Radiological assessment of gamma and radon dose rates at former Uranium mining tunnels in, Egypt

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Abstract

Radiological assessment was carried out at the mining tunnels (El Missikat and El Eradiya tunnels) in Egypt due to exposure to radon (^{222}Rn), thoron (^{220}Rn) and gamma radiation. ^{222}Rn/ ^{220}Rn measurements were carried out with two techniques; instantaneous (active) and discriminative (passive) radon and thoron solid state nuclear track detectors (SSNTDs) were used for longer representative measurements. The detectors exposed for long time inside the tunnels. The results showed that radon and thoron in general is very high due to non-ventilation drafts inside the tunnels and gamma radiation was low. The total annual effective doses were exceeded to the permissible limit 20 mSv/y. According to IAEA recommendations, the two tunnels are regulated and controlled areas. A radiation hazard could be associated with exceptional situations, such as elevated exposures to ionizing radiation at tunnels, so work within these tunnels must be prevented only after the application of IAEA regulation for radiation protection standards. The exposure for radon and thoron gases for long time can be damage the body cells and it will cause cancer.

Introduction and Objective

Uranium mining is unique in the nuclear industry being the only component of the nuclear production cycle that has associated with it a significant incidence of occupational illness. Uranium can be mined safely but it is clear from evidence that the radiological environment of underground uranium mines is quite hazardous unless appropriate controls are applied. Indeed, the hazard is not limited to uranium mines. Investigations have shown that the same radiological constituents that have caused lung cancer among uranium miners, i.e. radon and thoron, occur in other types of underground mines and, in some instances, also in sufficient concentration to cause occupational illness, (Abdel Razek, 2015).

^{222}Rn and thoron are responsible for about two thirds of the exposure of the world population to ionizing radiation from natural sources (UNSCEAR, 2008).

In this study an evaluate of the radiological exposure inside the former uranium (U) mining sites of Missikat and Eradiya in Egypt, these sites are important mining activities for exploration radionuclides. The occupational exposed inside the mining activities for gamma, radon (^{222}Rn) and thoron (^{220}Rn), so it need to asses of current radiation doses which resulted from gamma dose rates, indoor radon (^{222}Rn) and thoron (^{220}Rn) measurements. Gamma radiation, indoor radon, thoron and their progeny represent the largest contribution to the doses of ionizing radiation of the occupational in the U-mining tunnels inn Egypt.

Materials and Methods

DESCRIPTION OF THE SITES INVESTIGATED

Two tunnels U mining, exploration sites located in eastern central desert, Egypt (Fig. 1) were selected for this study, where the Egyptian Nuclear Materials Authority (NMA) established some projects to explore the radioactive elements in Egypt. One of them was established at the 85 k Qena-Safaga Road. This project operated in the exploration tunnels at El-Missikat and El-Erediya. So, the high radioactive exposure arises for a lot of workers in these projects from terrestrial radioactive elements such as uranium, thorium, potassium and radon. El-Misssikat tunnel located at 3 km south of the 85 km post on Qena-Safaga Road, it is composed of the main adit D (958.85 m) and two drifts; DI (256.3 m) and DII (589.5 m), which was shown in Fig (2). DII is open to the outer atmosphere, causing natural ventilation.

El-Erediya tunnel is located 35 km south of the 85 km post on Qena-Safaga Road. It is composed of the adit D (751.3 m) and thirteen drifts, which had shown in Fig. (3) (El-Tahir, 1985). DVIII drift is opened to the outer atmosphere, causing the ventilation in the area. The dimensions of these tunnels are 2-2.2 m wide and 2.2 m height. The explored rocks in this tunnel include younger granite altered and brecciated varieties. These tunnels designed according to the shear zone, which cleared above the mountains. It extended in sub surface parallel with shear zone which include on an important minerals as silicification, ferrugination, sericitization, kaolinization and Mn-Oxides. Abd Deif, 1985, stated that the main shear zones along the drifts DI, DII in El-Missikat tunnel included on abundant of uranium minealization. In each tunnel, ten monitoring stations were chosen to test the proposed dosimeter as shown in Fig (2&3). These stations were chosen to cover different conditions; Uranium, thorium and ventilation conditions.

