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Assessment of Radon and Gamma Radiation levels in Tummalapalle Uranium Mine

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A R T I C L E   I N F O

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A B S T R A C T

In uranium mine during the work, miners are exposed to internal and external radiation exposure. Radon and its short lived daughters is main causative agent responsible for internal exposure. The gamma emitting radionuclides of uranium decay chain present in the rock contribute towards external exposure. During the mining activities, measurement of radon concentration in a uranium mine is essential to understand the degree of ventilation required for different working faces and to minimize the internal exposure to the miners. Further, gamma radiation measurement is carried out to assess the external dose received to the miners and based on their nature of work in mine, minimization of dose and occupancy period could be decided. Radon concentration and gamma radiation levels were monitored fortnightly in different galleries of Tummalapalle mine during the year, 2014. The overall equilibrium equivalent radon (EER) concentration ranged from 0.05 to 1.38 kBq m^{-3} with an arithmetic mean of 0.63 ± 0.30 kBq m^{-3} and the overall gamma absorbed dose rate ranged from 0.08-4.85 μGyh^{-1} with an arithmetic mean of 1.54 μGyh^{-1}±0.61 μGyh^{-1}, respectively. Most of the measurements of radon and all values of gamma radiation levels were found to be well below the prescribed regulatory limits.

1. Introduction

All minerals and raw materials contain radionuclide of natural origin, of which the most important for the purposes of radiation protection are the radionuclide in the ^{238}U and ^{232}Th decay series and ^{40}K. The exhalation and release of radon gases into the environment are the products of the radioactive decay chain of primordial radionuclide, such as uranium or thorium, specifically the isotopes ^{238}U, ^{235}U and ^{232}Th.

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The radon isotopes formed from these decay chains are ^{222}Rn ('radon'), ^{219}Rn ('actinon') and ^{220}Rn ('thoron'), which are the direct decay products of the radium isotopes ^{226}Ra, ^{223}Ra and ^{224}Ra, respectively, in these chains. Due to the low abundance of ^{235}U in natural uranium and the short half-life of actinon (4 s), most work concentrates on ^{222}Rn and its decay products, since these are the major contributor of exposure. In general, most uranium deposits contain low primary thorium (^{232}Th) and hence thoron (^{220}Rn) is generally considered to be of minor radiological importance. Radon (^{222}Rn) is a chemically inert noble gas with a half-life of about 3.8 days, while its decay products of various isotopes of bismuth (Bi), polonium (Po) and lead (Pb) generally forms solids at normal environmental conditions. The half-lives of radon progeny vary from microseconds to minutes to years.

The rates of radon release are complex and depend on many factors, such as rock mineralogy and structure, the distribution of parent radionuclides (e.g. ^{238}U, and ^{226}Ra), temperature and moisture content. The inhalation of significant activities of radon and its short lived progeny has long been considered to be related to elevated incidences of lung cancer and other diseases in uranium industry workers[1, 2]. In India, uranium mining has been carried out for more than last four decades in the East Singhbhum district of Jharkhand and at present seven uranium mines and two processing plants are in operation. Other uranium reserves have been identified in Lambapur, Peddagattu and Tummalapalle of Andhra Pradesh, Western Kasi Hills in district of Meghalaya and Gogi in Karnataka. Recently, at Tummalapalle in the district of Kadapa Andhra Pradesh, an underground mine and processing plant have been developed and under the initial phase of operation. The present study has been carried out in Tummalapalle uranium mine. At each uranium mining and processing site, Health Physics Unit of Health Physics Division of BARC is established to carry out radiological and environmental monitoring, to control and to ensure safety in plant and in the surrounding environment. The foremost objectives of radiological monitoring in a low ore grade uranium mine are (i) to establish ^{222}Rn concentration and external gamma radiation levels in the mine, (ii) to evaluate the effectiveness of degree of ventilation provided in the different working ASD of the mine, (iii) to control the radiation exposure to the members of radiation workers associated with different mining activities and (iv) to assess engineering control measures to ensure the regulatory compliance.

