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Assessment to ^{222}Rn and gamma exposure of the miners in Narwaphar underground uranium mine, India

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ABSTRACT

Monitoring of concentrations of radon (^{222}Rn) and gamma level in underground uranium mines is essential to minimise the radiation exposure of miners within the prescribed limits stipulated by regulatory agencies. This paper presents the quantitative assessment of concentrations of ^{222}Rn and gamma radiation level at the different working places being operated at various depths of Narwapahar mine. Equilibrium Equivalent Radon (EER) concentration was found to be in the range varying from 60 to 850 Bq m^{-3} with a geometric mean of 289 Bq m^{-3} and geometric standard deviation of 1.94. The average value of EER in the mine was estimated to be about 29% of action level of 1000 Bq m^{-3} recommended by International Atomic Energy Agency (IAEA). Gamma radiation was found to be in the range of 0.73–6.15 µGy/h with arithmetic mean of 2.52 µGy/h and standard deviation of 1.49 µGy/h. Its average was calculated to be 31% of the derived regulatory limit of 8 µGy/h for 8 h working period in the mine. Furthermore, comparisons of EER and gamma radiation at various working places reveal that concentrations of EER are poorly correlated with grade of uranium ore whereas gamma radiation levels depend on it. The total annual radiation exposure of miners to radon and its daughters and gamma radiation in Narwapahar mine was evaluated to be 4.06 mSv/y, which was about of 20% of the prescribed limit of 20 mSv/y recommended by International Commission on Radiological Protection (ICRP). Thus it may be concluded that working condition of Narwapahar mine is considered as safe due to good ventilation condition of the mine and other control measures.

1. Introduction

Several guidelines have been recommended by the international radiation agencies to reduce the radiation levels in underground uranium mines. The international radiation agencies have recommended the limits of dose intake for radiation workers (IAEA, 1996; ICRP, 2007; UNSCEAR, 2008). International Commission of Radiation Protection (ICRP) has recommended the basic limit of 100 mSv for exposure of radiation workers in specified blocks of 5 years with the average of 20 mSv per annum. It has also recommended the lower and upper workplace reference levels of 500 Bq m^{-3} and 1,500 Bq m^{-3} respectively. International Atomic Energy Agency (IAEA) has recommended a limit of Equilibrium Equivalent Radon (EER) concentration of 1000 Bq m^{-3} in the workplace.

Uranium is the source of natural radiation. Due to the large abundance of ^{238}U in natural uranium, the contribution to the radiological hazards from this isotope and its daughters may be considered as significant. Since ^{238}U has a very long half-life period (4.5×10^9 y), the secular equilibrium between ^{238}U and its daughter products may be found in the uranium ore. Radiation hazards are generally classified as external and internal radiation hazards. The external hazards commonly occur due to the exposure of miners to gamma radiations emitted from the uranium ore, whereas the internal hazards are due to inhalation of radon (^{222}Rn) and its short-lived daughter products of the ^{238}U series. Radon (^{222}Rn) with a half-life of 3.82 days and a specific gravity of 9.7 g/cc is the inert gas in the decay series of ^{238}U. Radon in the mine air decays through a series of short-lived decay products such as ^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po. When the mine air is inhaled, radon and its short-lived products pass into the lung. Since its short-lived products are solid particles and potential alpha emitters, they get deposited in the lung tissues causing the lung cancer death. Epidemiological studies have revealed that prolonged exposure of underground miners to radon and its daughter products leads to an increase in lung cancer (ICRP, 2012; Laurier et al., 2004; Lubin et al., 1997; NAS, 1999; NRC, 1998; Tomasek, 2012; Yu and Nikezic, 2012). United States Public Health Service (US PHS) (1990) reported that the uranium miners exposed to radon levels of 1850–5550 Bq m^{-3} in the air for about 10 years have shown an increase in the frequency of lung

