THE COST OF OCCUPATIONAL DOSE

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INTRODUCTION

The current system of dose limitation recommended by ICRP (1) is such that compliance with dose equivalent limits is a necessary but not sufficient criterion for radiological protection; the emphasis is instead on the concepts of justification and optimisation. The result is that the 'as low as reasonably achievable' (ALARA) principle has become a primary objective for radiation protection when dealing with justified sources of exposure.

For the vast majority of day to day problems concerning occupational exposure, the ALARA principle can be satisfied by using the intuitive judgement of operational health physicists. A formal analysis employing the cost benefit techniques suggested by ICRP will not be warranted by the scale of the problem. However in circumstances where there may be potentially large exposures and various possible ways to reduce them, the use of such an analysis can be a useful input into the required decision making. The cost benefit technique can, in theory, identify optimum exposures ie, the level of exposure below which further reductions would not be justified. Nevertheless, in order to perform the analysis in practice, a monetary valuation of radiation exposure is required so that the cost of detriment, Y, can be made directly commensurable with the cost of protection, X. The problems of assigning a cost to health detriment for public exposure have been examined by the authors elsewhere (2). In this paper some aspects of the corresponding costing for occupational exposure will be discussed.

THE VALUATION OF DETRIMENT

The ICRP have defined the health detriment from radiation exposure as a mathematical expected value ie, a summation of the product of the frequency of (stochastic) health effects and weighting factors for their severity. Assuming a linear dose response relationship for the stochastic health effects and the homogeneity of risk and severity factors in populations it is possible to show that the health detriment is proportional to the collective dose equivalent, S (3). There is therefore a simple proportional relationship between collective dose and the number of predicted health effects. However, to establish a relationship between the cost of the health detriment, Y, and collective dose, a separate judgement is required. It has generally been assumed that Y is also simply proportional to collective dose, ie. $Y = \alpha S$ where α is "the cost of the man Sv" in £ man-Sv^{-1}. The use of this relationship implies a single monetary valuation of stochastic health effects independent of the level of individual risks involved. Without questioning the assumption of proportionality between dose and health effects, it is important to note that this does not automatically lead to a proportional relationship between Y and S; other relationships are possible and the appropriate choice is a matter of judgement.

One alternative is to use a cost benefit approach to valuing risk changes (4) which explicitly considers the size of population at risk and the significance of the risk increment to individuals. This leads to a variable value for α for public exposure which increases with increasing per caput dose (2). Such an approach to the functional form of α will tend to concentrate (limited) protection resources in areas of high individual risk; it can therefore be shown to be consistent with equity considerations and has a strong intuitive appeal. The use of a variable value in optimising occupational protection could be justified on the same criteria, although there may be other criteria that need to be considered, both in general and on a case by case basis.

IMPLICATIONS FOR OPTIMISATION

As previously stated the choice between a fixed or a variable α to convert health detriment into monetary terms is a matter of judgement. Nevertheless this judgement can be shown to have important implications for the optimisation of occupational exposure which arises from a common set of operational conditions; namely where the principal mechanism for controlling individual exposure is to vary the number of workers, N, employed on a specific task. Typically one may assume that increasing the number of workers will reduce average individual doses, H, for example by reducing the average time necessary for each worker to spend in radiation areas. However it would appear that this increase in the number of workers will be accompanied by a general increase in doses resulting from non-productive work (5). In the previous example this might arise during the entry and exit from radiation areas. Increasing the number of workers will, in general, tend to increase both the total time required to complete any given task and the total non-productive dose. Assuming that there is a fixed dose associated with the task itself, this will typically lead to an increase in collective dose, S. In order to fulfil the ALARA principle under these conditions, it is necessary to assess what is the optimum exposure to be associated with the task.

In accordance with the formal optimisation procedure recommended by ICRP, the solution to this problem is that at which the sum of the protection costs and the detriment costs (X + Y) for each feasible level of manpower, is minimised. If a fixed value for α is employed in the analysis then Y must be at a minimum for the option which results in the lowest collective dose. On the basis of the general assumptions outlined above, this will occur where the minimum number of workers are assigned to the task and the average individual dose is at its highest (within the constraint of the dose limits). Moreover, as the costs of protection will generally increase if there are more workers requiring, for example, specialist training or protective equipment for the task, this option is likely to also minimise X, and will therefore appear to be optimum. Thus whenever these general assumptions concerning N,H,S and X apply to actual operational conditions, the optimisation procedure will consistently advocate options characterised by the smallest collective dose and the smallest feasible number of workers and will involve the highest resultant average individual exposure. Indeed if the required data validate these relationships between N,H,S and X for a given situation, then the analysis itself is unaffected by the precise value assigned to α.

The results of an optimisation using a variable value for α provides a significant contrast. Even where the same postulated relationships between N,H,S and X hold, the increasing valuation of α with increases in average individual dose precludes any automatic relationship between reductions in detriment costs and reductions in collective dose. Thus while the minimum S and highest H option will still minimise X, it may no longer minimise Y. The optimisation of any given task will therefore be crucially dependent on the <u>specific</u> relationship arising between N,H,S and X and the numerical relationship between α and H.

SUMMARY AND CONCLUSIONS

The implementation of the ALARA principle within the workplace is intended to oppose the attitude that a worker's dose limit represents a constraint on a 'resource' which until reached, can be fully utilised in an arbitrary manner. Thus while the method for formal optimisation is based on the parameter of <u>collective</u> dose, the ICRP suggest that <u>individual</u> exposure at or near the limit is only acceptable if justified by "a careful cost benefit analysis" (1). Such an analysis will generally consider the relationships between the number of workers involved, the costs of their protection and the resultant individual and collective doses. Moreover, it seems likely that the optimum solutions will be significantly influenced by the manner in which collective doses are converted into monetary terms. A fixed conversion factor will ignore individual dose levels, and in attempting to reduce both protection and detriment costs will tend to increase average individual doses. A variable conversion factor which increases with increasing average individual doses will, in contrast, explicitly account for the distribution of individual doses in the assessment of detriment costs, will discriminate against high individual doses, and will tend to select options on a more case by case basis. Such an approach is fully in the spirit of the ALARA principle as applied to all exposures, both individual and collective.

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