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RADIATION PROTECTION OF NON-HUMAN SPECIES

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ABSTRACT

The effects of radiation on non-human species, both animals and plants, have long been investigated. In the disposal of radioactive wastes, the protection of non-human species has been investigated. Yet no radiation protection standard for exposure of animals and plants *per se* has been agreed. The International Commission on Radiological Protection has long taken the view that, if human beings are properly protected from radiation, other species will thereby be protected to the extent necessary for their preservation. However, the International Atomic Energy Agency has found it necessary to investigate the protection of non-human species where radioactivity is released to an environment unpopulated by human beings. It is proposed that the basis of such protection, and the knowledge of radiation effects on non-human species on which it is based, suggest a practical radiation protection standard for non-human species.

INTRODUCTION

Throughout its long history, the International Commission on Radiological Protection (I.C.R.P.) has rightly concerned itself to ensure the protection of human populations and individual human beings. In this highly populated world, in which human beings consume a vast range of animals and vegetables, it has been reasonable to consider the protection of non-human species to be ensured if human beings, at the peak of the food chain in general, are properly protected. But the disposal of radioactive wastes by dispersion in the sea has been assisted by disposal in waters remote from human beings and from human food sources, for initially it was assumed safe to dump much larger activities than would be permissible if human beings could be exposed. In this crowded world, few such places exist, and an increasing voice in more developed countries calls for prevention of disturbance of remote, pristine places. It is not surprising, therefore, that the International Atomic Energy Agency (I.A.E.A.) has seen fit to study the radiation effects of waste disposals, in remote parts of the sea, on animals and plants alone. The protection of animals and plants is not considered by the I.C.R.P. or the I.A.E.A. to be a matter of *individual* protection, but only a matter of species preservation.

EVOLUTION OF ATTITUDES TO RADIATION PROTECTION OF NON-HUMAN SPECIES

In 1977, the I.C.R.P. stated (I.C.R.P. 1977) "the level of safety required for the protection of all human individuals is thought likely to be adequate to protect other species, although not necessarily individual members of those species." In its study of deep-sea dumping of radioactive wastes, the I.A.E.A. stated (I.A.E.A. 1988): "Dumping occurs at depths greater than 4000 m, resulting in dilution and a large spatial separation between the dumping site and the pathways back to man.....It is therefore theoretically possible to sustain relatively high levels of dose to deep sea organisms, while keeping levels of human exposure to acceptable levels," and "The major effects considered in this review were those concerned with mortality and histopathological changes, reproductive success and genetics. It was considered that those relating to reproductive success were the most relevant to environmental impact assessment." The I.C.R.P. then stated (I.C.R.P. 1991) "Occasionally, individual members of non-human species might be harmed, but not to the extent of endangering whole species or creating imbalance between species." Thus, I.C.R.P. made a significant addition to its 'belief', for it now considered the need to protect against causing imbalance of species. The I.A.E.A. then published a study (I.A.E.A. 1992) whose objective it was "to determine whether the statements of the ICRP about protection of non-human organisms and populations are consistent with current knowledge." Both the statements of the I.C.R.P. and the I.A.E.A. in the 1990's follow a lone publication (Thompson 1988) that proposed that, although it was reasonable to use the 1977 statement of the I.C.R.P. as a working hypothesis, it was less reasonable that, 10 years later, it was not clear that the hypothesis was a good one. Furthermore, Thompson reported evidence that the hypothesis was being accepted, not as a working hypothesis, but as a fact in some official quarters.

SCOPE OF THIS PAPER

The situation then is that preservation of species and the species balance is an objective of the I.C.R.P. In this paper, this is taken to apply only to natural non-human populations, not to pet animals or treasured garden plants, which, in general, are not eaten by their owners, and are tended with great care, so are not of concern. This paper considers the radiation protection of natural populations of non-human species.

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ETHICALLY ACCEPTABLE RISKS TO NON-HUMAN POPULATIONS

Ethical values are considered in setting radiation protection standards for human individuals and populations. The ethical stances adopted (Bengtsson 1993) may be to minimise the total harm to human health, to distribute risks among the population equably, or maximise the resources devoted to protection of human health. Such sophistication of approach is inappropriate with respect to non-human populations. In natural populations, life-span of individual organisms is dependent on many factors, including variations in food and water supply, predation (as all, or most, form part of a food chain), excessive population expansion, disease, and climatic variation. It is fruitless to attempt to protect all individual members of a non-human species from any type of risk, including that from radiation. It is ethically sound to protect species from extinction, and further, to protect the whole environment to avoid upsetting the balance of species. This is not to suggest that species will always remain at a settled state of balance. They never have, in the whole history of life on earth. But a significant, abrupt upsetting of the current balance of species due to an excessive exposure of the environment to ionising radiation cannot be justified ethically.

