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THE VARIOUS WAYS OF INTEGRATING INDIVIDUAL DOSE EQUIVALENT OR TIME INTO THE OPTIMIZATION PROCESS (+)

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The dose limitation system recommanded by the ICRP in its Publication 26 /3/is based on three principles : justification, optimization and limitation of individual dose equivalents. This system has shown its validity in various ways since it was worked out. However many people involved in radiation protection wish to enlarge the framework of the optimization principle in order to have it better fit to practical needs. This wish is related to different problems such as : taking into account per caput dose distribution ; length of exposure integration ; uncertainty ; accidental exposure ; public or occupational exposure ; national or international exposure ... As a matter of fact the ICRP Publication 26 did not intend to take into account these differences. This is why the ICRP Publication 37 /4/ introduces a β term in the optimization formula. These β term is related to the introduction of per caput dose distribution but might be used for other dimensions. For the integration of time it is suggested to introduce a discounting function F(t). The aim of this paper is to analyse the advantages and drawbacks of these two possibilities.

THE INTEGRATION OF INDIVIDUAL DOSE EQUIVALENT INTO THE OPTIMIZATION PROCESS

If we analyze the differents levels of exposure of public or workers involved in the nuclear fuel cycle the results are contrasted. This is particularly right for occupational exposure where uranium miners are the most exposed group. For risk or equity consideration we may assume that it is desirable to focus on the protection of such exposed workers. It is therefore interesting to have an optimization procedure which allows to take into account the individual dose equivalent.

The NRPB has presented a procedure with alpha values depending on the per caput dose /5/. This method is quite comparable with the β formulation of the ICRP 37 (where the function f(Hj) can express the increase of the alpha values in function of the per caput dose) and we will use in our example this well known method.

To illustrate the interest of the integration of individual dose equivalent into the optimization procedure we will envisage the comparison of different protection strategies available to reduce the alpha contamination associated with short lived radon daughters in an underground uranium mine. The protection strategy i, its annualised cost Xi and the annual individual dose equivalent (Radon + Gamma + Ore dust) to the three groups of miners are given in the following table (data derived from another communication in this congress /6/).

(+) This paper is a summary of two studies carried out within the framework of two contracts with the "Euratom/CEA Association", Contracts n° SC 005 BIAF-423 F and SC 010 BIAF 423 F /1/ and /2/.

	PROTECTION STRATEGY			COST X_i	INDIVIDUAL DOSES (mSv/yr)		
i	T	PV	SV	(10^3 \$)	$D1_i$	$D2_i$	$D3_i$
1	N	20	3	19.36	40.8	34.5	28.9
2	N	30	3	31.9	28.4	22.3	17.1
3	Y	30	3	34.24	26	21	16.3
4	Y	60	3	59.53	17.3	12.7	8.4
5	Y	60	5	65.61	15.8	11.3	7.7

T = implementation (Yes or Not) of small fans (Turbulator) in the stopes ; PV, SV = primary and secondary ventilation rates (in m^3/s).

A first cost-benefit analysis with an unique value of alpha as it was suggested in the ICRP 26 gives the following results (Number of workers 17 : 4 for the two first groups and 9 for the third) for an alpha value of 20, 000 \$ per man-Sievert (highest value taken in the ICRP 37 examples).

The "optimal" protection strategy, which minimizes the sum of financial X_i and detrimental Y_i cost, $Y_i = \alpha S_i$ with $S_i = 4(D1_i + D2_i) + 9\, D3_i$), is the first one. The maximum individual dose is about 80 % of the annual dose limit when this minimal protection strategy is implemented.

A second analysis taking into account the individual dose equivalent distribution gives the following results. In this example we assume that ALL RISKS MUST BE TAKEN INTO ACCOUNT (Radon, Gamma, Ore dust) though the strategies are assumed to reduce only radon exposure. Following, the NRPB, the alpha values retained as an example here are 6 000 \$/man.Sv for annual individual dose equivalents less than 5 mSv ; 30, 000 \$/man.Sv for annual individual dose equivalents between 5 and 15 mSv and 150,000 \$/man-Sv for annual individual dose equivalents greater than 15 mSv.