2. Site description

Tummalapalle uranium deposit is located in the Vemula of Kadapa district of Andhra Pradesh at a distance of 70 km from district headquarters. The nearest town is Pulivendula, which is about 15 km from the project (by road) towards the North West. The deposit is covered under the survey of India Toposhet Nos 57 j/3 and 57 j/7 between latitudes 14^0 18' 36" N & 14^0 20' 20" N and longitudes 78^0 15' 16" E & 78^0 18' 3.3" E. The nearest railway station is Muddanuru on the south central railway Hyderabad-Chennai BG line which is about 50km towards the North East. It has been reported strata bound uranium mineralization at Tummalapalle in the Vempalle Formation of the Cuddapah Super Group. The average ore grade of the mine is estimated to be 0.0407% as U_3O_8 content. The cut off grade has been considered as 0.02 % of U_3O_8. The rated production of the mine has been planned to be 3000 Tons per day(TPD). The location map of the Tummalapalle site is presented in Fig. 1.

Fig. 1 Map shows Tummalapalle Site

3. Geology of the study area

The study area lies in the south western part of the crescent shaped to late Proterozoic Kadapa basin. The basin constitutes a metamorphosed to slightly metamorphosed thick (1500 m) arenaceous and argillaceous sedimentary sequence overlying the profound eparchean unconformity. Highly metamorphosed and deformed late archean to early proterozoic granite gneisses and dharwarian schists lie under this thick sedimentary pile. The sediments are mostly undisturbed on the SW margin of the basin while these are thrust over by Dharwarian schist and gneisses on the eastern margin. Tummalapalle uranium deposit is located in the middle of the south-western margin of Kadapa basin. Vempalle carbonate rock formation, is the host rock of uranium mineralization, forms the upper part of papaghni group of the rocks and is underlain by gulcheru quarzite

4. Measurement technique

^{222}Rn concentration in the mine air was measured by using a scintillation cell technique. In scintillation cell method, alpha particles emitted in the decay of radon and its progeny are made to interact with ZnS (Ag) phosphor to produce scintillation. The emitted light pulse is viewed by a photomultiplier, coupled optically to the phosphor, converting the light pulse into electrical pulse and counted using electronic counting system. The scintillation cell is a cylindrical aluminum chamber having 150ml volume. One end of the cell is closed with a glass window and other end is provided with a swage lock quick connector valve. The internal surface except the glass window is coated with ZnS (Ag) (10 mg cm^{-2}) as detector. The cell is evacuated and air sample is drawn into it at the desired locations in the mine and delayed for 3 h to attain equilibrium between ^{222}Rn and its short lived progeny .The scintillation cell later connected to the photomultiplier assembly and then counted for alpha activity [3].

The efficiency of the system is about 75% and the minimum detection level for short counting period (10min) of this technique is 40 Bq m^{-3}. Concentration of radon is calculated as follows:

$$^{222}Rn\ Conc.(Bq\ m^{-3}) = \frac{C \times \lambda}{3 \times V \times E \times e^{-\lambda t} \times (1 - e^{-\lambda T})} \quad (1)$$

where C is the net counts in T seconds (counting time), λ is the decay constant of ^{222}Rn, E is the efficiency (%) of the cell, V is the volume (m^3) of the scintillation cell, t is the delay (> 180 s) between sampling and counting time(s). Further, Micro-R Radiation Survey Meter (PRM -151S), supplied by Pla Electro Appliances Private Limited, India was used for measurement of external gamma radiation level in air at different working locations inside the mine.

