THE ESTABLISHMENT OF DE MINIMIS LEVELS OF RADIOACTIVE WASTES

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INTRODUCTION

The working assumption currently accepted for radiological protection purposes, is that the probability of occurrence of stochastic health effects is directly proportional to the level of radiation exposure received, without threshold. This implies that a finite level of risk is associated with any increment of dose no matter how small and that the incidence of stochastic effects in irradiated populations is proportional to the collective dose received, irrespective of its distribution among affected individuals. This notwithstanding, there has been a protracted debate within the radiological protection community, as to whether or not it is a reasonable procedure to sum very small individual doses, additional to those accumulated from natural background, in the calculation and use of collective dose estimates.

This issue has assumed considerable importance in the field of radioactive waste management, as much of the collective dose arising from the dispersion of effluents or low-level solid waste disposal, is delivered at very low individual dose rates. A widespread feeling has emerged that this procedure may over-emphasise the significance of low level exposure; promoting undue public anxieties to waste management practices resulting in essentially trivial levels of risk, and diverting limited regulatory resources which could be better employed in other, higher risk, areas. It has therefore been suggested as an alternative, that a de minimis level of individual dose or risk should be established, below which, there would be no further need for concern on the part of regulatory authorities. This concept of de minimis is under active consideration internationally, by a number of competent authorities and, for example, seems likely to feature in forthcoming regulations by the US Nuclear Regulatory Commission(1). The purpose of this paper is to examine this concept and its implications, and to describe NRPB proposals for establishing de minimis dose levels in the UK(2).

PREVIOUS APPROACHES TO DE MINIMIS

Individual Assessment

The concept of an insignificant level of risk is by no means new, and proposals on this topic were first considered at NRPB in 1977(3). In a survey of comparative risks experienced by the population, Webb and McLean concluded that an annual probability of death of the order of 10^{-6} y^{-1} is not taken into account by individuals in arriving at decisions as to their actions. Considering the possible multiplicity of sources of radiation exposure, the annual individual dose of the order of 10^{-4} Sv y^{-1} corresponding roughly to this insignificant level of risk was reduced by a factor of 100 to 10^{-6} Sv y^{-1}, so that if an individual was exposed to a large number of different sources each of which had been ignored, his aggregated dose would not exceed the de minimis level of 10^{-4} Sv y^{-1}.

Similar conclusions based on risk comparisons with other activities or variations in natural background exposure have subsequently been reached by other authors and bodies(4,5). A general consensus appears to have emerged, that a risk level of the order of 10^{-6} to 10^{-7} y^{-1} is of no significance from the point of view of an affected individual. However, even where due allowance is made for potential multiplicity of radiation sources, there remains the question of application of an individual related de minimis dose level, by itself, to source related assessments involving irradiated population groups.

Source Related Assessment

Source related aspects of population exposure are treated by ICRP within its system of dose limitation, by application of a cost benefit analysis procedure[6]. The benefits from reduced radiation exposure have to be compared directly with the costs of protective measures, requiring a monetary valuation of radiation-induced health detriment, which is generally expressed as a cost per unit collective dose. The adoption of de minimis individual dose levels within cost benefit analysis could then be achieved either by excluding doses below this level from assessments of collective dose, or by assigning this portion of collective dose estimates a zero valuation for use in cost benefit analysis. However, the net effect of either mechanism would be to ignore small individual doses for decision-making purposes; reflecting the view that if the doses involved are of no significance to affected individuals then it does not matter how many such doses are added up, the resultant collective dose is of no significance to society.

The ICRP, among others, do not accept this view. As implied by their concept of "objective health detriment"[6], they suggest that the societal health consequences of say, one man sievert, is the same whether it arises in a population of one hundred thousand people each exposed to 10^{-5} Sv, or a population of one hundred million people exposed to 10^{-8} Sv. NRPB has adopted a similar line in developing its formal advice on the optimisation of protection of the public[7]. For very small individual doses, below the insignificant levels defined above, a number of alternative valuations of collective dose were initially considered, including a 'de minimis' option of a zero cost. However, this option was rejected in favour of a finite value, based on lost economic output and health care costs associated with the health detriment statistically predicted per unit collective dose, at all individual dose levels. This is reflected in the formal costing scheme by a baseline valuation of £2000 per man Sv, which may be taken to correspond with the ICRP formulation for the cost of objective health detriment, and is applicable to all annual individual doses in the range from zero to 5.10^{-5} Sv[7].

NRPB PROPOSALS

Although NRPB have rejected the idea of applying de minimis individual dose levels in isolation, it has been increasingly recognised that the provision of data for optimisation studies may be costly to obtain in terms of time and resources. It might therefore be argued that where in the absence of further protective measures, the residual individual doses and the collective dose commitment are sufficiently small, the cost of performing the optimisation may in itself, outweigh any potential reduction in health detriment costs. In such situations the rigorous use of cost benefit analysis would not be warranted, and the initial levels of exposure may be excluded from further consideration, not because they are of no concern per se, but because they are optimal. Thus in this context, the concept of de minimis reduces to nothing more than a specific form of ALARA appropriate for trivial radiological problems.

