RADON EMANATION STUDIES IN JADUGUDA URANIUM MINE

A.H.Khan and M. Raghavayya
Health Physics Division
Bhabha Atomic Research Centre
Bombay-400085, India

Abstract

Radon gas emanating from the rock surfaces is the major source of radon in uranium mines and ventilation is the only effective means of keeping the radon levels within the acceptable limits. Quantitative estimation of the radon emanation rates is therefore essential for calculating the fresh air requirements of a working face.

Measurements of radon emanation rates have been carried out in laboratory and in the underground mine. In laboratory, the uranium ore sample is enclosed in a large air-tight glass container. Radon from the sample diffuses out andaccumulates in the air volume of the container. Samples are periodically drawn from the container and radon activities are determined. The radon emanation rate is then computed from the activities obtained at different sampling intervals.

This paper describes in detail the studies conducted in the laboratory and in the uranium mines. Results obtained are presented and compared with the emanation rates published elsewhere in literature.

INTRODUCTION

The major radiation hazard in a uranium mine originates from the short-lived radon - progency, concentrations of which mainly depend on that of the parent, radon-222. Formed within the ore body, radon enters mine atmosphere by diffusion through the rock surface. The rate of emanation is characterised by the ore grade and porosity of the rock[1,2]. Suction effect caused by lowering of the atmospheric pressure is another additive factor[3]. Although underground water[4] and broken ore piles also contribute substantially to the radon content of a mine drift, the main supply comes from the continuous diffusion through the ore body. Ventilation plays the most effective role in reducing the airborne radiation levels underground. Knowledge of radon emanation rate is therefore essential for an efficient and economic design of a uranium mine ventilation system.

This paper describes the efforts being made at Jaduguda to estimate the radon emanation rate in the uranium mine. The present investigations were confined to study the dependence of emanation rate on the grade of ore. Simple laboratory and field methods have been described. Emanation rates obtained in Jaduguda Uranium Mine have been compared with those reported in literature from elsewhere.

METHOD OF EMANATION RATE MEASUREMENT

Laboratory Experiments

Small pieces of uranium ore were placed in glass jars of approximately one litre capacity, and were covered with air tight lids provided with a stop cock. The gas emanating from the ore samples was allowed to accumulate in the free-air-space of the emanation jars. Radon levels within the jars were usually found to reach measurable concentrations in 5 to 6 hours after sealing. The radon build-up in the jar follows an exponential pattern, and reaches a constant concentration value after a period of about a month. In order to establish that our measurements were done during the near linear region of the build-up curve, the build-up was followed and was found to be fairly linear within the first 5 days. All our sampling for emanation studies were done within the first two days. Samples of air were drawn from the jar at desired intervals directly into evacuated scintillation flasks. Air drawn from the emanation jar during sampling was replaced by introducing radon free air. Sampling from each jar was repeated at suitable intervals and the concentration of radon at each sampling instant was estimated by measuring the activity in the scintillation flask after a lapse of about 200 minutes.

The rate of diffusion of radon through unit surface area of the ore piece is termed as the Emanation Rate, 'J'. It can be calculated using the following formula suggested by Thompkins et al[1].

$$J = \frac{K(C_2 - C_1\, e^{-\lambda t})}{3600} \times \frac{V}{A} \qquad \ldots\ldots(1)$$

Where $K = \dfrac{\lambda}{(1 - e^{-\lambda t})}$ = depletion factor,

C_1 = radon concentration in the accumulation volume at instant t_1, Ci/l,

C_2 = radon concentration in the accumulation volume at instant t_2, Ci/l,

λ = decay constant of ^{222}Rn, h^{-1}

A = emanating area of rock surface, cm^2

V = Radon accumulation volume, l.

Field Experiments

For field measurements underground, holes of 34 mm dia and 1 to 3 metre length were drilled in the ore body. Holes were thoroughly washed to remove loose particles of ore dust. After flushing with compressed air the holes were sealed with rubber stoppers provided with a stop cock. Radon emanating from the inner surface of the rock was allowed to accumulate in the drill hole. Samples of radon were directly collected in pre-evacuated scintillation flasks at known time intervals. Volume and surface area of the drill hole were measured. The concentrations of radon obtained within the holes at different sampling instants were used to estimate the radon emanation rate using the relation shown in equation (1).

