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Assessment of naturally occurring radioactive materials in the surface soil of uranium mining area of Jharkhand, India

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ABSTRACT

Activity concentration of naturally occurring radioactive materials in surface soil was measured in 30 different locations in the uranium mineralized area of Jaduguda, India. The mean activity concentration of ^{238}U, ^{226}Ra, ^{232} + ^{234}Th and ^{210}Po in soil was found to be 35 ± 34, 47 ± 24, 106 ± 56, and 49 ± 35 Bq.kg^{-1} respectively. Gamma dose rate, external and internal hazard indices and radium equivalent activity in surface soil were estimated and the obtained result suggests that the mean external and internal hazard indices were 0.47 and 0.57 respectively. The average radium equivalent activity was found to be 187 Bq.kg^{-1}. The annual effective dose to population was in the range of 31–170 μSv y^{-1} with a mean value of 98. The excess life time cancer risk was found to be in the range of 0.12 × 10^{-3}–0.65 × 10^{-3} with an average value of 0.39 × 10^{-3}. The risk is comparable to global value of 0.29 × 10^{-3}.

1. Introduction

The chemical composition of soil is a mixture of solid materials, air, water and organic matter which reflects the geological formation of the area. Activity concentration of radio element and heavy metals in soil largely depends upon the geological formation and mineralisation in the troposphere. Distribution of radionuclide in soil is of great concern as their geochemical mobility allows them to move easily and contaminates different components of the environment. Due to weathering, sedimentation and chemical interaction in the earth crust, the primordial radionuclides are found in varying concentrations in soil. At background concentrations, the naturally occurring radionuclides in the uranium, actinium, and thorium series contribute about one-half of the natural background external radiation (USEPA, 2012). The average concentration of uranium in earth crust varies between 2 and 4 ppm (Gupta and Singh, 2003) and ^{226}Ra averages at 40 Bq.kg^{-1} (Niren, 1994). The global average concentration of thorium in earth crust varies between 8 and 12 ppm (Mares and Tvrdy, 1984).

Naturally occurring radionuclide can be concentrated in the environment by activities, such as mining, extraction and purification of uranium minerals, phosphate and phosphate fertilizer production, coal ash generation and oil and gas production. The objective of the present study is to estimate the activity concentration of naturally occurring radionuclide in soil and its radiological implications around the uranium mining industry.

2. Materials and methods

2.1. Study area

The study was carried out around the uranium mining industry in India at Jaduguda (Long 22° 30′, Lat 86° 20′) in the central sector of Singhbhum shear zone (Fig. 1). The proterozoic Jaduguda U (–Cu–Fe) deposit in the shear zone is located in the eastern of India and hosts the oldest and most productive uranium deposit in India (Pal et al., 2010). The geological features of the area are well documented elsewhere (Banerji, 1974; Dunn and Dey, 1942; Naha, 1965; Saha, 1994; Sarkar and Saha, 1962; Sarkar, 2000a,b; Sarkar, 1984). The shear zone is a site of acid and basic volcanism and most of the rocks have been metasomatically altered to varying degrees. In the central and southeastern part, this zone hosts a number of copper and uranium deposits with associated nickel, molybdenum, bismuth, gold, silver, tellurium, selenium and magnetite. Deposits of apatite–magnetite and kyanite are also located in this zone. Copper and uranium mineralisation has taken place along the zone of shearing particularly in the central and southeastern sector (Sarangi et al., 2009). Copper, nickel and uranium mining activities are continuing since last five decades (Sahoo et al., 2010). Mining and processing of uranium in India at this study location started in early sixties. Uranium is recovered as magnesium-di-uranate by sulphuric acid leach technique using pyrolusite as oxidant. The highly acidic liquid and solid waste generated in the process plant are mixed and neutralized at pH 9.5 by lime treatment to precipitate most of the metal and radionuclide. The mixed slurry is separated to coarse and fine fraction by the help of a hydro-cyclone. The coarse fraction is sent back to mine for back filling whereas fine fraction is discharged in an

