OPTIMISATION OF PROTECTION OF RADIATION WORKERS

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INTRODUCTION

Under the current ICRP system of dose limitation, the principle of optimisation of protection has become established as a major objective of practical radiological protection; requiring all doses to be reduced to levels which are As Low As Reasonably Achievable or "ALARA" within the constraint of dose limits. Application of ICRP recommendations is the responsibility of national authorities and, in the UK, the National Radiological Protection Board has already advised on a provisional framework for optimising the exposure of the public, using the technique of cost benefit analysis(1). This framework contains recommendations in a number of areas, including a costing scheme for the monetary valuation of radiation-induced health detriment.

In presenting this advice on the optimisation of protection of the public, it was stressed that the recommendations, and particularly the numerical suggestions on the monetary values of collective dose, should not be applied to occupational exposure(1). The Board nonetheless recognised that for full implementation of cost benefit analysis as an input to decisions on ALARA, the framework would need extending to include radiation workers, and proposals for achieving this objective have recently been outlined in a consultative document(2). As with the Board advice for members of the public, this concerns only routine exposures during normal operations, but it is intended to apply to all those occupationally exposed, whether in the nuclear industry, medicine, general industry, research or elsewhere. This paper describes some of the factors which influenced the proposals and their implications for practical optimisation studies.

THE ROLE OF COST BENEFIT ANALYSIS

The application of cost benefit analysis to radiological protection as described in ICRP publications(3,4) has been couched in considerable mathematical formalism. While this presentation can provide a precise analytical framework for the implementation of ALARA, in other respects it can give the wrong impression. It may, for example, imply a degree of complexity such that the technique appears to be relevant for only major radiological problems. It may also encourage the idea that quantitative cost benefit analysis is all that is required for decision-making. To dispel such misconceptions, it is important to outline the role which we envisage for cost benefit analysis in the optimisation of protection of radiation workers.

Cost benefit analysis provides a straight-forward framework for optimisation. The necessary inputs are assessments of the cost of radiological protection and radiation-induced health detriment for alternative courses of action, so that the choice which minimises the sum of these costs (or equates 'marginal' costs) can be identified. Most of the effort in providing these inputs is in the assessment of protection costs and dose reductions associated with each control option considered; these assessments should be carried out in any case before coming to a decision. For large scale problems, perhaps involving complex or novel technologies, this assessment can be a specialised exercise embracing alternative plant designs and the use of mathematical models for dose calculations. But it must be emphasised that the level of sophistication and corresponding degree of effort given to the assessment should reflect the scale of the radiological problem being considered. For small-scale operational problems, rough estimates of costs and dose reductions by professional health physicists are entirely adequate.

The principal advantage in applying decision-aiding techniques, such as cost benefit analysis, is not that the need for judgements is removed but that the judgements are clarified and made consciously. This feature is particularly relevant to the evaluation of health detriment costs in the Board framework, which reflects broad socio-economic considerations in addition to matters of science. The inherent subjectivity in quantifying such considerations should always be kept in mind, to counter the impression of numerical accuracy that may otherwise be implied by these valuations. Furthermore, it must be emphasised that cost benefit analysis will not be the sole means by which specific decisions on radiological protection are taken, if only for the reason that it will rarely encompass all of the judgements involved. For example, the monetary valuations of health detriment put forward by NRPB will be generic, relating to 'average' radiation workers in 'typical' working environments. But the practical management of occupational exposure is concerned with the protection of specific individuals and may need to account for such factors as their age, sex and cumulative exposure. The Board framework for optimisation should therefore be regarded as more relevant to the design of installations involving notional workforces and to broad operational decisions concerning working practices. It will be less applicable to day-to-day decisions, although even here it may have a role to play, allowing health physicists and others to examine the implications of their decisions on ALARA. In all these contexts, the valuations of health detriment will provide a guideline against which actual expenditures on dose reductions may be compared.

PRINCIPLES UNDERLYING THE VALUATION OF COLLECTIVE DOSE

It is clear from ICRP publications that the assumption made for protection purposes is that the health detriment in irradiated populations will be directly proportional to the collective dose received. It is then tempting to go on to assume a linear relationship between the cost of this health detriment and the collective dose, but this simple costing procedure (implying a constant cost of unit collective dose) would ignore some very important features of practical radiological protection. These include the existence of dose limits and equity considerations which have led health physicists in general to attach considerable importance to high individual doses, even where few individuals are involved so that the collective dose is small. While it is certainly possible to carry out optimisations using a constant cost of unit collective dose, judgements on the relative significance of the individual doses involved are still likely to be necessary before reaching decisions on ALARA. We believe that more consistent decision-making will result by incorporating such judgements within the numerical costing scheme for health detriment. This may be achieved by assigning a higher cost to unit collective dose made up of higher individual doses, particularly those approaching the dose limit, as recommended by the Board for exposure of the public[1]. The effect of this scheme is to concentrate resources on the protection of those individuals who are most highly exposed, thereby achieving compatibility with the practical emphasis in radiological protection on critical groups.