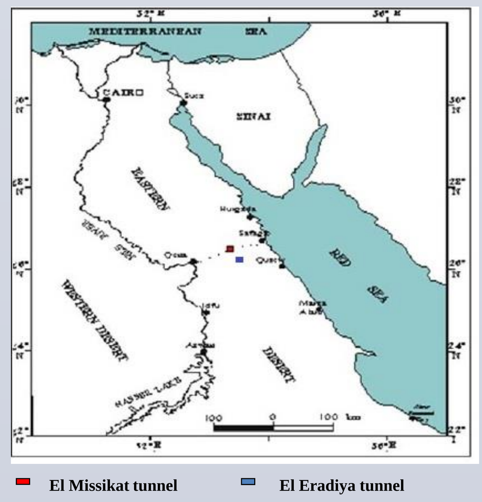

Fig 1: Location map of El Missikat and El Eradiya tunnels in eastern central desert, Egypt.

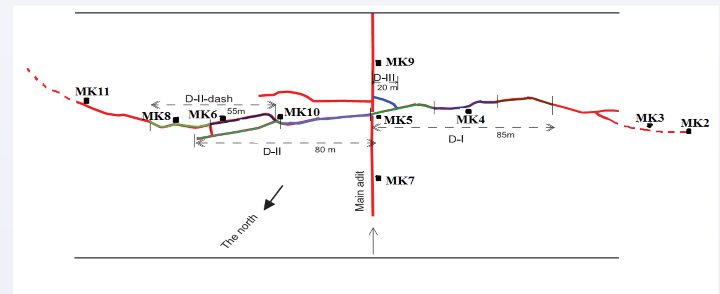

Fig 2: Plan of El-Missikat mining work (Abu Deif, 1985)

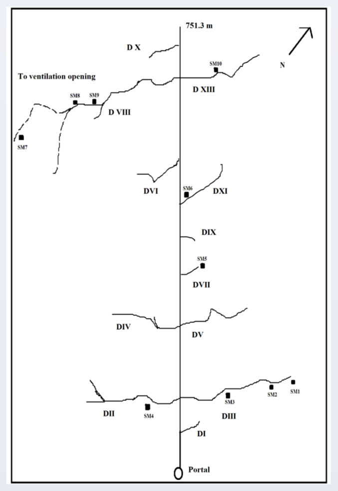

Fig 3: Plan of El Eradiya mining work, (El Taher, 1985).

ANALYTICAL METHODS USED

GAMMA DOSE RATE MEASUREMENTS

The gamma dose rates (µSv/h) due to γ-ray exposures were directly measured at 1m from the sides at each monitoring station at the two tunnels, using ALNOR RDS-100 gamma survey meter calibrated against a 60Co γ-source of activity 7.4 x108 Bq at the National Institute of Standards and Technology (NIST), where The measurements of dose rate were carried out according to the international measuring protocol: 1 m above ground, and occasionally at ground level (Stegnar et al., 2013).

RADON (222Rn) AND THORON (220Rn) MEASUREMENTS

The active and passive techniques have been used in measuring 222Rn and 220Rn concentrations, simultaneously with indoor gamma dose rate measurements. Measurements, 222Rn/220Rn discriminative solid state nuclear track detectors (SSNTD) were used for long-term (Abdel Razek et al., 2015). The dosimeter was hanged at a height of 1.5 m and distant 10 cm from the surface of the granitic walls. Due to the measurements of radon and thoron in non-ventilation tunnels, so the radiological assessments are based on a short exposure time for SSNTDs per one month. The gamma measurements based on the worker exposure for it every day through the work time.

DOSE ASSESMENT

The annual effective radiation doses (mSv/a) were calculated using the following criteria and assumptions:

^{222}Rn (Rn) and ^{220}Rn (Tn)

$$E_i = (DCF \times F)_{Rn/Tn} \times \sum_i C_i \times O_i$$

Ei Annual effective dose rate (mSv/y), Ci Concentration of 222Rn or 220Rn at location i (Bq/m3), Oi Occupancy (exposure time at location i): 2000 h per year, DCF Dose Conversion Factor for 222Rn and 220Rn decay, products (222RnDP and 220RnDP). These assumed to be 9 (nSvh-1 per Bqm-3) and 40 (nSvh-1 per Bqm-3) for 222RnDP and 220RnDP, respectively (UNSCEAR, 2000), F Equilibrium Factor between 222Rn and its short-lived daughter products was assumed to be 0.4 in the indoor environment, and F for 220Rn to be 0.1 (UNSCEAR, 2000).