5. Results and Discussion

5.1 Radon concentration and gamma radiation level in the mine

For mining of the ore body from the mine, three declines have been constructed. Centre decline is designed for conveyor for the transportation of ore from the underground mine to surface ore bins and east and west decline will be used for transport of man and material. The apparent inclination of the decline is 9^o in dip direction and the size is 5m (width) ×3m (height). Mineralization of the Tummalapalle mine has been established up to 275m depth. Room and pillar method is followed for mining of the ore body and at present 16 ASD already developed in east and west direction up to a vertical depth of 190m. Size of the ASD is 4.5m (width) ×3m (height). For circulation of fresh air to working faces, three numbers of ventilation fan (PV-120) have been installed over four bore holes of diameter of 1.5m and ventilation shaft2 has been commissioned at western side. By installation of these fans (PV-120) about each 35 $m^3\ s^{-1}$ and main ventilation shaft2 about 125 $m^3\ s^{-1}$ air is being handled for the western side ASD of the mine. Another main ventilation fan (VF-3000) has been commissioned at ventilation shaft No. 3 for handling 125 $m^3\ s^{-1}$ air and borehole fan (PV-120) at 8E crusher chamber for the eastern side of the mine. However, for ventilation of working face, auxiliary duct fans are used inside the mine to circulate fresh air to work face by taking fresh air from the intake air circuit. The fresh air enters different ASD of western and eastern side of mine through the three declines. The statistical analyses of data on equilibrium equivalent radon (EER) concentrations and external gamma radiation for the overall mine are presented in Table 1.

Table 1: Statistical analysis of the EER concentration and gamma radiation level in Tummalapalle uranium mine.

Parameter	EER concentration ($kBqm^{-3}$)	Gamma radiation (μGyh^{-1})
No. of data	238	247
Minimum	0.05	0.08
Maximum	1.38	4.85
Range	0.05-1.38	0.08-4.85
Arithmetic mean	0.63	1.54
Standard deviation (SD)	0.30	0.61
Geometric mean	0.57	1.39
Geometric standard deviation (GSD)	1.87	1.77
Median	0.58	1.50
25^{th} percentile	0.45	1.23
75^{th} percentile	0.82	1.84
Quartile Range	0.37	0.61
Skewness	0.29	0.74
Confind. -95%	0.60	1.46
Confind. +95%	0.67	1.62

The overall EER concentration in the mine air was found to vary from 0.05-1.38 kBq m^{-3} with arithmetic mean (AM) of 0.63 kBq m^{-3} and standard deviation (SD) of 0.30 kBq m^{-3}. The first quartile, median and third quartile values for overall radon concentrations in mine were estimated to be 0.45, 0.58 and 0.82 kBq m-3, respectively. About 85% of the measurements of radon concentration showed lower value than the derived air concentration of radon of 1 kBq m^{-3} in Tummalapalle mine. The frequency distributions of EER concentration has been studied and is presented in Fig. 2.

