2003) and the BEIR VII Committee of the National Research Council of the National Academies (2005), and in draft documents posted on the ICRP website in 2005, have endorsed the assumption of the LNT model. However, they do not refer to important evidence that conflicts with the LNT assumption. The authors of these reviews may have good reasons for dismissing such evidence but, without a considered analysis, it is difficult to understand and concur with their conclusions.

The Working Group’s attention was drawn to reports concerning more than 180 apartment buildings, constructed in Taiwan more than 20 years ago using reinforcing bars contaminated with cobalt-60 (apparently from an orphaned source, which had been inadvertently recycled through a steel fabrication plant). It has been estimated that up to 10,000 residents

incurred an average dose of about 400 mSv from the cobalt-60, some of them being exposed initially to dose rates greater than 500 mSv/y. Chen *et al* (2004) have reported dramatic reductions in the overall incidences of cancers and hereditary defects amongst these residents – by factors of more than ten below the numbers which would be expected for an unexposed population. This extraordinary incident and report have attracted little independent analysis by other authors and seem to have had essentially no impact on the theory or practice of radiation protection.

REACHING CONSENSUS AND ADOPTION OF THE STATEMENT

Beyond the agreement that was reached on points 1 to 12 above, opinions within the Working Group ranged widely on all other issues discussed. Significant compromises were necessary to reach a consensus on the wording of the Statement. The resulting document, entitled “ARPS Position Statement on Risks from Exposure to Low Levels of Ionizing Radiation” (Appendix 1), was circulated to ARPS members and was adopted by the Society at its Annual General Meeting held in Melbourne, on 14 November 2005.

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APPENDIX 1. THE ARPS POSITION STATEMENT (ADOPTED 14 NOVEMBER 2005)

Controversy continues in the radiation protection literature on whether or not ionizing radiation is harmful at very low doses. There is scientific uncertainty about the dose-effect relationship below a few tens of millisieverts in a year, and in order to settle what regulatory controls, if any, should apply in this dose region an assumption has to be made relating dose to the possibility of harm or benefit. The assumption made and, more particularly, the way it is applied can have far-reaching effects not only on the scale of regulatory compliance required but also on public perception of risk and therefore on the technological choices made by society. It is important therefore that decisions reached concerning regulation of low doses of ionizing radiation have an ethical basis and derive from rational argument. It is also important that such decisions are neither portrayed nor perceived as resolving the scientific uncertainties: rather they serve merely to facilitate the implementation of appropriate safety measures.

Following a review of available information, the Australasian Radiation Protection Society has adopted the following position. Based on the features observed, the range of exposures has been divided into three broad dose groups, but it should be noted that the boundaries between them are not known with precision.

Doses above about 10 mSv in a year

- There is strong epidemiological evidence that acute exposure to ionizing radiation of more than about 100 mSv carries a risk of developing fatal cancer that increases with dose, with some limited evidence supporting a risk at slightly lower doses. There are also epidemiological reports of statistically significant risk from long-term cumulative exposures that correspond to doses received at rates down to a few millisieverts in a year, but it is difficult to be confident that the observed effects can be reliably separated from possible confounding factors.
- In the light of the above, for the purpose of applying regulatory controls to radiation protection when effective doses exceed a few tens of millisieverts in a year, it is reasonable to assume a generalized risk coefficient for fatal cancer of 1 in 20 per sievert for a population of all ages, as recommended by the International Commission on Radiological Protection [ICRP Publication 60]. This assumption is less reliable for exposures below 100 mSv in a year than above.
- Consistent with this assumption, an effective dose limit for occupational exposure of 20 mSv per year, averaged over 5 years and no more than 50 mSv in any one year, remains appropriate, as does a requirement to optimize protection below this value. Separately, safety measures are required to avoid deterministic effects of radiation at very high doses.

Doses between about 0.1 and about 10 mSv in a year

- There is insufficient epidemiological evidence to establish a dose-effect relationship for effective doses of less than a few tens of millisieverts in a year above the background level of exposure. It is possible that both an adverse effect, through causation of cancer following radiation damage to DNA, and a beneficial effect, through stimulation of repair mechanisms, may operate. It has also been speculated that such a stimulatory effect might reduce mortality from cancer caused by agents other than radiation, resulting in a net decrease in risk. Consequently, neither harmful nor beneficial effects can be ruled out.
- To put doses in this range into perspective, it is worth noting that the worldwide average exposure to natural radiation sources is estimated by the United Nations Scientific Committee on the Effects of Atomic Radiation to be 2.4 mSv in a year, with a typical range of 1 to 10 mSv in a year. There are a few areas of the world where much higher doses are

received from naturally-occurring sources without causing discernible risks to health.

- Taking an ethical position of caution in the face of uncertainty, the risk coefficient adopted above for higher doses may be used for the purpose of establishing control measures for exposure to radiation at lower doses. In particular, the use of an effective dose limit of 1 mSv in a year for members of the public is appropriate for exposure caused by the conduct of business activities. This limit will ensure that the additional risk of harm, if any, arising from such activities is acceptably small. However, no inference may be drawn concerning the risk to health or risk of fatality of an individual from an effective dose below 10 mSv in a year. For individual doses less than some tens of millisieverts in a year, risk inferences are unreliable and carry a large uncertainty that includes the possibility of zero risk.

Doses below about 0.1 mSv in a year

- The risk to an individual of doses less than a few hundredths of a millisievert in a year is so small, if it exists at all, that regulatory requirements to control exposure at this level are not warranted. Business activities causing individual effective doses of the order of 0.01 mSv in a year or less should be automatically exempted from regulatory control, provided that the activity is inherently safe: that is, there is little likelihood of accidents leading to significantly higher doses. Activities causing levels of exposure up to 0.1 mSv in a year may also be exempted if the regulatory body determines that the application of controls is not warranted, taking into account all relevant factors. In deciding whether control measures are warranted, or how stringent they should be, regulatory bodies should have in mind, *inter alia*, the principle that societal resources should not be wasted or freedoms inhibited through mandatory observance of unnecessary regulatory controls.

Collective dose

- Estimates of collective dose to groups or to populations should be used with caution. In view of the uncertain association between low doses and risk, estimates of collective dose arising from individual doses that are less than some tens of millisieverts in a year should not be used to predict numbers of fatal cancers for the exposed group or population.
- However, if collective doses to subgroups of an exposed population are each assigned an appropriate weight, they may play a role in making a choice between possible control measures and thus in optimizing protection. The component of collective dose arising from the summation of individual doses that are less than about 1 mSv in a year should be as-

signed little significance relative to components associated with sub-groups receiving higher doses, and the component associated with doses less than some hundredths of a millisievert in a year may be assigned a weight of zero. Various values for this cut-off have been proposed, from 0.01 to 0.1 mSv.

What is 'safe'?

- The word 'safe' may be used to describe business activities that meet currently prescribed radiation safety standards. While there may be some, as yet uncertain, risk arising from such activities, it is known to be small at most and, through application of the justification principle, to be outweighed by the benefits brought by the activity. It follows that exposures of this order may be described as 'safe', understanding that the word is used not in an absolute sense but with the meaning of causing an acceptably small risk, if any.