INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

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Areas of Research to Support the System of Radiological Protection

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One of the three priorities in the International Commission on Radiological Protection (ICRP) Strategic Plan for 2016-2020 is to "maintain and improve the system of radiological protection". A key action under this priority is to "identify and encourage research needed to support radiological protection". This document presents ICRP's views, to encourage dialogue and help focus research initiatives. In no particular order, the areas of research identified are:

- **Effects of protracted exposures and low dose rates**
- **Mechanisms of low-dose effects and dose-response models that take account of them**
- **Organ-specific, and age and sex differences in, sensitivity to cancer induction**
- **The role of genetic differences in determining individual sensitivity**
- **Effects other than cancer and genetic effects and their contribution to detriment**
- **Relating exposures, doses, and effects on population viability for non-human biota**
- **Reliability of dose assessments**
- **Dosimetry and protection methods in medicine**
- **Ethical and social dimensions of the system of radiological protection**
- **Mechanisms for interaction with stakeholders**

Effects of protracted exposures and low dose rates

Studies of population groups exposed as workers, patients, or public are important to provide information relating to protracted exposures to moderate doses and low dose rates (< 5 mGy/h) from external sources and internally deposited radionuclides.

Mechanisms of low-dose effects and dose-response models that take account of them

Health effects at low doses (defined as <100 mGy) and low dose-rates are generally not discernible in epidemiological studies but are inferred based on biological plausibility and quantitative estimates obtained using risk extrapolation models, the simplest of which is the LNT model used for protection purposes. There is a need for further studies of mechanisms of low dose effects at molecular, cellular and tissue levels and the development of dose-response models that take account of these mechanisms. Biological samples of normal and diseased tissues taken during epidemiological and experimental studies have the potential to link molecular changes to observed health effects.

Organ-specific, and age and sex differences in, sensitivity to cancer induction

There is a reasonable understanding of the effects on human health of high and moderate doses of radiation in relation to tissue reactions and stochastic effects. However, it is important that all sources of direct information continue to be pursued, including, but not limited to, the follow-up studies of the survivors of the atomic bombings at Hiroshima and Nagasaki, which have provided much of the quantitative data on cancer risks that are used in the development of protection standards. This and other epidemiological studies will yield additional information on organ/tissue sensitivity to cancer induction and age and sex differences in sensitivity.

The role of genetic differences in determining individual sensitivity

As noted above, there are differences in the sensitivity of groups to exposure to radiation based on age and sex. Differences due to some lifestyle characteristics, such as smoking, have also been observed. The role of genetic differences in determining individual sensitivity also has potential to significantly influence radiological protection, and requires further study.

Effects other than cancer and genetic effects and their contribution to detriment

Stochastic effects are taken to include cancer, for which there is direct epidemiological evidence, and hereditary disease, for which reliance is placed on mouse data. There are concerns that some diseases thought to occur above dose thresholds, notably including circulatory diseases and opacities of the lens of the eye, might in fact exhibit dose-response relationships more like the linear non-threshold (LNT) dose-response assumed for stochastic effects. Further work is required to determine whether other diseases should be considered as contributors to low-dose detriment.

Relating exposures, doses, and effects on population viability for non-human biota

In general, considerations applying to effects of radiation in humans apply also to non-human fauna and flora. Thus, it is important to develop appropriate dosimetric models, understand dose-response relationships and account for differences in sensitivity between organisms and life stages. However, the focus of protection for non-human biota is on population viability and hence on tissue reactions, including gross impairment of reproductive capacity and effects on future generations. Further research is needed to understand exposures, doses, and effects relevant to population viability for various species. This would include improving the understanding of dosimetry in the environment, the relationships of those measurements to a measure of exposure to the organism of interest, and the relationship of those estimated exposures to population endpoints.

Reliability of dose assessments

All studies of health effects caused by radiation require reliable assessment of dose. In general, absorbed dose is calculated as an average for the mass of a whole organ or tissue but, in a few

cases, account is taken of the location of target cells for the induction of stochastic effects, assumed to be the stem cell population. Such considerations are important when calculating doses from radionuclides with short-range emissions of, for example, alpha particles and low energy beta particles. Also important in such cases are considerations of radiation quality and the relative effectiveness of radiations in causing health effects. Further work is required to ensure the reliability of dose assessments, including considerations of localised doses within tissues in relation to target cells, radiation quality and microdosimetry.

Dosimetry and protection methods in medicine

Improved radiological protection in medicine and other applications requires a better understanding of dosimetry and methods of protection of patients, staff and the public. Assessment of lens of the eye, skin, and extremity doses and methods of protection is necessary to improve occupational protection in interventional and nuclear medicine procedures. Similarly, lens of the eye, skin and organ dose evaluation must be better understood to improve protection for patients who undergo CT and high-dose interventional procedures. Dosimetric data are needed to help in the assessment of non-cancer effects (such as cardiovascular and cerebrovascular) in radiotherapy and high-dose imaging procedures. Additional methods need to be developed, on a continuing basis, to reduce patient dose while maintaining diagnostic information.

Ethical and social dimensions of the system of radiological protection

In the consideration of the development of an integrated protection system for humans and the environment, further analysis and case studies will be required to evaluate suitable approaches and methodology. It is also important that ethical and social values are appropriately applied in circumstances of occupational, public, environmental, and medical exposures, to achieve acceptable and sustainable decisions. Tolerability and acceptability of radiation exposures depends upon the situation and circumstances of exposure. Further work is required to elaborate and increase the practical utility of guidance provided to support these judgements, particularly in relation to existing and emergency situations, developing approaches to the determination of what may be reasonable levels of exposure, balancing potential benefits and inferred risks.

Mechanisms for interaction with stakeholders

Practical implementation of decision making following the principles of justification and optimisation of protection relies on the development of mechanisms for involving stakeholders. Further research, based on the analysis of successful experience, is needed to identify approaches to engage those directly impacted more effectively. This is particularly relevant for existing and emergency exposure situations.