DOSIMETRY FOR NON-HUMAN POPULATIONS

The weighting factors recommended by the I.C.R.P. in calculating effective doses to human beings make allowance for the different biological effectiveness of different radiations of different energies, and the different sensitivities of different tissues. Such differences will also exist in the irradiation of animals and plants, albeit with different weighting factors. In its study of deep sea dumping of radioactive waste, the I.A.E.A. (I.A.E.A. 1988) made allowance for the different biological effectiveness of different radiations by adopting the 'quality factors' recommended by the I.C.R.P. (I.C.R.P. 1977) for exposure of human beings, expressing doses for benthic organisms as 'dose equivalents' in 'mSv'. In its study of an actual dumping site, the N.E.A. (N.E.A. 1985) adopted a similar approach. However, later (I.A.E.A. 1992), the I.A.E.A. expressed all doses as absorbed doses, converting dose equivalents for α-particles using a 'quality factor' of 20. However, it is suggested here that the weighting factors may be disregarded, and that radiation protection standards for non-human species can be expressed, initially, in terms of the absorbed doses received. This approach is similar to the early development of radiation protection standards for human beings.

RADIATION EFFECTS ON NON-HUMAN SPECIES

In the early days of nuclear energy, many research projects were carried out on the effects of radiation exposure on animals and plants. At this time, before the strong vegetarian/anti-vivisectionist lobby that has arisen in highly developed countries in recent years, much of the research was aimed at gaining information relevant to the estimation of human sensitivity to radiation, and about the concentration of radioactivity in food chains leading to human beings. This research revealed a huge variation in sensitivity to radiation of non-human species and a lower sensitivity, in general, than that of human beings. Trees and insects have been found to be much less sensitive to ionising radiation than animal species, in general (Edwards 1969, Platt 1965). When these lower sensitivities are combined with the ethical stance taken above, it is to be expected that a radiation protection standard for non-human species may be set much higher than for human beings.

The results of the many studies of irradiation of plants, animals, insects and fish have mainly been directed to the overall (direct) effect of irradiation on populations of a species. Only a relative few have examined the indirect effects of irradiation. For example, a reduction of vegetation can have an indirect effect on the similarly irradiated populations of insects (Poinsot-Balaguer et al. 1991). Further, a sensitivity difference of different species of animals in a food chain can upset the normal pattern of predators and prey, indirectly affecting the survival of species under irradiation (Edwards 1969, Poinsot-Balaguer et al. 1991); a case of disturbing the species balance.

Mortality and Extinction of Non-Human Species

Extensive reviews of the studies of radiation effects on non-human species have been made in relation to disposal of radioactive wastes to the sea (I.A.E.A. 1988, N.C.R.P. 1991, I.A.E.A. 1992). In its 1988 report, the I.A.E.A., after surveying all relevant literature, stated "extensive mortality in the vicinity of a disposal site would be expected only in those areas receiving dose rates in excess of $10\ mSv \cdot h^{-1}$." and "changes in reproductive success may occur as the result of damage to gonadal tissue and alterations in development. The dose rate at which this response occurs is about $1\ mSv \cdot h^{-1}$ and appears to define a limit above which

1a group of effects on reproduction, development and genetic integrity are detectable in sensitive tissues and organisms." The N.C.R.P. (N.C.R.P. 1991) concluded, for protection of aquatic organisms: "it appears that a chronic dose rate of no greater than 0.4 mGy·h⁻¹ ... to the maximally exposed individual in a population of aquatic organisms would ensure protection for the population"

In its 1992 report, the I.A.E.A., after further review of research on terrestrial, as well as aquatic, biota, stated: "There is no convincing evidence from the scientific literature that chronic radiation dose rates below 1 mGy·d⁻¹ will harm animal or plant populations." and "It would appear that chronic dose rates of 1 mGy·d⁻¹ or less to even the more radiosensitive species in terrestrial ecosystems are unlikely to cause measurable detrimental effects in populations and that up to this level adequate protection would therefore be provided." In the case of aquatic biota, the I.A.E.A. stated in the same report "it would appear that limiting chronic dose rates to 10 mGy·d⁻¹ or less to the maximally exposed individuals in a population would provide adequate protection for the population"

From these two reports by I.A.E.A., it is suggested that we can draw the conclusion that, to protect *populations* of non-human species *per se* from extinction and disturbance of the balance of species, an upper limit of 1 mGy·d⁻¹ can be adopted with confidence. In the case of aquatic biota, since only a small group may receive 10 mGy·d⁻¹, it seems reasonable to set the population dose an order of magnitude lower.