With these hypotheses the "optimal strategy" his now the forth-one. The maximum individual dose equivalent is then reduced to about 35 % of the annual dose limit.

The signifiant discrepancy between these two results is due to the rather large increase of the man-Sievert value in the calculation of the second analysis (individual dose equivalents are larger than 15 mSv for about all the options, hence the relevant value of alpha is 7.5 times higher than in the first analysis).

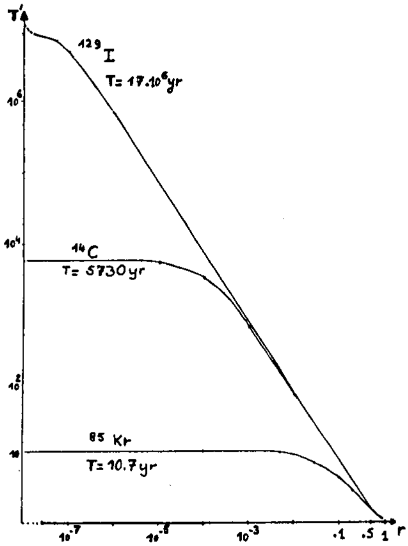
However it should be noted that the conclusions of the second analysis are probably more consistent with radiological protection of uranium miners.

THE INTEGRATION OF TIME INTO THE OPTIMIZATION PROCESS

The infinite time-integral of the collective dose, which is a measure of the total health detriment does not appear necessarily as being a realistic indicator within a decision aiding framework. Such a calculation has not been yet implemented for other risk than ionizing radiation, besides the prediction of events supposed to happen in millions of year can be questionable. A simple way of solving such a problem is often suggested by various authors. It consists of introducing a discounting exponential factor (e^{-rt} where t is time and r the discounting rate) which originates from the economic theory. However this manner of expressing the preference for present times vs the future is probably much more relevant when dealing with short or medium term decisions but not with very long term ones.

If one wishes to illustrate the impact of the discounting procedure (discounting rate r), it can be demonstrated that it is equivalent to the substitution of a radionuclide half-life T by a "pseudo" half life T' = T log2/(log2 + rT) inferior to T(*).

The following graph shows the variation of T' according to the value of the discounting rate r, for 3 radionuclides.



As can be seen, an annual discounting rate of 1 °/₀₀ shifts the half life of ^{129}I from 17.10^{6} yr to about 690 yr (less than ^{14}C half life).

The use of a discounting procedure underweights significantly the long term consequences of present decisions. For example using an annual rate r = 1 % is equivalent to a reduction of the integration time interval P from infinite to 100 yr (in a first approximation P = 1/r see /2/).

The continuous attenuation of the health detriment cost with time tends to discard the future too heavily. Subsequently, an alternate way of tackling the problem of time distribution is to use various alpha values according to time or to adopt a step function in the ICRP 37 formula (which is equivalent to the former procedure). Various time intervals may be distinguished. Taking as an example the wastes disposal the first one can be identified to the life time of the storage center (t $\leq$ 25 yr) the second one can be a period during which protection choices are kept reversible (25 $<$ t $\leq$ 100yr) the last one (t $>$ 100 yr) may be cut so as to neglect time periods within which quantitative assessment present such a degree of uncertainty that it would be meaningless to take them into account (1 000 yr, 5 000 yr, 10 000 yr).

(*)

$$\int_0^{\infty} \frac{1}{(1+r)^t} \exp\left(-\frac{\log 2}{T}\right) t \, dt \simeq \int_0^{\infty} \exp -\left(\frac{\log 2 + rT}{T}\right) t \, dt$$

CONCLUSION

The use of various set of alpha values in order to take into account time and per caput dose distribution, (or similarly the introduction of β and F(t) in the equation of health detriment) is an appropriate way of expressing the multidimensionality of radiological protection choices.

The extension to other dimensions such as the need to distinguish between national and international exposure, the public and the workers etc.. might be envisaged in a further step of the elaboration of a practical decision aiding model for radiological protection.

However we should seek for a compromise between the adequation of the model to reality and the relative simplicity of this model which ought to be practicable and clearly understood by the various actors of the radiological protection system.

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