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Short Research Article

Radiation protection of man and the environment†

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Abstract: Radiological protection has traditionally been concerned with the protection of human beings, but it is now recognized that this approach has to be complemented by a measured concern for the protection of the environment as a whole. This broader synthesis brings with it both new challenges and opportunities, some aspects of which are briefly discussed. Copyright © 2007 John Wiley & Sons, Ltd.

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Introduction

The primary aim of radiological protection has been, as stated by the International Commission on Radiological Protection (ICRP),[1] to provide an appropriate standard of protection for people without unduly limiting the beneficial practices giving rise to radiation exposures. The ICRP has nevertheless had regard to the potential impact upon other species, although it has not made any general statements about the protection of the environment as a whole. Indeed, in its Publication 60 it stated that, at that time, the ICRP concerned itself with mankind's environment only with regard to the transfer of radionuclides through the environment, because this directly affects the radiological protection of human beings. It did, however, also express the view that the standards of environmental control needed to protect human beings to the degree currently thought desirable would ensure that other species are not put at risk.

The health objectives of the ICRP's system of human radiological protection are relatively straightforward: to manage and control exposures to ionizing radiation so that acute effects are prevented, and so that the risks of long-term health effects are limited to acceptable levels. And although such objectives may be affected by moral and ethical values, the consequences of such differences are relatively minor compared with the level of agreement upon which the advice and recommendations are based.

In contrast, there is no simple or single universal definition of 'environmental protection' and the concept differs from country to country, often because of differences in moral and ethical values, as well as from one circumstance to another. The levels and forms of protection required for the environment, in relation to all manner of human activities and circumstances, are therefore continually being defined and redefined by different countries in order to meet their own internal societal needs and international obligations. Nevertheless, it is highly desirable to maintain some form of common approach to radiation protection of the environment, and to derive a common understanding and scientific base for the radiological protection of both man and non-human species in an environmental context, and attempts are now being made to do so.

Human radiation protection

The current systematic approach to human radiological protection is based on the fundamental principles of both justification and optimization of protection in relation to the sources of radiation exposure, and the principle of dose limitation in relation to the individuals who are exposed. It is an approach that has evolved over many years in order to manage situations (*categories of exposure*) in the context of medical exposures, occupational exposures, and exposures of members of the general public, both now and in the future. It also relates to three *types of exposure* situations: those that are planned and fully under

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operational control; other situations that currently exist and may need to be brought under control; and situations that may be regarded as accidents or emergencies. It is based on an enormous range of knowledge on the effects of radiation on human beings, including epidemiological studies, supplemented by other data from experimental studies on animals, and investigations at the molecular and cellular level. The ICRP attempts to convert all of these data, together with their errors, uncertainties, and knowledge gaps, into pragmatic advice that will be of value in managing all exposure situations.

The advantage of such a comprehensive and systematic approach is that, as the needs for change to any component of the system arise (as in the acquisition of new scientific data, or changes in societal attitudes, or simply from experienced gained in its practical application) it is then possible to consider what the consequences of such a change may have elsewhere within the system, and upon the system as a whole. Such a system would not work unless it was based on a numerical framework that contained some key points of reference, particularly with respect to how best to relate exposure to dose, dose to the risks of radiation effects, and the consequences of such effects. A key step in developing this scientific framework has been the creation of an entity known as Reference Man, which has served as a conceptual and analytical tool for many of the ICRP's numeric analyses and resulting conclusions.

The development and application of these ICRP principles has, inevitably, been subject to interpretation and examination from an ethical point of view, essentially ranging from what is seen as a *utilitarian* ethic (maximizing the net benefit) to a *deontological* ethic (concern for the individual);[2,3] although, in practice, the consequences are relatively small compared with the level of concordance that exists with respect to the underlying science.

Environmental protection

In contrast, although the need to protect the environment is now generally accepted around the world, attitudes and approaches to its practical achievement differ widely. Such differences are, to some extent, a reflection of the many points of view that can currently be identified within the environmental ethical spectrum. Such views arise from philosophical considerations about what has moral standing or value in the world, and why. For convenience, they may be summarized as *anthropocentric*, in which human beings are the main or only thing of moral standing, and thus the environment is of concern primarily as it affects humans; *biocentric*, in which moral standing can be, and often is, extended to individual members of other species (particularly in view of the fact that many animal species can be shown to be *sentient*, in that they can experience pleasure and pain) and thus moral obligations pertaining to such individuals arise as a consequence; and *ecocentric*, in which moral standing can be extended to virtually everything in the environment, biotic and abiotic, and thus includes landscape features such as rivers and mountains, where the focus lies more with the entirety and diversity of the ecosystem rather than with the moral significance of each and every individual component of it. There are, of course, considerable ranges of views within and amongst each of these three broad categories.

