Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 23-25, 2013

Radiation Monitoring of Underground Uranium Mine in Mongolia

Enkhbat Norov *
Nuclear and Quantum Engineering Dept., KAIST, 291 Daehak-ro, Yuseong, Daejeon 305-701
**Corresponding author: enorov@kaist.ac.kr*

1. Introduction

Radiological hazards in underground mining are more serious than in open cast mines and in-situ leaching. The first step of environmental impact assessment is necessary to determine natural background radiation around uranium mines before starting uranium production in Mongolia [1]. Uranium was produced from the Dornod deposit in Mongolia by Russian interests to 1995. Mongolia has substantial known uranium resources and geological prospectively for more. Since 2008 Russia has re-established its position in developing Mongolian uranium. There is currently no uranium mining in Mongolia. According to the 2011 Red Book, Mongolia has 74,000 tU in Reasonably Assured Resources plus Inferred Resources, to US$ 130/kg U. However, geological indications reported in the Red Book suggest that uranium resources could be 1.47 million tU [2].

The paper discusses about safety assessment methodology for uranium mining. A case-study for radiation safety assessment of uranium mine is also considered on the Gurvanbulag underground uranium mine. Annual effective dose to mine workers was estimated by the sum of the external exposure to gamma and the internal exposure to long lived radioactive dust and radon.

2. Methods

Annual effective equivalent dose (D) to mine workers involving radioactive material may be calculated as sum of external exposure (D_γ) and internal exposure of long lived radioactive dust (D_{LLRD}) and radon progeny (D_{Rn}).

$$D = D_\gamma + D_{LLRD} + D_{Rn} \quad (1)$$

Gamma dose rate (P_γ) may be calculated as the way of that background of survey-meter (P_b) and cosmic ray (P_c) substitute from value of survey meter(P).

$$P_\gamma = P - (P_b + P_c)\ , nGy/h \quad (2)$$

Effective equivalent dose to external exposure is:

$$D_\gamma = 10^{-6} \cdot K \cdot \Sigma P_{\gamma i} \cdot t_i, mSv/y \quad (3)$$

where: $P_{\gamma i}$- radiation dose rate at point i, nGy/h; t_i- working hours at point i, hr/year; K- ratio of equivalent dose rate and absorbed dose rate for average gamma energy of natural radionuclides (Sv/Gy) and the ratio is 0.7 Sv/Gy [3]. Internal exposure to mine workers through inhalation of long lived radioactive dust (LLRD) in mine air is expressed by:

$$D_{LLRD} = 10^{-3} \cdot \Sigma A_i \cdot \varepsilon_i \cdot V \cdot f \cdot t, mSv/a \quad (4)$$

where: A_i– Specific activity of radionuclide i in mine dust, Bq/m^3; ε_i- dose coefficient for radionuclide i via. inhalation, Sv/Bq [2]; V - breathing volume, m^3/h (assuming 1.2 m^3/h for medium load) [4]; t-working hour for dust condition, h/a; f- average concentration of dust in breathing zone (mg/m^3) for working hour (t).
Internal exposure to mine worker from radon in secular equilibrium:

$$D_{Rn} = 10^{-6} \cdot 7.8 \cdot C_{EECRn} \cdot t\ , \text{mSv/a} \quad (5)$$

where: $C_{EEC.Rn}$ – Average equilibrium-equivalent concentration (Bq/m^3) of radon, t *is* working year (t, h/a).

Radon concentration in workplace of the Gurvanbulag uranium mine was drawn in 5 minutes using by Model 224-PCXR4 Universal Sample Pump (SKC Inc., PA 15330 USA) which has pump rate of 2.5 liter per minute and radon progeny with short half-life on the filter paper was counted in TM372 scintillation counter (Environmental Instrumentation Canada Inc.) after 7 minutes. Radon WL was calculated by the following equation:

$$WL = \frac{N \cdot \varepsilon}{R_f \cdot \upsilon \cdot t \cdot \eta}. \quad (6)$$

where: N- the giving counts per 3 min in alpha counter after 1 min delay since sampling; ε - the collection efficiency for Rn progeny of the filter paper; R_f- Roll coefficient (213); υ - air flow rate (l/ min); t – counting time for the filter paper, 3 мин; η - the efficiency of alpha scintillation counter.

3. Results

Radiation measurement has been conducted to the Gurvanbulag uranium mine site in year of 2007, 2009 [1]. Table 1 shows value of gamma dose rate(P_γ), working hours at the point(t) and calculated external dose rate (D_γ).

