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RADIOLOGICAL AND ECONOMIC ASSESSMENT OF VARIOUS OCCUPATIONAL PROTECTION OPTIONS IN URANIUM MINES

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INTRODUCTION

Object of this study is to present an example of a radiological and economic assessment of various protection options against alpha energy due to short lived Radon daughters in an underground non sedimentary mine /1/. The aim of the options is to reduce both the collective and individual effective dose equivalent received by the miners. In order to calculate these dose equivalents, a model has been prepared, which enables the simulation of the various protection strategies (+).

PRESENTATION OF THE MODEL

The mine model

One can imagine a mine as a more or less complex combination of a set of simple elements designated here by the term "branch". Each branch consists of a main gallery, an old stope and ten active ones.

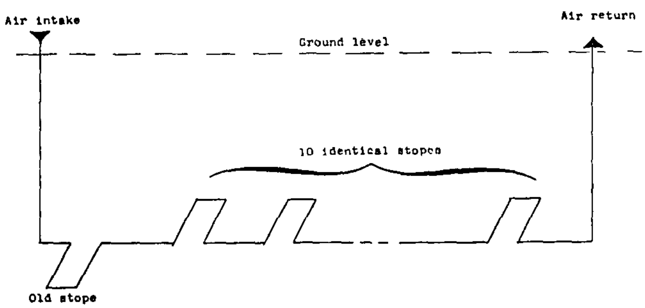

Fig. 1 : The considered mine model

The square section of the gallery and its stopes has an area of 16 m^2. All stopes are identical rectangular parallelepipedes with length, height and width of 12 m, 4 m and 4 m respectively.

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We assume a descending section mine. A figure of 0,1 ‰ for uranium tenor in quasi-sterile zones is assumed and one of 2 ‰ for tenor in the ore. Furthermore, the age of ^{222}Rn emanating from the old stope is assumed to be 25 mn.

The personnel employed in the branch consists of seventeen miners, distributed among the various zones of the mine according to their activity.

The alpha contamination model

The branch is considered as a sequence of ten "gallery-stope" pairs. The alpha energy in a gallery is calculated starting from the concentration of short lived ^{222}Rn daughters.

These concentrations are obtained by solving a system of differential equations relating the concentrations of ^{222}Rn and its daughters as functions of time. The concentration equations thus obtained involve the whole set of parameters related to the characteristics of the mine (volume, area, ^{222}Rn emanation flow, old stope), and to the protection options (primary ventilation rate, eventual presence of a parpen wall sealing the old stope. The modelling of alpha energy in a stope uses a compartment model, in order to properly account for the phenomenon of air stagnation caused by the working face that acts as a "cul de sac".

Here again, the equations that give the concentrations of short-lived ^{222}Rn daughters in both sections, involve the parameters related to the influence of the protection options (secondary ventilation rate, presence of filters, etc...).

Once the short-lived ^{222}Rn daughter concentrations are given, then it is possible to calculate the potential alpha energy inhaled by the various groups of miners and, subsequently, the associated collective and individual effective dose equivalent, using the factor proposed by the International Commission of Radiological Protection /2/for optimization purposes :

HE/IP = 2,5 Sv per Joule
HE : Effective dose equivalent per unit of potential alpha energy intake (IP)

DESCRIPTION OF THE PROTECTION STRATEGIES

A protection strategy is a combination of elementary protection options. The elementary options are the following :

a) Parpen wall (W) : putting up a wall isolating old stopes ;
b) Primary ventilation rate (PV) : choosing among four primary ventilation rates : 20, 30, 60 or 120 m^3/s ;
c) Secondary ventilation rate (SV) : choosing among three secondary ventilation rates : 3, 5 or 11 m^3/s ;
d) Turbulator (T) : introducing a small power rating fan (≃2 KW) into the working section in order to better ventilate the working face ;
e) Filters (F) : placing electrostatic filters (1, 2, 3 or 4) that would filter the primary air entering the stope and hold back the short-lived ^{222}Rn daughters.

The interdependence of the elementary options as far as effectiveness is concerned makes necessary the analysis in terms of strategies, that is combinations of elementary options. The effectiveness of a given elementary option depends, in fact, on the options already implemented.

THE ASSESSMENT OF THE PROTECTION STRATEGIES

In order to assess the various strategies, a cost-effectiveness analysis is carried out that compares the total cost and the reduction of the effective collective dose equivalent corresponding to each of the 240 available strategies for a given ten year period. Moreover, the maximum individual effective dose equivalent is calculated for each strategy in order to compare it to the occupational dose limit of 0,05 Sv/yr. Actually there is no need to carry out the analysis for the 240 strategies. It is only necessary to consider the lower part of the convex hull of the set of points corresponding to the 240 strategies.

Results and comments

The following table provides a summary of the results obtained.

i	PROTECTION STRATEGY W	T	F	PV	SV	Ci 10^3 \$	Di man-Sv	EIDEi 10^{-3} Sv/yr	$\alpha i = \frac{Ci-Ci-1}{Di-1-Di}$ (10^3 \$/ Man.Sv)
R	N	N	0	20	3	151.2	7.04	55.9	-
1	Y	N	0	20	3	193.6	4.54	40.8	17
2	Y	N	0	30	3	319	2.50	28.4	61.5
3	Y	N	0	30	3	342.4	2.28	26	106.4
4	Y	Y	0	60	3	595.3	0.89	17.5	181.9
5	Y	Y	0	60	5	656.1	0.70	15.8	320
6	Y	Y	0	120	5	1 129.7	0.29	13.3	1 155
7	Y	Y	0	120	11	1 378.7	0.19	12.3	2 490
8	Y	Y	4	120	11	2 067.5	0.14	12	13 776

W,T : implementation (Y) or not (N) of wall or turbulator ; F : number of filters per stope ; PV, SV : primary and secondary ventilation rates in m^3/s ; Ci : total cost over a 10 year period expressed in 1981 US \$; Di : radon daughters effective collective dose equivalent for 10 years ; EIDEi : annual effective individual dose equivalent due to radon, Gamma and ore dust exposure.

Table 1 : Summary of the results

It should be noted that the annual effective individual dose equivalent has been calculated for the most exposed category of miners, i.e. the drillers. Moreover, this calculation takes into account the contribution of gamma external irradiation ($4.5\ 10^{-3}$ Sv/yr) as well as the ore dust (a figure of $6.5\ 10^{-3}$ Sv/yr has been assumed, according to /3/).

The results obtained show that the reference strategy (R) cannot be considered as an acceptable one from the radiological protection standpoint because it does not comply with the third principle of the ICRP dose limitation system /4/. The cost-effectiveness analysis does not lead directly to the choice of a strategy among the eight available ones. For this it would be necessary to have a man-Sievert reference value α. If this value was fixed, then the "optimal" strategy (in the sense of ICRP /4/), would be the one having the highest man-Sievert cost figure α_i but inferior to this reference value α.

CONCLUSION

Object of this study is to make a contribution to the assessment of radiological protection strategies. The cost-effectiveness analysis allows in fact to compare the new techniques such as the turbulator or the electrostatic filters, to the more traditional ones (changing the ventilation rate).

REFERENCES

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