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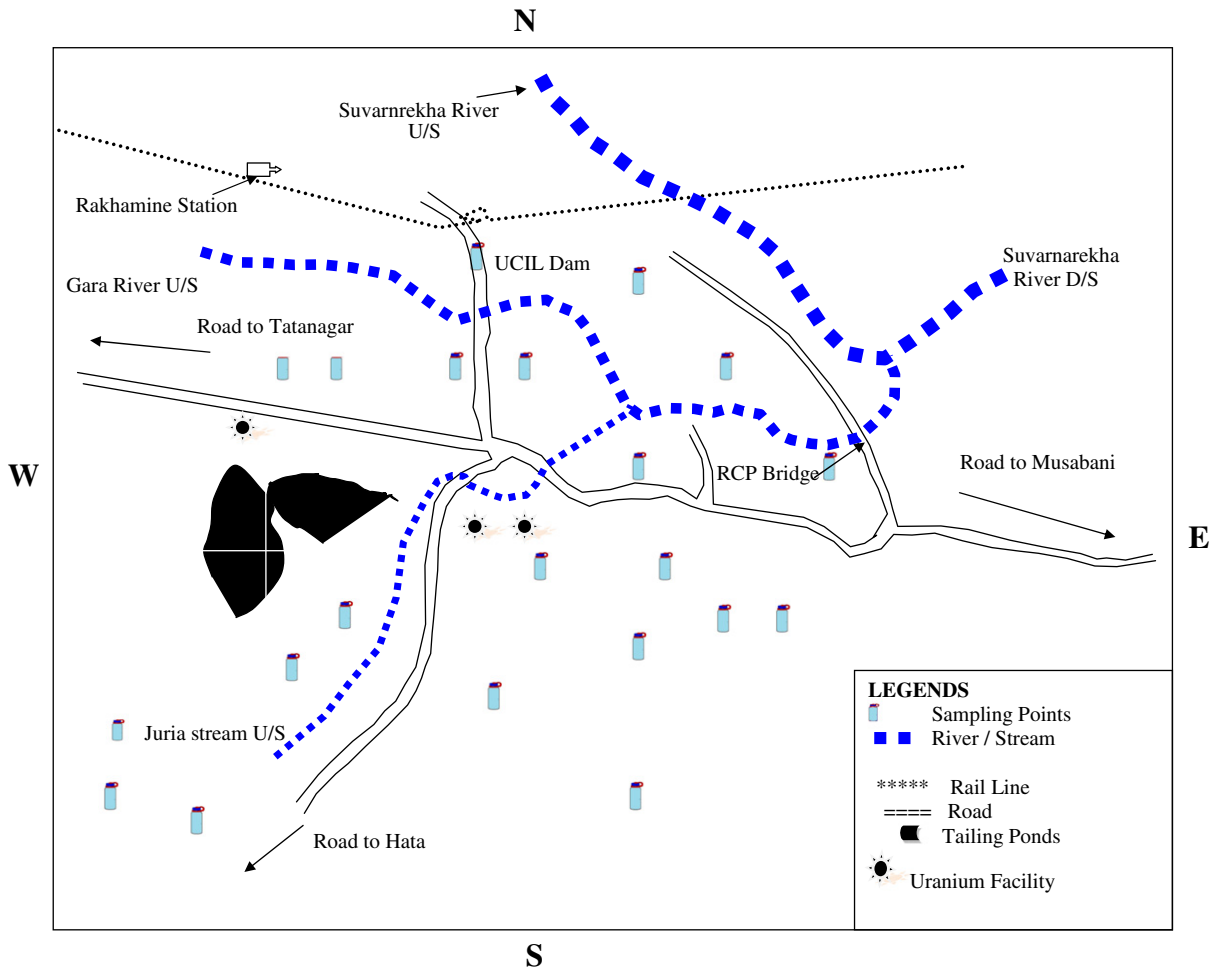

Fig. 1. Map of study area showing important sampling locations (not to scale).

engineered impoundment system or tailing pond (Khan et al., 2000). In the tailings pond the fine slurry consolidates by the help of gravity and the supernatant liquid effluent from tailings pond decanted to effluent treatment plant for treatment. The liquid effluent is treated for removal of radionuclide and chemical toxin before discharge to environment. The consolidated fine tailing slurry in the tailings pond may get airborne and deposited in the surrounding surface soil and vegetation. The investigation was carried out to find activity concentration of uranium series radionuclide in the surface soil around the uranium mining complex. The area receives an average of 1000 mm of rain fall annually with a maximum temperature in summer of 45 °C and minimum of 5 °C during winter.

2.2. Sampling methodology

Manual sampling technique using stainless steel spoon (USEPA, 2011) was used to collect the soil samples. Sampling locations were decided as per the systematic sampling by dividing the study area to grids. Sample weighing 1 kg was collected from each location up to a depth of 15 cm and, debris, grass roots, & pebbles were removed. Sample from each location was homonized to reduce variance within the sample (USEPA, 1992, 1996). The collected samples were air dried for 5 days at 110 °C, minced, crushed, passed through a 1 mm mesh sieve to remove roots and stones. Dried soil sample were processed by temperature controlled microwave assisted acid digestion system (Antonpaar Multiwave, 3000) using aqua regia. The temperature was controlled <200 °C to avoid loss of polonium. Reagent grade chemicals were used as per USEPA protocol (USEPA, 1992). 5 g processed sample from each location was digested in the microwave reaction system and volume was made to 100 ml.

2.3. Analysis of natural uranium

Uranium in soil sample was analyzed by solid flourimetric technique using an ultraviolet excitation source (Kolthoff and Eiving, 1962; Sethy et al., 2011a,b). 1 ml of concentrated H_2SO_4 was added to 10 ml soil sample aliquot and evaporated to dryness until white fumes disappear. Further, 20 ml 0.5 M H_2SO_4 was added refluxed for 30 min to ensure formation of soluble sulfate complexes of uranium (Sethy et al., 2011a, b). The soluble sulfate complexes of uranium present in the solution are allowed to react with 10 ml of alamine in benzene (2% alamine in 98% benzene) solution by mixing and shaking in a separating funnel. The uranium complex present in the aqueous phase is quantitatively transferred to the organic alamine phase (Eappan and Markose, 1986). The aqueous phase is drained out and 100 μl from organic phase was transferred to a platinum disk, fused with 250 mg of NaF–Na_2CO_3 (15:85) at 800 °C (Eappan and Markose, 1986) in a muffle furnace for 3 min. The platinum disk containing fused samples was exposed to ultraviolet excitation source (3650 Å) and emitted fluorescence (5546 Å) wavelength (Kolthoff and Philip, 1962; Veselsky and Degueldre, 1985) was measured in a Fluorimeter. The intensity of fluorescence proportional to the amount of uranium present in the sample