Table 1. Gamma dose rate (P_γ), working hours at the point(t) and calculated external dose rate (D_γ).

Location	$P_{\gamma i}$, nGy/h	t_i, h	D_γ, mSv/a
Dry building	170	2000	0.24
Geologist building	147	2000	0.21
Core shed	185	2000	0.26
Underground mine	310	2000	0.43
Mine site	196	2000	0.27
Main shaft	210	1500	0.22
Outside of core shed	268	2000	0.37
Emeelt mines camp	251	1500	0.26
Average	*217*	*1857*	*0.28*

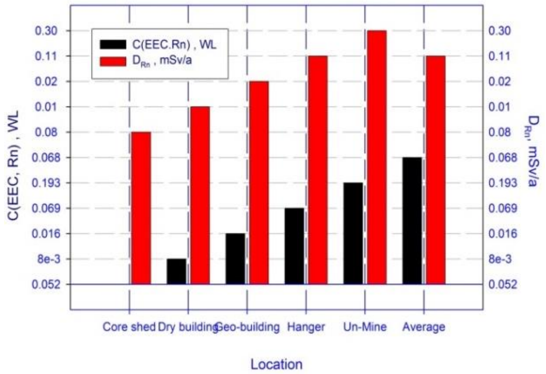

Figure 1. Average radon working level (WL) and internal exposure to mine workers (D_{Rn}) in the mine workplaces.

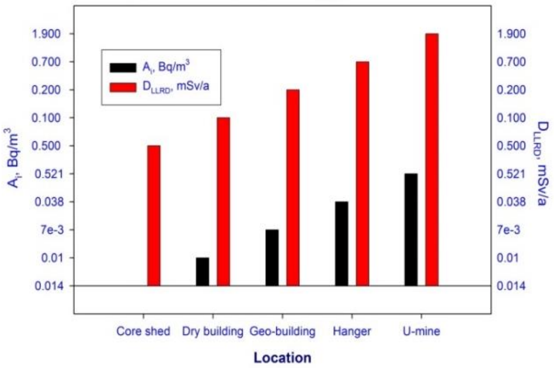

Figure 2. Average concentration of radon (A) and internal exposure from long lived radioactive dust (D_{LLRD}) in the mine workplaces

A unit of radon equivalent volume activity in Austral, Canada expresses by Working Level (WL). 1 WL is equivalent to 3.7 kBq/m^3 while radon is in equilibrium with its progeny [4, 5].

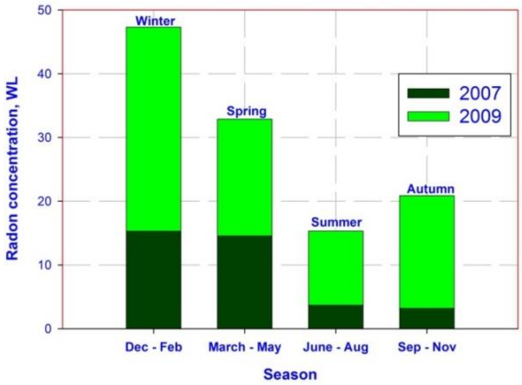

Figure 3. Annual variation of radon (WL) in the mine workplaces

4. Conclusions

This method is possible to estimate of radiation dose to mine workers. Providing all necessary safety measures is taken as recommendation in the ICRP system of dose limitation and as well as guidance on IAEA's safety series and code of practices, uranium production cycle can be managed easily and with confidence so that the workers, members of the public and the environment are safe. For the Gurvanbulag underground mine in Dornod underground mine with higher grade of uranium ore (0.2%), radiological safety is more difficult than other mine. The method is very significant to evaluate radiation safety and protection of mine workers based on their different survey result in Mongolia.

References

[1] Safety Series No.RS-G-1.6. "Occupational Radiation Protection in the Mining and Processing of Raw Materials Radiation Monitoring in the Mining and Milling". IAEA, Vienna (2004).

[2] OECD/International Atomic Energy Agency (IAEA) (2011), *Uranium 2011: Resources, Production and Demand*, OECD Publishing. doi: 10.1787/uranium-2011-en

[3] UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). Sources and Effects of Ionizing Radiation (Report to the General Assembly). Vol. II. New York: United Nations (2008).

[4] International Atomic Energy Agency. "International Basic Safety Standards for protection against ionizing radiation and for the safety of radiation sources". *BSS115*. IAEA, Vienna. (1996).