Due to the uncertainty of dosimetry for 220Rn, the derived radiation doses from indoor 220Rn measurements are considered as preliminary. Namely, several different DCFs (Dose Conversion Factor) were reported for 220RnDP, ranging from 51 to 114 (nSvh-1 per Bqm-3) (Kranrod et al., 2010), thus representing values different from those reported in UNSCEAR 2000.

GAMMA RADIATION DOSES

The assessment of gamma dose in the indoor environments:

$$\mathbf{D} = \sum_i D_i \times O_i$$

Here the annual dose rate is the sum of the products of gamma dose rate Di (mGy/h) and exposure time Oi (occupancy) for all locations, where the exposure for gamma radiation inside the tunnels for the whole body for worker exposed, so the conversion factor equal unit, so the annual effective dose rate equal dose rate.

Results

MISSIKAT TUNNELS

GAMMA DOSE RATES

In the Missikat tunnel mission, the measured gamma dose rates in air at each station (Fig. 2). The gamma dose rate measurements ranged from 0.72 to 3.2 mSv/y. External exposure arises from terrestrial radionuclides only in the tunnel that are present at trace levels in all soils. Higher radiation levels are associated with igneous rocks, such as granite, so the gamma which measured by a portable detector equal to the estimated gamma from terrestrial radionuclides. The results were in good agreement with the recommended measurements for occupational workers in all stations, (UNSCEAR., 2008).

^{222}Rn and ^{220}Rn

Radon concentrations were screened inside the tunnel at all stations Fig. 2. In these study CR- 39 nuclear track detectors of 1 mm thickness are used to evaluate the radon concentrations, (Pershore mouldings, England). The passive radon dosimeter geometry consists of a closed chamber into which radon diffuses (Al-Jarallah and Rehman, 2003). In Table(1) the results of radon concentrations ranged from 778 to 16353 Bq.m^{-3} and the concentrations of thoron ranged from 74 to 4872 Bq.m^{-3}, these results accepted in general with the Instantaneous ^{222}Rn measurements that depend on the climate conditions (temperature, humidity, wind direction and velocity) at the time of the measurements. The values obtained were generally in good agreement with other. The results showed in this tunnel is higher than the occupational recommended limit, so it regulated tunnel and it must be governed by the regulations of IAEA.

Table 1: ^{222}Rn and ^{220}Rn concentrations[a], gamma dose rates and ^{222}Rn annual effective doses in selected locations in tunnel Missikat.

St.no	C_{Rn} (Bq.m^{-3})	C_{Tn} (Bq.m^{-3})	E_m (mSv/y)	E_{Rn} (mSv/y)	E_{Tn} (mSv)
1	15046	384	0.76	108	2.5
2	7887	4872	1.72	57	-
3	7523	728	3.2	54	2.3
4	3223	1913	0.88	23	-
5	778	206	0.88	6	8.1
6	983	217	1.72	7	2.9
7	1239	74	1.14	9	1.2
8	16353	3726	0.72	118	2.3
9	1436	-	0.74	10	1.1
10	1618	606	1.72	12	2.5
Ave	5609	1273	1.348	40	2.3
SE	593	171	0.078	4	0.23

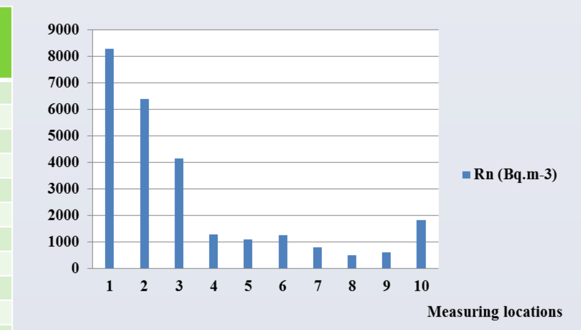

Fig 4: Plan of El Missikat mining work, (El Taher, 1985).