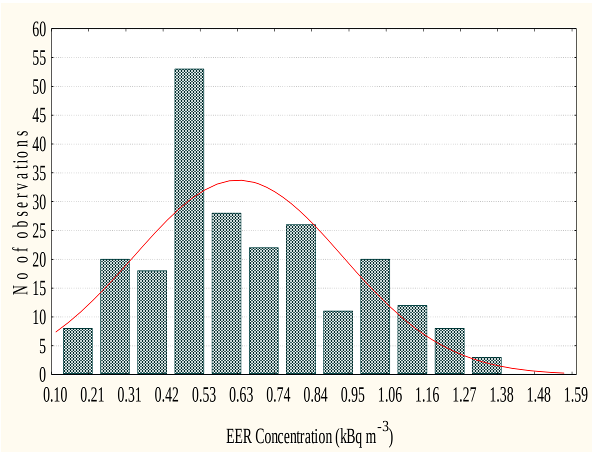

Fig. 2 Frequency distribution of EER concentration in Tummalapalle mine

From the total measurements, about 39 % of the data showed EER concentration < 0.50 kBq m^{-3}, 85% data showed EER concentration between 0.5-1.0 kBq m^{-3} and about 15% data showed EER concentration above 1kBq m^{-3}. This may be attributed for initial development and operation of the mine. Further, all data on radon measurements were found to be well within the upper reference level of radon concentration of 1.5kBq m^{-3} as recommended by ICRP[4]. However 85% measurements of radon concentration were below recommended action level of radon concentration of 1kBq m^{-3} of IAEA[5]. Further, to reduce ^{222}Rn concentration in underground mine much understanding in the ventilation circuit and improvement of ventilation would be required to minimize exposure due to radon at work place. It is interesting to compare the mean EER concentration of the present study with other underground uranium mines operating in the Singhbhum Thrust Belt (STB) of Jharkhand, India. The mean EER concentration of Tummalapalle mine is found to be comparable with Narwapahar (0.39-1.23 kBm^{-3}), Bhatin (0.44-0.64 kBm^{-3}) and Jaduguda (0.39-0.54 kBm^{-3}) underground uranium mines [6,7].

Further gamma radiation level was also studied in Tummalapalle mine. The overall gamma absorbed dose rate was found to vary from 0.08 -4.85 μGyh^{-1} with AM of 1.54 ±0.61 μGyh^{-1}. The first quartiles, median and third quartile values of overall gamma radiation were estimated to be 1.23, 1.50 and 1.84 lGy h-1, respectively. All measurements of gamma absorbed dose rates were found to be well below the regulatory limit of 8 μGy h^{-1} for 8 hours working period in the mine. The frequency distribution of gamma absorbed dose rate has been studied and is presented in Fig. 3.

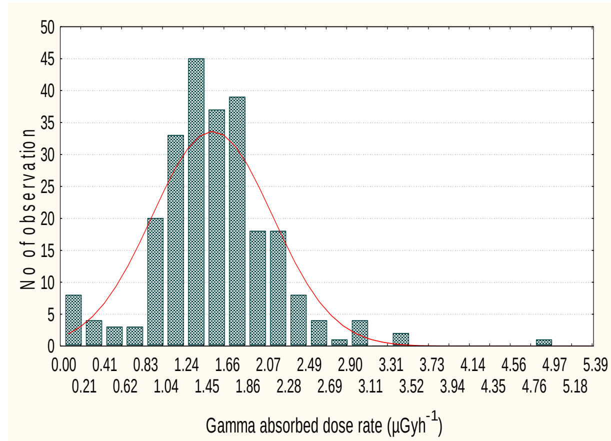

Fig. 3 Frequency distribution of gamma absorbed dose rates in Tummalapalle mine

From the total measurements, about 50 % of the data showed gamma absorbed dose rate < 1.50μGy h^{-1}, 32% data showed gamma absorbed dose rate between 1.5-2.0 μGy $h^{-1}$and about 18% data showed gamma absorbed dose rate between 2.03-4.85 μGyh^{-1}.The mean gamma absorbed dose rate of the present study can be compared with other underground uranium mines of STB of Jharkhand, India. The mean gamma absorbed dose rate of Tummalapalle mine is comparable with Narwapahar (0.81-1.80μGy h^{-1}), Bhatin (1.80-2.80μGy h^{-1}) and Jaduguda mine (2.15-3.91 μGy h^{-1}) [7,8].

6. Conclusion

The overall EER concentration in Tummalapalle mine was found to vary from 0.05-1.38 kBq m^{-3} with an arithmetic mean of 0.63 ± 0.30 kBq m^{-3}, which is well below the prescribed derived air concentration limits of radon as recommended by national and international regulatory agencies. Further most of the measurements of EER concentration in the mine were observed to be well below the occupational exposure limits of 1kBq m^{-3} of radon. Further exposure from radon can be reduced by regular improving of ventilation in different working faces of the mine by employing auxiliary ventilation system. The overall gamma radiation level in the mine was found to vary from 0.08 to 4.85 μGyh^{-1} with arithmetic mean of 1.54 ± 0.61 μGyh^{-1}. All measurements of gamma radiation level were found to be well below the regulatory limit of 8 μGy h^{-1} for 8 hours working period in the mine. The data obtained on EER concentrations and gamma radiation levels of Tummalapalle mine during the primary phase operation were found to be comparable with other uranium mines operating in the STB of Jharkhand. Hence, working in a low ore grade uranium mine is quite safe under the remedial and control measures.

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