This type of costing scheme appears even more appropriate for radiation workers, as in general, occupational exposures are closer to the dose limits. Furthermore, in the working environment, judgements on the relative importance of individual and collective doses are often reflected in decisions taken by management. Cost benefit analyses of these practical situations will be significantly influenced by the manner in which collective doses are converted into monetary terms. A constant conversion factor (i.e. a single value for the cost of unit collective dose) will reduce the cost benefit procedure to the minimising of collective dose. This can be shown in many cases to lead to solutions in which the "optimum" is to expose the smallest number of people as close to the dose limit as possible. In contrast to this, a conversion factor which increases with increasing individual dose levels will discriminate to some extent against high individual exposure and lead to a more equitable distribution of risk; under operational conditions where say, individual doses can be controlled by varying the number of workers assigned to a specific task, it will allow reasonable trade-offs to be made between the sometimes conflicting objectives of reducing the individual and collective doses.

COSTING SCHEMES FOR OCCUPATIONAL EXPOSURE

In order to proceed from these general principles to a system for practical application, it is necessary to assign monetary values to unit collective dose as a function of the individual doses involved. In theory, this relationship should take the form of a progressively increasing or convex curve. However, the use of such a continuous function in assessing health detriment costs would require rather precise knowledge of the individual dose distribution. This knowledge might be available for existing operations based on monitoring results for individual workers. But optimisation studies are concerned with changes in radiation exposure arising from changes in the level of protection and this requires prediction of the associated dose distributions.

A requirement for detailed knowledge of potential dose distributions is regarded as impractical, especially for design studies involving new installations. The costing scheme put forward by the Board therefore assigns values to unit collective dose within various annual individual dose bands, providing a 'step' function as an approximation to a smooth curve. This requires a number of judgements to be made on both monetary valuations and the range of dose bands selected. A principal purpose of the consultative document was to solicit comments on the numerical values suggested, so that these judgements could be refined in the development of formal Board advice. In the event, responses were obtained from a wide range of organisations and individuals, including some from outside the UK, and the proposed scheme is currently being reviewed in the light of these comments.

Among other factors influencing these proposals was the recognition that for some decisions, such as whether to install additional radioactive waste treatment at nuclear sites, reductions in doses to the public may be accompanied by increases in doses to radiation workers, so that comprehensive optimisation studies would involve trade-offs between the two groups. To address these practical situations within a common framework implied a need for broad compatibility between the costing scheme for occupational exposure and previous Board advice for members of the public, and these two costing schemes are shown in Tables 1 and 2, respectively.

It can be seen from these tables that both schemes incorporate three annual individual dose bands, with changes of a factor of 5 in monetary values between adjacent bands. However for radiation workers, the choice of individual dose bands reflects the fact that those occupational exposures which are measured or assessed fall within a range of about two orders of magnitude. The bands are therefore more tightly grouped than were the corresponding bands for members of the public, whose predicted doses may be spread over many orders of magnitude and seldom approach the dose limit. Furthermore, to account for the higher levels of individual dose received by radiation workers greater relative weight is assigned to occupational doses approaching dose limits. In contrast to this, public exposures are generally given greater relative emphasis at individual dose levels below 5mSv, except at very low dose levels. This reflects considerations of both risk aversion and equity, since not only are workers better informed and more familiar with the nature of radiation risks, but unlike members of the public, they have an element of choice in accepting such risks for the personal benefits attained through employment.

CONCLUSIONS

The proposals outlined in this paper represent a step in the development of formal Board advice on the use of cost benefit analysis in the optimisation of protection for radiation workers. They include suggestions on the costs to be assigned to collective dose received by workers for comparison with costs of protective measures and, in some cases, the costs associated with public exposures. It should again be stressed that the cost benefit process is intended as an input to decisions on ALARA and not as a prescription for making such decisions. Nonetheless, by structuring the application of judgements in this quantified manner, it is hoped that the Board framework for optimisation will assist those with responsibilities for the radiological protection of workers to more consistently implement the ALARA requirement.

REFERENCES

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3. Recommendations of the ICRP. Oxford, Pergamon Press, ICRP Publication 26. Ann. ICRP, 1, No. 3 (1977).

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Table 1 Proposed costs of unit collective dose for radiation workers[2]

Individual annual dose band (mSv)	Percentage of annual dose limit for radiation workers, 50 mSv	Cost* of unit collective dose made up of individual doses within the band (£/man Sv)
< 5	< 10	4,000
5 - 15	10 - 30	20,000
15 - 50	30 - 100	100,000

* In 1980 prices

Table 2 Recommended costs of unit collective dose for members of the public[1]

Individual annual dose band (mSv)	Percentage of annual dose limit for members of the public, 5 mSv	Cost* of unit collective dose made up of individual doses within the band (£/man Sv)
< 0.05	< 1	2,000
0.05 - 0.5	1 - 10	10,000
0.5 - 5	10 - 100	50,000

* In 1980 prices