RADIATION EXPOSURE OF INDIAN URANIUM MINERS AND ESTIMATE OF ASSOCIATED RISK

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1. INTRODUCTION

The uranium mine at Jaduguda, India is semi-mechanised and employs a large work force for underground ore winning operations. The strength of workers has increased from about 700 in the 1960s to 1250 at present. The radiation environment in the mine has been under surveillance from the very beginning to keep the radiation exposure of workers within the prescribed limits. The trend of radiation exposure during the past 18 years and an estimate of the mortality risk are presented in this paper.

2. METHODOLOGY AND RESULTS

2.1 Estimate of Radon Daughter Concentrations

The practice has mainly been to monitor the mine air for radon, using the scintillation cell technique. Radon daughters being the major contributors to the radiation dose, their concentrations (WL) have often been estimated with those of radon. At other times the equilibrium factor (WL:Rn) and radon levels have been used to estimate the radon daughter concentrations in Working Level (WL) units. The concentrations of radon and radon daughters ranged from 0.7 to 13.0 Bq/ℓ and 0.02 to 0.52 WL respectively. The mean F values varied from 0.10 to 0.43.

2.2 Duration of Exposure

For a reasonably realistic exposure estimate the number of hours spent underground annually by groups of workers was obtained from a sample survey. The results of this survey are given in Table 1.

Table 1, Estimate of time spent underground by groups of miners

Miner group	% of total work force	Time spent underground (h/y)		
		Moving about	On regular job	Total
Drillers	12	115	1606	1721
Muckers	26	132	1934	2066
Auxiliary workers	48	113	1786	1899
Maintenance staff	9	762	889	1651
Supervisors	3	762	889	1651
Engineers	2	380	380	760

2.3 Internal Exposure Estimate

The radon daughter levels in the mine during different operations over the years have varied widely. The cumulative exposure (WLM) of miners in different trades is estimated by multiplying the radon daughter concentrations (WL) with the corresponding durations of exposure. Table 2 shows the trend in cumulative exposure of the miners to radon daughters during 18 years of radiological surveillance.

Table 2, Estimated cumulative exposure of different categories of miners (WLM)

Year	Cumulative exposure (WLM)		
	Drillers	Muckers	Others
1965	4.9 ± 2.6	2.1 ± 1.1	1.7 ± 1.0
1966	2.3 ± 1.2	3.5 ± 1.8	2.2 ± 0.9
1967	2.0 ± 1.1	5.2 ± 2.7	1.6 ± 1.1
1968	3.8 ± 2.0	3.2 ± 1.6	2.6 ± 1.5
1969	4.1 ± 1.2	6.5 ± 3.4	2.4 ± 1.7
1970	2.1 ± 1.1	3.0 ± 1.2	0.8 ± 0.5
1971	1.7 ± 0.9	2.0 ± 1.1	1.1 ± 0.8
1972	0.7 ± 0.6	1.6 ± 1.4	1.4 ± 1.3
1973	0.6 ± 0.3	0.7 ± 0.3	0.7 ± 0.5
1974	1.6 ± 0.6	5.5 ± 5.0	2.0 ± 1.6
1975	2.2 ± 0.8	2.3 ± 1.9	3.5 ± 1.7
1976	5.5 ± 4.5	2.5 ± 1.1	0.7 ± 0.1
1977	1.6 ± 0.6	1.7 ± 0.7	1.4 ± 0.7
1978	0.8 ± 0.2	1.4 ± 0.7	1.5 ± 0.8
1979	2.6 ± 1.0	2.1 ± 0.6	1.7 ± 0.3
1980	2.2 ± 0.2	0.4 ± 0.2	0.2 ± 0.1
1981	1.8 ± 0.5	1.7 ± 0.5	1.4 ± 0.2
1982	1.8 ± 0.8	1.3 ± 0.6	1.1 ± 0.4

The effective dose-equivalent from WLM unit to mSv is obtained from the curve given in International Commission on Radiological Protection Publication No. 32 (ICRP 81). With the unattached fraction (radon daughters) of 0.07 for the mine, the dose-equivalent works out to 10 mSv/WLM.

2.4 External Exposure Estimate

The external gamma radiation levels in different areas of the mine range from 2 to 10 uGy/h, averaging about 5 uGy/h. The effective dose-equivalent computed from the average dose-rate and the duration of exposure ranges from 4 to 10 mSv/y.

2.5 Total Effective Dose-Equivalent

The total dose-equivalent is the sum of the dose-equivalents from internal and external sources (ICRP 77). The weighted mean of the effective dose-equivalent — both per caput and collective — for the miners are shown in Fig. 1.