A primary implication of this approach is that each radiological problem must initially be assessed as if it were to be formally optimised. Practical experience in the UK indicates that the minimum cost of a formal optimisation exercise concerning routine releases of radioactivity or disposal of solid wastes, is likely to be in the range of £10^3 - £10^4, and this may be used as a basis to define a de minimis collective dose commitment. Using the NRPB valuation of £2000 per man Sv this leads to a de minimis collective dose of the order of one man Sv. However, the criterion of de minimis collective dose alone is insufficient and must be accompanied by a de minimis individual dose proposed at 5 10^{-6} Sv y^{-1}, and applicable to the maximum future annual dose to members of a critical group arising over the release lifetime of the source. This will require some care in defining the radiation source under consideration, so that the totality of the operation or source is addressed, with particular regard to the build up of doses over time.

Future Detriment

In its formal advice on optimisation, NRPB advocated the principle of discounting future detriment costs arising from present-day practices, recommending a range of annual discount rates from zero, which assigns the same weight to doses whenever received, up to a value of 3% per year(7). This precludes the unique definition of a de minimis collective dose commitment since it requires the minimum cost of optimisation to be compared with a discounted 'present value' of health detriment costs which is a function of both the temporal distribution of collective dose and the discount rate applied. If cautiously a zero discount rate is employed, a collective dose commitment of less than one man Sv, arising over the operating lifetime of a given radiation source, will be automatically regarded as de minimis. Alternatively, where finite discount rates up to 3% per year are applied, the present value of health detriment costs should be compared against a de minimis level of £2000. In both cases, as before, the individual levels of dose must additionally be less than 5 10^{-6} Sv y^{-1}.

PRACTICAL IMPLICATIONS

The intent of these proposals is to reduce regulatory efforts in the optimisation of protection for trivial radiological problems. Having specified the radiation source under consideration, there will be a sequential examination of the associated individual and collective doses and possibly, the discounted present value of health detriment costs; all of which would be required in any case for optimisation purposes. It is envisaged that simplifying and cautious assumptions will initially be employed in dose calculations, to be replaced by more rigorous environment modelling results if necessary. But in many practical situations, having determined that the maximum future annual dose to the critical group is less than the de minimis individual dose of 5 10^{-6} Sv, and with knowledge of the half-life and residence time in the biosphere of the nuclides involved, it may be readily established that the collective dose commitment does not exceed one man Sv. Both of the de minimis dose conditions will then be fulfilled, and no additional regulatory consideration will be required.

Furthermore, in such cases where the overriding constraint involves individual doses to critical groups, it will be possible to establish de minimis levels of activity or quantities of nuclides, in an analogous manner to the calculation of generalised derived limits corresponding to ICRP dose limits. The release or disposal to the environment of such derived de minimis quantities might then be authorised without the need for explicit dose calculations, further reducing demands on regulatory resources. This procedure and a range of possible outcomes can be notionally illustrated with regard to the four nuclides listed in the table below, drawing on recent NRPB calculations of the collective dose commitment associated with generalised derived limits of discharge to atmosphere(8).

Nuclide	30 year operating lifetime discharge level (Bq s^{-1})	collective dose commitment (man Sv)	Cost of health detriment (£) zero discount rate	Discounted at 3% per year
Kr-85	$4.05\ 10^{8}$	$2.86\ 10^{1}$	$5.72\ 10^{4}$	$3.22\ 10^{4}$
I-129	3.70	$2.26\ 10^{1}$	$4.52\ 10^{4}$	$2.95\ 10^{2}$
Cs-137	$3.46\ 10^{1}$	$4.38\ 10^{-1}$	$8.76\ 10^{2}$	-
Pu-239	$3.52\ 10^{-1}$	$1.60\ 10^{-1}$	$3.20\ 10^{2}$	-

The table presents results of a derived level of discharge for each nuclide corresponding to the de minimis individual dose of $5\ 10^{-6}$ Sv y^{-1}. The total collective dose commitment is for the discharge continuing over 30 years, and of health detriment costs valued at £2000 per man Sv. It can be seen from this that such discharges of caesium-137 and plutonium-239 clearly satisfy the de minimis collective dose commitment of 1 man Sv, while those of krypton-85 and iodine-129, both of which are globally dispersed, exceed this criterion by approximately a factor of 25. However, given its extremely long half-life, the discounting of health detriment costs associated with iodine-129 discharges has a substantial impact; reducing the present value relative to undiscounted costs for annual discount rates in the range of 1 - 10% by about two orders of magnitude(9). On this basis, the discounted health detriment cost for iodine-129 is found to be well below the proposed de minimis health detriment cost of £2000, and would therefore preclude the need for any further optimisation where finite discount rates are to be applied. In contrast to this, the results for the short-lived krypton-85 are relatively unaffected by discounting(9) and exceed the de minimis health detriment cost, although further reduction of the discharge may still not be warranted on the basis of an optimisation study.

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