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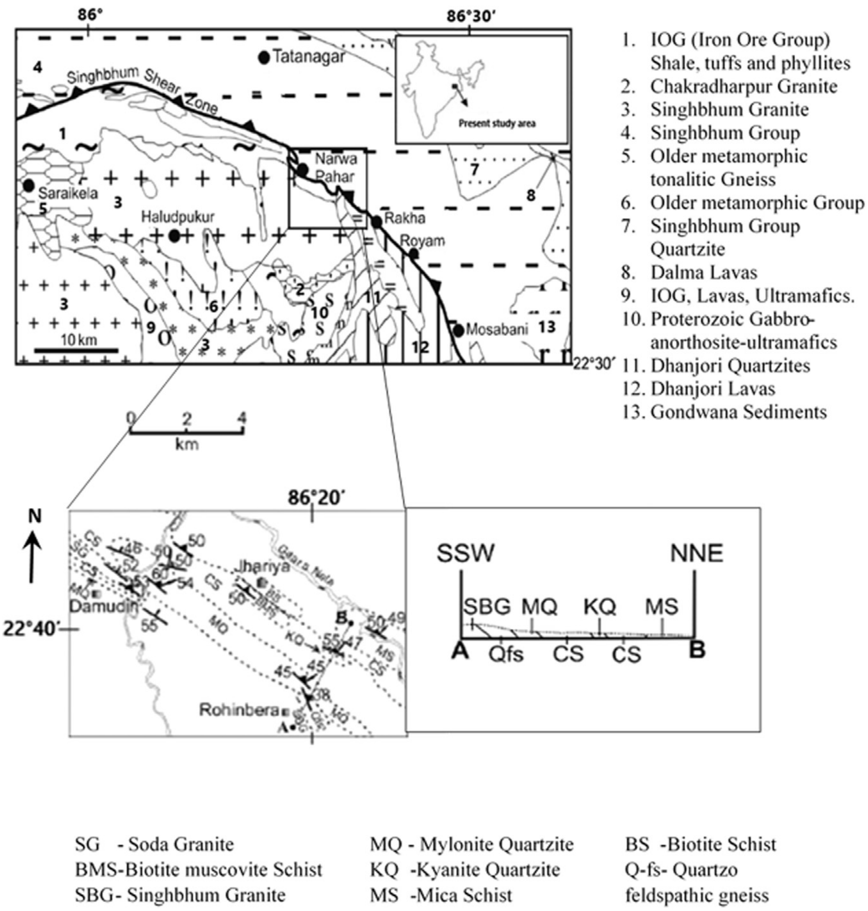

Fig. 1. Map of Singhbhum Shear Zone showing the lithological units of Narwapahar mine (Matin et al., 2012).

cancer.

In the present study, various radiological parameters such as radon concentration, gamma radiation level and ore grade in the different working places of Narwapahar underground uranium mine were measured. The main objective of this study was to assess the radiation exposure of the miners based on the measurements of gamma radiation level and radon concentration inside the mine. Furthermore, comparison of radiation levels at various working places, which are located at different depths of the mine, was also discussed.

2. Study area

Narwapahar uranium mine (Latitude 22°41′N and Longitude 86°16′E) is located at the central part of the Singhbhum Shear Zone in the Singhbhum district of Jharkhand state, India (Fig. 1). Narwapahar mine was commissioned with an extension of 3 km in 1995. Narwapahar mine is considered as one of the highly mechanized and trackless underground mines installed with a vertical shaft connecting the various levels having a difference of 45–50 m between them. Declines of 7° are made more or less along the dip. This mine has six mineralized zones identified as Main Band 1, Main Band 2, Main Band 3, hanging wall lode west of the fault, Khundungri 1 and Khundungri 2 with the thickness varying between 2.50 and 20 m extending to depth of 355 m from the surface.

2.1. Geological structure of the research (study) area

The entire Singhbhum Shear zone separates the Early Proterozoic rocks in the north from the Archean Singhbhum Granite and Iron Ore Group (IOG) in the south where the intensity of metamorphism and alteration is less in comparison to the former as shown in Fig. 1. Granites (Soda granite) and gneisses are the major lithological unit in the entire shear zone in the area of Narwapahar the soda granite has been altered with different intensities to form quartzo felspathic gneiss and intensely deformed phyllosilicate rich layers in which chlorite are generally present as a porphyroclast which are surrounded by fine grains of chlorite and sericite (Matin et al., 2012). Quartz chlorite sericite schist was encountered as the host rock with uraninite and pitchblende deposition are the primary uranium ore minerals. Matin et al (2012) further investigated the deformation history in the Narwapahar area which shows the major lithological unit along the strike line A-B shown in Fig. 1. The exclusive character of Narwapahar ore deposit is that it shows extensive leaching and dispersal of uranium mineral throughout the outcrop because of the prominent effect of weathering to considerable depth due to intensive humidity and heavy rainfall.

2.2. Ventilation of the Narwapahar Mine

Horizontal cut-and-fill and Room and pillar method in Narwapahar uranium mine are being used for mining of the ore. The mine follows a split Ventilation system. The total air quantity circulated by three exhaust axial flow fans are 230 m^3/s. The fans are installed at three different places, viz. west ventilation fan house, east ventilation fan house and Khundungri ventilation fan house. The capacity of each fan installed at west ventilation fan house and east ventilation fan house is 100 m^3/s at static pressure of 170 mmwg and the fan installed at Khundungri ventilation fan house is varying in the range of 8–38 m^3/s at the static pressure of 10–90 mmwg.