2.6 Risk Estimate

Increase in the incidence of lung cancer among American and Czech uranium miners has been attributed to their prolonged exposure to radon daughters (Lundin 71, Sevc et al 76). Risk estimation being a complex problem, widely varying values of the risk factor are given in the literature for radiogenic lung cancer. After a critical evaluation of these values a lifetime risk factor of 1.5 - 4.5 x 10^{-4}/WLM has been suggested on epidemiological considerations (UNSCEAR 77; ICRP 81). Based on the data collected, the general level of mortality risk for Indian uranium miners from radiogenic lung cancer for 30 years exposure is given in Table 3.

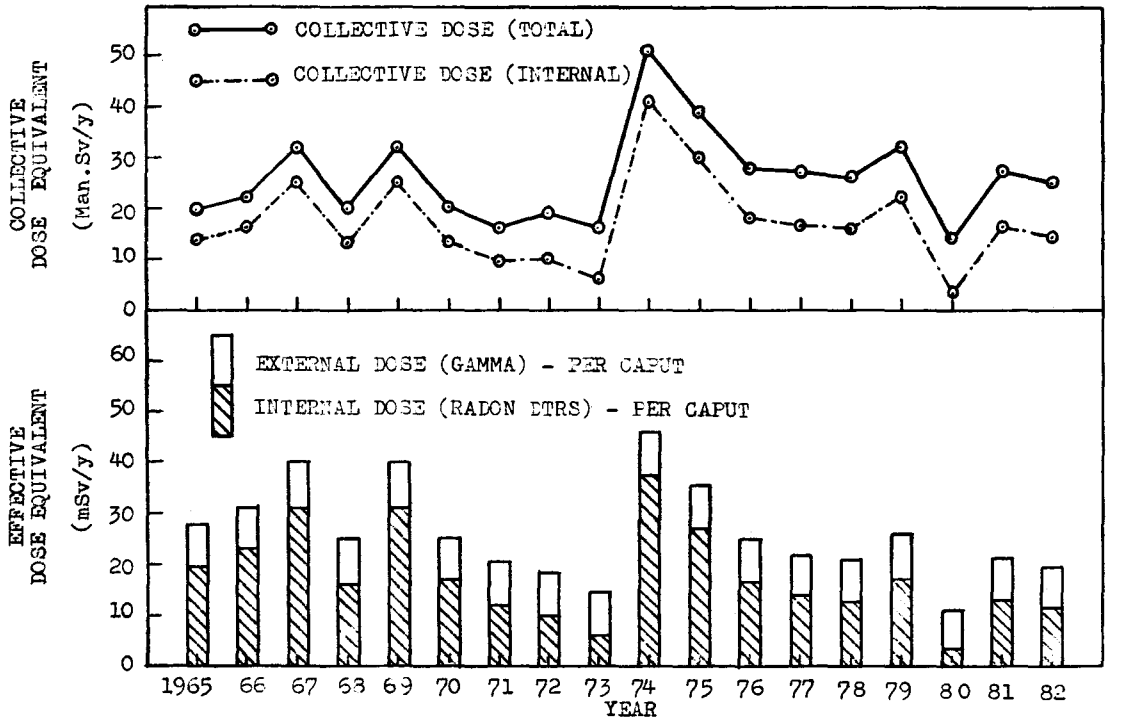

FIG. 1. TREND OF RADIATION EXPOSURE OF INDIAN URANIUM MINERS

Table 3, Estimated life-time risk of radiogenic lung cancer for 30 years exposure

Miner group	Mean cumulative exposure (WLM/y)	Individual risk	Collective risk per 1000 miners
Drillers	2.3	$1.1 - 3.2 \times 10^{-2}$	1 - 4
Muckers	2.7	$1.2 - 3.6 \times 10^{-2}$	3 - 9
Others	1.6	$0.7 - 2.1 \times 10^{-2}$	4 - 13
Weighted mean	1.8	$0.8 - 2.4 \times 10^{-2}$	8 - 24

Corrected for percentage composition.

3. DISCUSSION

From Table 1 the weighted mean of the time spent underground is 1868 h/y. The exposure of the miners has rarely reached the limit of 5 WLM/y; generally it has been much lower. The drilling and mucking crews are exposed to relatively higher concentrations (Table 2) but the weighted mean of the cumulative exposure to radon daughters is 1.8 WLM/y (Fig. 1). This will account for an average whole body dose of 18 mSv/y from internal exposure. The trends of total per caput and collective dose estimates show fluctuation around a mean of 26 mSv/y and 26 man.Sv/y respectively.

The risk estimates presented in Table 3 are based on the risk factors derived from cumulative exposures above 120 WLM. The risk factor may be different at lower exposures (below 60 WLM). However, no case of lung cancer has so far been detected among Indian uranium miners.

The estimated lung cancer risk of 8 - 24 per 1000 miners in 30 years is comparable to the risk of fatal accidents of 0.23 - 0.34 per 1000 miners per year in Indian metal mines (Patnaik & Ghose 82).

4. ACKNOWLEDGEMENT

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5. REFERENCES

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