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OPTIMIZATION IN RELOCATION DECISIONS

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Abstract

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After major accidents involving relocation of population groups, decisions would be required regarding permission to reinhabit evacuated areas or to continue using other areas. One component of these decisions can be based on optimization assessments, taking into account the residual contamination and the ensuing doses and the cost of maintaining the countermeasures as a function of time. This paper presents a rationale for such optimization assessments and the procedures for obtaining intervention levels from them, and summarizes some applications of this approach in emergency planning in Argentina.

1. INTRODUCTION

Optimization of radiation protection is a basic requirement of the dose limitation system recommended by the International Commission on Radiological Protection (ICRP) [1]. The optimization requirement applies to all situations where radiation exposures can be controlled by protection measures. The ICRP has also recommended that "although optimization, as a component of the system of dose limitation, applies strictly to situations where the radiation source is under control, similar considerations can be used for planning some of the protective actions to be taken in case of an accident" [2]. This paper discusses the application of the optimization requirement to relocation decisions.

Evacuation is the urgent removal of people from an area to avoid or reduce their exposure from high levels of activity due to radioactive materials deposited from the plume into the ground, following a large accident. Evacuation is adopted when it is expected that people will return to the area concerned on a foreseeable time scale.

Relocation, on the other hand, is applied either to end the evacuation measure or to remove population groups from contaminated areas to avoid chronic exposure when return to the area is not contemplated at the time. This paper is concerned with radiation protection decisions related to the first situation, i.e., to situations of relocation after evacuation. The term "relocation", therefore, will be used in this paper under the context of "re-entry" into a contaminated area.

For relocation of population groups, decisions would be required regarding permission to reinhabit the evacuated areas or to continue the use of other areas. One component of these decisions can be based on optimization assessments, taking account of the residual contamination and the ensuing doses, and the cost of maintaining the countermeasures as a function of time. This paper presents a rationale of such optimization assessments and the procedures to obtain intervention levels from them, and summarizes some applications of this approach in emergency planning in Argentina.

2. THE OPTIMIZATION REQUIREMENT

After some time has elapsed, the radioactivity level of the contamination that had necessitated evacuation would have decayed sufficiently and the radiological harm avoided by maintaining evacuation may well not justify the efforts involved. Competent authorities must then decide whether to permit the reinhabitation of the evacuated areas, returning the people evacuated. For making the decision rational and consistent with radiation protection recommendations, optimization must enter in the decision process.

Several techniques have been proposed for implementing the optimization requirement. Cost-benefit analysis is a particular aggregative method which has been used. It assumes that: (a) the criteria involved are the costs of protection and of the avoided detriment; and (b) these costs can be expressed in monetary terms.

In relocation decisions, many factors should be considered before deciding when the evacuation measure must be terminated. Some of these factors may not be readily amenable to aggregation. However, in this paper, the cost-benefit approach will be explored, recognizing that it oversimplifies the problem.

3. COST-BENEFIT ANALYSIS IN THE FRAMEWORK OF RELOCATION

Cost-benefit techniques for optimizing protection have been analyzed in detail by ICRP [2]. For situations of emergency planning, however, examples of application are scanty. An exception is the proposal for developing intervention levels in terms of the dose at which an action is required [3]. For the case of relocation decisions, no practical examples of the application of optimization appear to be available.

For relocation decisions, the two relevant variables in the cost-benefit procedure will be the cost X of continuing evacuation and the cost Y assigned to the radiological detriment avoided by such continuation. The protection parameter will be the time τ at which evacuation should be terminated and relocation accepted.

X will normally be proportional to time τ and to the number of people N who have been evacuated. Thus,

$$X = K\ N\ \tau \tag{1}$$

where K is the cost to maintain evacuated an average person per unit time.

Since at low individual doses, the health detriment is proportional to the collective dose [2], in this paper, the cost of the detriment Y is also taken to be proportional to the collective dose S.

$$Y = \alpha\ S \tag{2}$$

where α is the cost assigned to the unit collective dose.

On the other hand, the dose rate that an individual will incur as a result of the deposited contamination will be:

$$\dot{D} = \sum_i \dot{D}_{0i}\ e^{-\kappa_i t} \tag{3}$$

where $\dot{D}_0$ is the rate at time zero and κ is a decay constant, which takes into account not only the physical decay λ but also any other environmental removal of activity, both for each nuclide i involved.