EMANATION RATE DATA

Radon emanation rates of twenty one ore samples from different areas of the mine were measured in the laboratory. Grade of ore in respect of each sample was estimated radiometrically. The ore grades thus obtained were grouped into discrete classes for simplicity. For instance, all values from 0.070 to 0.090 were considered as 0.08 and those from 0.090 to 0.110 as 0.10 and so on.

The mean of emanation rates of the samples corresponding to the different groups of ore grade are presented in Table-1.

Table-1

Radon Emanation Rates of Uranium Ore Samples

Grade of ore (% U_3O_8)	Radon Emanation Rates(J) x 10^{-16} Ci/cm^2 sec.
0.02	0.10
0.04	0.41
0.06	0.14
0.08	0.25
0.10	0.67
0.12	0.35
0.14	0.32
0.16	0.85
0.20	0.12
0.24	0.61

Range of J: 0.10×10^{-16} to 0.85×10^{-16} Ci/cm^2.sec.

For field measurements, drill holes at 15 locations in the mine were chosen and the emanation rates were estimated. Rock samples were chipped off from around the individual holes and the ore grades were estimated. The values of J obtained for different groups of ore grades around the drill holes are given in Table-2.

Table-2

Radon Emanation Rate in the Mine

Grade of ore (% U_3O_8)	Radon Emanation Rate(J) x 10^{-16} Ci/cm^2.sec.
0.02	0.13
0.06	0.37
0.08	0.36
0.10	0.19
0.12	1.20
0.16	1.18
0.18	1.35
0.20	1.69

Range of J: 0.13×10^{-16} to 1.69×10^{-16} Ci/cm^2 sec.

DISCUSSION

The radon emanation rates obtained in laboratory experiments are generally lower than those obtained under actual mining conditions. The deviations in the two ranges vary from a factor of 1.3 to 2. This variation may be attributed to a variety of reasons. One is that the ore pieces used in the laboratory studies were very small as compared to the massive ore body inside the mine. Secondly, since the mine employs exhaust type of ventilation, the barometric pressure under ground is depressed in comparison to that outside. The difference in the pressure is of the order of 32 mm of water gauge. It has been reported that reduction of pressure increases the emanation of radon[3].

Contrary to expectations, the attempts made to establish a precise relation between the ore grade and emanation rate did not yield any conclusive result in respect of laboratory experiments. Although no definite explanation could be given for this anomaly, it is likely that the violent forces at work during blasting might have altered the rock characteristics to varying degrees and hence the inconsistency. In case of the underground experiments, however, the emanation rate did appear to follow the ore grade, as may be seen from Figure-1.

As the atmospheric concentrations of radon in our mines are generally found to be well within the permissible limits, a comparison of emanation rate in Jaduguda mines with those elsewhere may be of interest. For this reason, emanation rates prevalent in American mines and in some soils have been compiled in Table-3.

Table-3

Comparative Values of Emanation Rates

Area/Countries	Radon Emanation Rate J, x 10^{-16} Ci/cm^2.sec.
Jaduguda Mines, India	0.13 to 1.69
New Mexico, USA, (Mines)[2]	500.00
Southern Utah, USA, (Mines)[5]	150.00
Socorro, New Mexico (Soil)[6]	0.90
Pelindaba, South Africa (Soil)[7]	0.14
Tailings used as back fill in Jaduguda	14.20

This comparison shows that radon emanation rate in Jaduguda mine is much lower than those obtained in American mines. Though the ore grade in American mines are presumably higher than that in our mine (0.07% U_3O_8), their emanation rates are too high to be accounted for by the ore grade alone. It is known that in New Mexico uranium occurs in sand stone and in Utah in shales. These rocks are highly porous as compared to our densely packed archaean and metamorphic rocks. The soils of socorro and Pelindaba, though having lower uranium and radium concentrations, have radon emanation rates comparable with that of Jaduguda mine. Thus, the porosity appears to affect the emanation rates of radon substantially.

Rate of radon emanation was determined by the authors from coarse uranium mill tailings, used as backfill in the mine. The rate was 14.2×10^{-16} Ci/cm^2.sec. The radium content of these sands was of the order of 60 pCi/g while that of the ore of grade 0.07% U_3O_8 is about 200 pCi/g. The emanation rate of this ore as seen from Figure-1 is 0.41×10^{-16} Ci/cm^{2}sec. The emanation rate from the sand is thus about 35 times that of the ore despite the radium content being only about one third. The emanation rate from the tailings would therefore be about a hundred time greater than that from the ore when normalised to equal radium content. The porosity of the sand was about 50% while the porosity of the ore was about 0.5%. The porosity ratio of the sands to the ore is therefore the same as the emanation ratios, indicating that porosity plays a far more important role in radon emanation than the ore grade alone.