ERADIYA TUNNEL

GAMMA DOSE RATES

In the Eradiya tunnel, the gamma dose rates were measured at each station (Fig. 3) in this tunnel different for the Missikat tunnel due to the difference for the construction of rocks. The gamma dose rate measurements ranged from 0.36 to 1.36 mSv/y. Also, the results were in good agreement with the recommended measurements for occupational workers in all stations, (UNSCEAR, 2008). In general, all body of worker expose gamma radiation, so the conversion factor for gamma equal to 1.

^{222}Rn and ^{220}Rn

Also, in Table (2) the results of ^{222}Rn and ^{220}Rn concentrations were screened inside the tunnel at all stations lower than the Missikat tunnel results. This difference due to the construction of rocks. The results of radon concentrations ranged from 704 to 7862 Bq.m^{-3} and the concentrations of thoron ranged from 134 to 1012 Bq.m^{-3}. The climate conditions (temperature, humidity, wind direction and velocity) at the time of the measurements acted on the results, where these conditions in this tunnel different for the Missikat tunnel. The values have been obtained were generally in good agreement with other. The results showed in this tunnel is higher than the occupational recommended limit, so it regulated tunnel and it must be governed by the regulations of IAEA. These results didn't accepted in general with the Instantaneous ^{222}Rn measurements, because the measuring processes have been occurred in high warming day.

Table 2: ^{222}Rn and ^{220}Rn concentrations, gamma dose rates and ^{222}Rn annual effective doses in selected locations in tunnel El Eradiya.

St.no	C_{Rn} (Bq.m^{-3})	C_{Tn} (Bq.m^{-3})	E_m (mSv/y)	E_{Rn} (mSv/y)	E_{Tn} (mSv)
1	7862	321	0.36	57	3.07
2	4456	-	0.78	32	38.98
3	4476	286	1.34	32	5.82
4	1077	-	1.36	8	15.31
5	908	1012	0.78	7	1.65
6	874	364	0.5	6	1.74
7	704	149	0.7	5	0.59
8	1639	292	1.16	12	29.81
9	819	134	0.74	6	-
10	2641	317	1	19	4.85
Ave	2545	287	0.872	18	10.18
SE	237	29	0.034	2	1.3

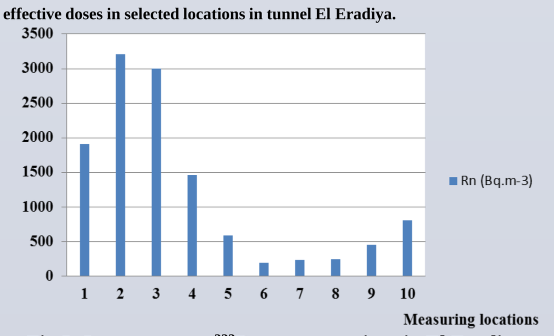

Fig 5: Instantaneous ^{222}Rn concentrations in El Eradiya tunnel

ASSESMENT OF ANNUAL EFFECTIVE DOSES

In El Missikat and El Eradiya tunnels are used various behaviors for the assessment of effective doses due to gamma and $^{222}Rn/^{220}Rn$ exposure.

EL MISSIKAT

For occupational in El Missikat tunnel, an exposure time of 8 h per day for 5 days per week for 50 weeks per year, total 2000 h per year, would result in ^{222}Rn and ^{220}Rn annual effective doses ranging from 6 to 118 mSv with average 40 mSv and ^{220}Rn annual effective doses ranging from 1.1 to 8.1 mSv with average 2.3 mSv, these results showed it's higher than the recommended limit 20 mSv, (UNSCEAR, 2008), due to non-ventilation in this tunnel. The annual effective doses due to gamma radiation for the occupational ranging from 0.72 to 3.2 mSv with average 1.3mSv, it's lower than the recommended limit.

EL ERADIYA

Also, For occupational in El Eradiya tunnel, an exposure time of 8 h per day for 5 days per week for 50 weeks per year, total 2000 h per year, would result in 222Rn and 220Rn annual effective doses ranging from 5 to 32 mSv with average 18 mSv and 220Rn annual effective doses ranging from 0.59 to 38.98 mSv with average 10.18 mSv, these results showed it's higher than the recommended limit 20 mSv, (UNSCEAR, 2008), due to non-ventilation in some of drafts for this tunnel, but it has many ventilation drafts. The annual effective doses due to gamma radiation for the occupational ranging from 0.36 to 1.36 mSv with average 0.87 mSv. In these tunnels the annual effective doses could reach levels of several tens of mSv, thus potentially exceeding the permitted radiation dose of 50 mSv per year for occupational exposure, the risk assessment from radon and thoron exposures for long time inside these tunnels without ventilating pump.