Thus, the collective doses due to maintaining evacuation after a time τ will be the time integral of equation (3) multiplied by the number N of people involved.

$$S = N \int_{\tau}^{\infty} \sum_i \dot{D}_{0i} \; e^{-\kappa_i t} \; dt \qquad (4)$$

where the interval of integration starts at τ. Except for very long-lived and persistent nuclides, the collective dose will then be

$$S = N \sum_i \frac{\dot{D}_{0i}}{\kappa_i} \; e^{-\kappa_i \tau} \qquad (5)$$

4. OPTIMIZED RELOCATION DECISION

Optimized protection would be obtained in conditions satisfying the following equation:

$$\frac{dX}{d\tau} + \alpha \frac{dS}{d\tau} = 0 \qquad (6)$$

Therefore,

$$K N - \alpha N \sum \kappa_i \frac{\dot{D}_{0i}}{\kappa_i} e^{-\kappa_i \tau} = 0 \qquad (7)$$

or

$$K = \alpha \sum \dot{D}_{0i} \; e^{-\kappa_i \tau} \qquad (8)$$

But, since

$$\sum_i \dot{D}_{0i} \; e^{-\kappa_i \tau} = \dot{D}_\tau \qquad (9)$$

where $\dot{D}_\tau$ is the dose rate at time τ resulting from all nuclides, then, the dose rate at the optimized time for relocation is

$$\dot{D}_\tau = \frac{K}{\alpha} \qquad (10)$$

Therefore, under the assumptions made in the paper, the optimized time for re-entry of evacuated people should be such that the dose rate at that time is equal to the ratio of the cost rate K for keeping evacuated an average person and the monetary value α assigned by the regulatory authority to the unit collective dose for the purposes of radiation protection.

5. DISCUSSION

It is interesting to note that the optimal solution depends on two parameters, α and K, that are not related to any physical condition of the accident and its consequences. It is independent of the radiochemical composition of the release, of the subsequent dispersion, deposition and transport of the radioactive materials and -therefore- of the weathering, penetration in soil and other transport phenomena, and of the exposure conditions of the people -including their location and habits. This conclusion has been reached under assumptions that are quite normal under the framework of optimization implemented by cost-benefit analysis techniques.

Regulatory authorities are using -implicitly or explicitly- α values that range from a few thousand to a few tens of thousands of US dollars per man sievert, reflecting different attitudes and socio-economic conditions in various countries. An interesting conclusion is that the ratio K/α will probably be less socio-economically dependent than α or K by themselves. It seems likely that, if conditions in a given place are such as to encourage authorities to select a high or a low value of α, the value of K will also be high or low owing to the same conditions. It seems, therefore, that the α/K ratio should be rather insensitive to local conditions.

6. USE IN ARGENTINA

The Argentine regulatory authorities have selected a value of α equivalent to US$ 10 000 per man–sievert for purposes of optimization of radiation protection. The cost (additional to the usual cost of living) of maintaining evacuated an average person is estimated in the order of US$ 100 per month per person.

Therefore, the optimum dose rate for deciding relocation in Argentina would be of the order of 10^{-2} Sv/month, if no other considerations -such as individual risk limitation- were taken into account.

It is interesting to note that, based on individual risk limitation criteria, values of 0.05 - 0.1 Sv in a year were considered by the Argentine authorities, these values being consistent with the optimized results presented in this paper.

REFERENCES

[1] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Recommendations of the International Commission on Radiological Protection, ICRP Publication 26, Pergamon Press, Oxford and New York (1977).

[2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Cost-benefit Analysis in the Optimization of Radiation Protection, ICRP Publication 37, Pergamon Press, Oxford and New York (1983).

[3] FRITELLI, L., TAMBURRANO, A., "An application of cost-effectiveness analysis to restrict the damage caused by an accidental release of radioactive material to the environment", Radiation Protection: A Systematic Approach to Safety. (Proc. 5th. Int. Congr. of the International Radiation Protection Association, Jerusalem, 1980), Vol. 2, Pergamon Press, Oxford (1980) 785–789.