Disruption of the Balance of Non Human Species

Disruption of the balance of species by radiation has been investigated using chronic irradiation and acute irradiation. With either, a change in the normal balance of species has been found when an ecosystem has been irradiated. C.A. Edwards reported (Edwards 1969) "The susceptibilities of the common groups of small soil animals to a large dose of gamma radiation are compared . The most striking feature of these data is the clear correlation between the activity and mobility of the animals and their susceptibility to the radiation. The more active animals, such as centipedes, wood lice, surface-dwelling Collembola (Entomobryidae and Sminthuridae), parasitic mites and symphylids were very much more susceptible to irradiation than the sluggish oribatid mites or deep soil-dwelling Collembola (Onychiuridae and Poduridae). Worms, nematodes, fly larvae and beetles are of intermediate activity and are also moderately susceptible to irradiation.".

Poinsot-Balaguer and co-workers (Poinsot-Balaguer et al 1991, Poinsot and Bigot 1974) reported striking differences in sensitivity of different species of soil arthropods to chronic irradiation, leading to a change in species balance. They reported (1974) "After three years, the *Psocoptera* population had increased explosively. The *Collembola* had disappeared almost completely in the most irradiated zone. Only two series could maintain themselves.". In 1992, they reported. "In the most irradiated zones, the overall animal density was low, with a small number of *Oribatei* (which are dominant in the rest of the oak forest) and a dominance of other *Acaridiae* ... *Oribatei* thus seem to be the most sensitive to irradiation and the other *Acaridiae* occupy the vacuum left after their disappearance. The replacement of highly specialized species by ubiquitous species perfectly adapted to environmental disturbances confers a specificity to the edaphic population of the irradiated soil system."

In a forest system in the U.S.A., R.B. Platt (Platt 1965) studied the effects of fairly acute irradiation. He also found that at doses above 30 Gy, the species balance was disturbed. Pine trees were much more sensitive than hardwood trees to the fast neutrons and γ-radiation to which they were subjected.

CONCLUSION

In Table 1 are assembled the dose rates (and some doses) above which the effects discussed above may occur. The first four entries in this table indicate a rapid evolution downwards in the limiting level for serious effects on reproduction. The last three entries indicate that disruption of the balance of species appears only at much higher dose-rates, when the mortality rate of some of the more sensitive species is increased. This paper has considered the protection of non-human species for radiation in the general environment, not just in aquatic environments. There are still remote places on land that are not inhabited by human beings, where the resident biota may include more sensitive species. Hence, it is suggested that a universal radiation protection standard for populations of non-human species be established as **1 mGy·d⁻¹**. This is significantly greater than the appropriate standard for human beings, yet would seem to protect all non-human species from extinction or disruption of species balance due to radiation. Then such species need only cope with all the other man-made and natural stresses that may harm them.

Table 1

Comparison of Levels of Absorbed Dose Above which Effects of Imbalance or Extinction of Non-Human Species have been Found

Reference	Biota	Radiation Effect	Absorbed Dose Rate
I.A.E.A. 1988	Aquatic	Reproductive changes	24 'mSv'·d^{-1}
N.C.R.P. 1991	Aquatic	Reproductive changes	0.4 mGy·h^{-1} (9.6 mGy·d^{-1})
I.A.E.A. 1992	Aquatic	Reduction in reproduction	10 mGy·d^{-1}
I.A.E.A. 1992	Terrestrial	Reduction in reproduction	1 mGy·d^{-1}
Platt 1965	Vegetation	Species balance disrupted	0.3-2 Gy·d^{-1}
Edwards 1969	Soil invertebrates	Species balance disrupted	11,700 Gy·d^{-1} (100 Gy)
Poinsot-Balaguer et al. 1991	Soil invertebrates	Species balance disrupted	360 mGy·d^{-1}

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