RISK ASSESMENT

In these tunnels the radiological risk is high relatively, because according to the data which showed that the exposure time for workers should be decrease. It's can be avoid the exposure for high radon and thoron concentrations by designing a big ventilation pump to refresh the tunnels before starting the work. In the tunnel environment the radiation doses did not exceed the limit of 50 mSv per year, above which intervention to protect the workers may be required. Due to the exposure to elevated gamma doses and ^{222}Rn and ^{220}Rn concentrations then persons can be received high individual radiation doses. Fig.6 show the radon and thoron gases are representing the high radiological risk.

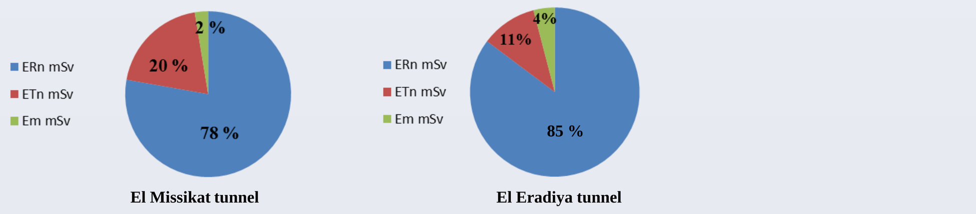

Fig 6: Comparison of annual effective dose rates from gamma, ^{222}Rn and ^{220}Rn exposures at El Missikat and El Eradiya tunnels.

Conclusion

The uranium mining tunnels represent exploration sources of natural radionuclides. The tunnels should be managed and controlled to avoid the exposure to ionizing radiation, can be exposed to physical hazards from radon, thoron and gamma radiation. According to IAEA recommendations, the two tunnels are regulated and controlled areas. Work within these tunnels must be prevented only after the application of IAEA regulation for radiation protection standards. The gamma, ^{222}Rn and ^{220}Rn doses were in general high, above the recommended annual threshold level of 20 mSv for members of the occupational, for example The maximum permissible concentrations for Rn 1000 Bq/m^3 for working environment, (IAEA, 2003). According to ALARA (As Low As Reasonably Achievable) purpose, which state it must be the radiological risk is very low, but in this study, it's high due to radon and thoron gases specially. In some of drafts inside tunnels are non- ventilated, so the exposure for radon and thoron gases for long time can be damage the body cells and it will cause cancer.

References

Al-Jarallah MI, Rehman F. Indoor radon measurements in dwellings of four Saudi Arabian cities. Radiat Meas 2003; 36: 445–448.

Abdel Razek Y M, Masoud S M, Hanfi M Y et al. Study of the parameters affecting radon gas flux from the stream sediments at Seila area Southeastern desert, Egypt. Environ Earth Sci 2015; 73: 8035–8044.

IAEA. Radiation Protection Against Radon in Workplaces Other than Mines. Safety report Series. IAEA, Vienna. 2003.

Kranrod C., Ishikawa T., Tokonami S., et al. Comparative dosimetry of radon and thoron. Radiation Protection Dosimetry 2010; 141: (No. 4), 424-427.

Stegnar P., Shishkov I., Burkitbayev M., et al. Assessment of the radiological impact of gamma and radon dose rates at former U mining sites in Central Asia. Journal of Environmental Radioactivity 2013; 123: 3-13.

United Nations Scientic Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation. Report to the General Assembly of the United Nations with Scientific Annexes. United Nations Sales publication E.00IX.3, New York . 2000.

UNSCEAR. United Nations Scientic Committee on the Effects of Atomic Radiation, New York, United Nations. 2008.

Abu Dief, A. Geology of uranium mineralization in El-Missikat area, Eastern Desert, Egypt. M.Sc. Thesis, Faculty of Science, Al-Azhar Univ. 1985; 103 p.

El-Tahir M A. Radioactivity and mineralization of granitic rocks of El-Erediya occurrence, Eastern Desert, Egypt. Ph.D. Thesis, El-Azhar Univ., Cairo, 1985; 132 p.

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