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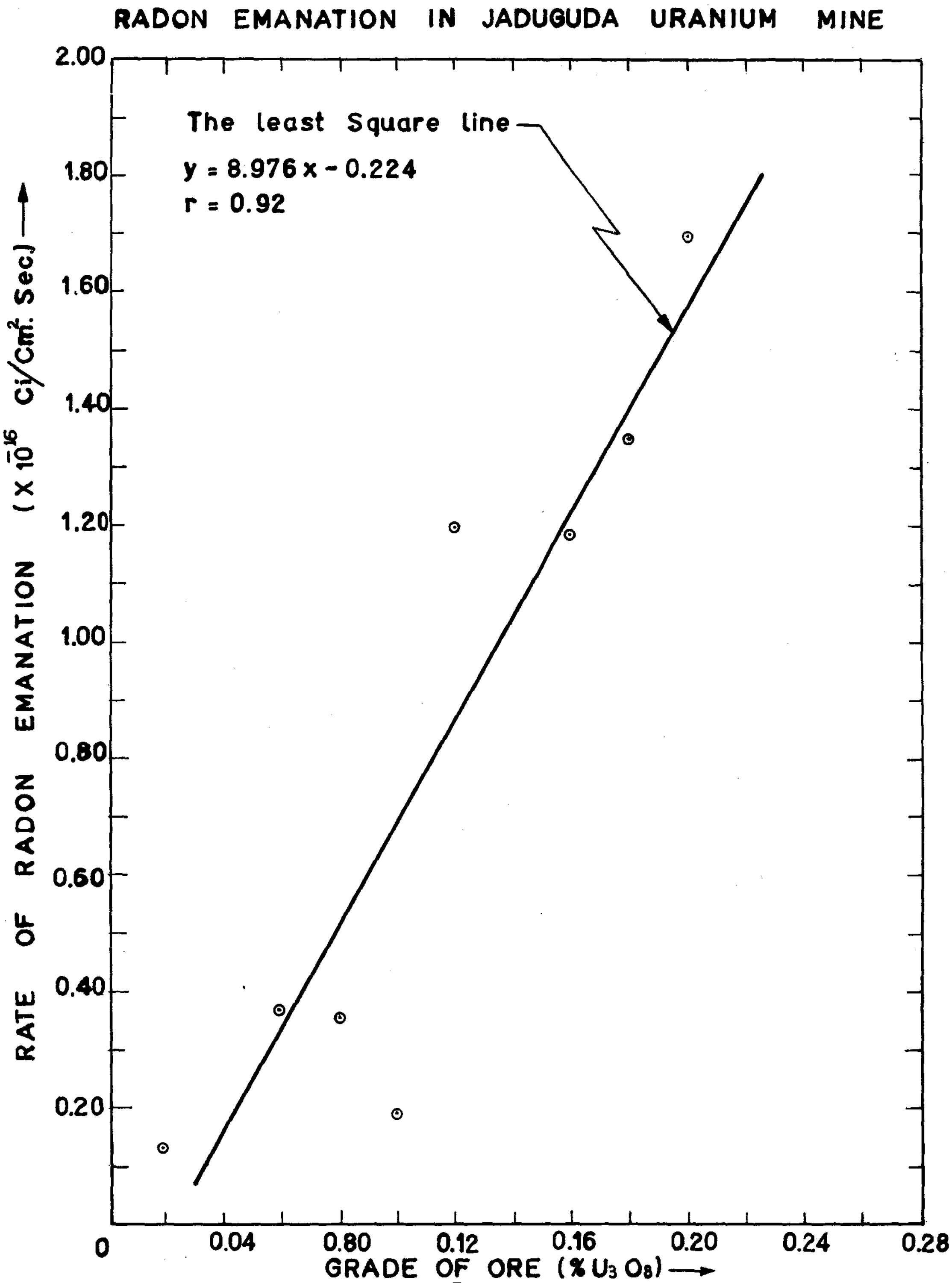
RADON EMANATION IN JADUGUDA URANIUM MINE
The least Square line
y = 8.976 x - 0.224
r = 0.92
RATE OF RADON EMANATION (X 10^-16 Ci/Cm^2. Sec)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0
0.04
0.80
0.12
0.16
0.20
0.24
0.28
GRADE OF ORE (% U3 O8)
Fig 1