But notwithstanding all of these different ethical views, a number of multilateral environmental agreements have emerged in recent years, particularly with regard to the need to maintain biological diversity both within species (i.e. their genetic, morphological, and physiological variations), and amongst species (their overall number and variety) and to protect habitats and ecosystems. From a practical point of view, however, the environment is generally managed by way of legislation that directly relates to such activities as pollution control, or the use of natural resources, or nature conservation. Collectively, or individually, such frameworks ultimately result in restrictions that may be placed upon the siting or operation of relevant industrial facilities. Advice with regard to the actual or potential effects of radiation on the environment, resulting from different types of exposure situations, therefore – needs to be tailored to interface with such existing frameworks of environmental management.

Radiation effects and its consequences in an environmental context

For human beings, it has been convenient to consider the effects of radiation as being of a non-stochastic (causing tissue damage) or of a stochastic nature. Such effects are also seen in mammals, and data from studies on a number of species have been extensively used to help gain a clearer picture of the effects of radiation on human beings. With regard to non-human species in general, however, not only is there a lack of data to classify radiation effects in such a way, but there is also no clear reason as to why or how such information could be useful in assuring that any of the objectives of protecting the environment had been achieved. From a practical point of view, most information about the effects of radiation can only be derived at the level of the individual (or small groups of individuals), whereas the primary environmental protection

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requirements arise primarily at the 'population level' or higher. Thus, bearing in mind that a population may be defined in terms of number, birth rate, death rate, age distribution, sex ratio, density, or by 'genetic breaks', the factors dominating such parameters are primarily those of mortality, fertility, fecundity, and mutation rate. Other ways of considering radiation effects are therefore likely to prove to be more useful for assessing potential detriment to non-human species, such as those that cause early mortality, or morbidity, or reduced reproductive success, irrespective of the stochastic or non-stochastic nature of the underlying causes.

And also in contrast to the human animal, such biological end points may relate to different stages in the animal or plants' life cycle that, simultaneously, occupy different parts of the environment. Thus, for example, the eggs of a free-swimming fish may be laid on the sea floor or, as in the case of most frogs, the eggs and young may inhabit the aquatic environment whereas the adult may be largely terrestrial. The most critical evaluations of dose and effect may therefore be either in relation to the gonad of the adult residing in one part of the environment, or to its eggs and young simultaneously residing in another.

And a further complication – as if one were needed! – is that some species reproduce several times in their life times (*iteroparous*), and such reproduction may be more or less at any time of the year, or limited to a specific season. Such populations will therefore have overlapping generations; although, in the case of the latter, discrete cohorts of the population can usually be identified. Some species, however, reproduce only once in a lifetime (*semelparous*), and if this occurs seasonally, then each entire population will also consist of a discrete (genetic) generation.

Creating points of reference

So where to start? The possession of a clear framework for examining the science base has been a key component in the successful development of the ICRP's system of protection for human beings. Given the vast range of animals and plants that could potentially be of interest, and their many interactions at population, community, and ecosystem levels within different environments, the need for some points of reference is essential. But, of necessity, they also have to be limited in number. Thus, in order to generate a more fundamental understanding and interpretation of the relationships between exposure and dose, and between dose and the risk of certain categories of effect, and the consequences of effect for a few clearly defined biotic types, the ICRP is now developing a small set of Reference Animals and Plants (RAPs).[4] The concept is therefore similar to that of the use of a Reference Man, in that such entities are intended to act as conceptual models, to serve as a basis for reference calculations, as in dosimetry, and to serve as a focus for interpreting exposure and effects data in a manner that should be useful as a basis for future decision making. (It is therefore also important to note that such RAPs are not necessarily the *direct* objects of protection – any more than Reference Man is!) And bearing in mind the need to provide guidance that could be of value across different conceptual approaches to 'environmental protection', or at least environmental management, with regard to all three types of exposure situations, the set as a whole has to be chosen bearing in mind not only the need to reflect a range of dosimetric geometries, but life styles, life cycles, longevities, reproductive strategies and so on. This work is now being progressed through a new Committee (Committee 5) of the ICRP, drawing upon other existing research programmes worldwide, and in close collaboration with other international bodies.

Conclusion

There is a clear need to develop a common approach to protection of the environment generally, and to develop one that is also compatible with the scientific approach to human radiological protection for a range of actual and potential exposure situations. This need has now been recognized, and steps are being taken to address it at an international level.

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