Journal of Environmental Radioactivity 126 (2013) 77–82

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

Assessment of occupational radiation exposure in underground artisanal gold mines in Tongo, Upper East Region of Ghana

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ARTICLE INFO

Article history:
Received 21 November 2012
Received in revised form
13 June 2013
Accepted 11 July 2013
Available online 22 August 2013

Keywords:
Occupational exposure
Radon
Solid State Nuclear Track Detectors
Artisanal gold mines
Gamma ray spectrometry

ABSTRACT

Assessments of radon and gamma radiation levels were carried out in underground artisanal gold mines in Tongo. This is one of the numerous artisanal gold mining communities in Ghana. Solid State Nuclear Track Detectors (SSNTDs) were used to estimate the mean ^{222}Rn concentration and dose rates during the Harmattan season (November 2010 to February 2011). The values for the ^{222}Rn concentration at each monitoring site ranged from 14 ± 4 Bq m^{-3} to 270 ± 9 Bq m^{-3}, with a mean value of 98 Bq m^{-3}. These measurements are well below the lower action level of 500 Bq m^{-3} recommended by ICRP for workplaces. The activity concentrations of ^{40}K, ^{232}Th and ^{238}U were determined using gamma-ray spectroscopy method. The effective dose estimates of 0.11 ± 0.02 mSv y^{-1} to 0.68 ± 0.04 mSv y^{-1} were below the allowable limit of 20 mSv per annum for occupational exposure control recommended by the ICRP. The total annual effective dose varied from 0.22 ± 0.04 mSv y^{-1} to 1.92 ± 0.08 mSv y^{-1}.

1. Introduction

Naturally occurring radionuclides are ubiquitous and present in very low concentrations in the earth's crust. They may be brought to the surface through human activities such as burning of fossil fuels, metal refining, manufacture and use of fertiliser (UNSCEAR, 2000) and through natural processes like exhalation of radon gas to the atmosphere or by dissolving in ground water (IAEA, 1999). It has been indicated that the use of buildings as dwellings and workplaces can also lead to exposure to Naturally Occurring Radioactive Materials (NORMs) (Baxter, 1996).

Mining activities particularly mine tailings sites carry the potential to induce risk to cause lung cancer as a result of the large quantity of radon released from the slimes dams. It follows from the historical evidence that radon decay products are associated with health risks to the underground mining population of Scheeberg (Germany) and St Joachimstahl (Bohemia) in the sixteenth century (Wilcot John Speelman, 2004). Figs. 1–3

Since uranium is found everywhere in the earth's crust, ^{226}Ra and ^{222}Rn are present in almost all rocks, soil, and water. ^{222}Rn and its progeny are the greatest source of effective dose due to natural radiation. If the gas is inhaled into the lungs, its decay and more importantly the decay of the radon progeny that enter the lung can increase the chance of getting lung cancer (Fhulufhelo Nemangwele, 2005).

The radon progeny are present in air either attached with the aerosols or as free atoms (Tufail et al., 1992). The radon progeny present in the ambient air constitute significant radioactive hazards to human lungs. Radon decays by alpha emission, the radon progeny have a positive charge and so are electrostatically attached to particulates in the air. Radon progeny are then carried by air currents and become attached to aerosols, droplets, dust, or other surfaces, thus they can be inhaled and deposited into the lungs. These decay products are also radioactive, and many decay by alpha particle emission. The alpha particle energy delivers a dose to the lung where the particles are deposited.

In mines, radon and its progeny are most prevalent owing to uranium and thorium in the host rocks or through infiltration of radium-bearing ground water (Hewson and Ralph, 1994). Also, depending on the ventilation conditions in the underground mines, there is the potential for radon and its progeny to accumulate to a level that may be unacceptable for continuous exposure. The contribution to occupational radiation exposure in this case is mainly by inhalation of radon and its progeny exposure to external gamma radiation, and inhalation of dust containing long-lived emitters of the U–Th series (Hewson et al., 1994; ICRP, 1986). The

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0265-931X/$ – see front matter
http://dx.doi.org/10.1016/j.jenvrad.2013.07.007

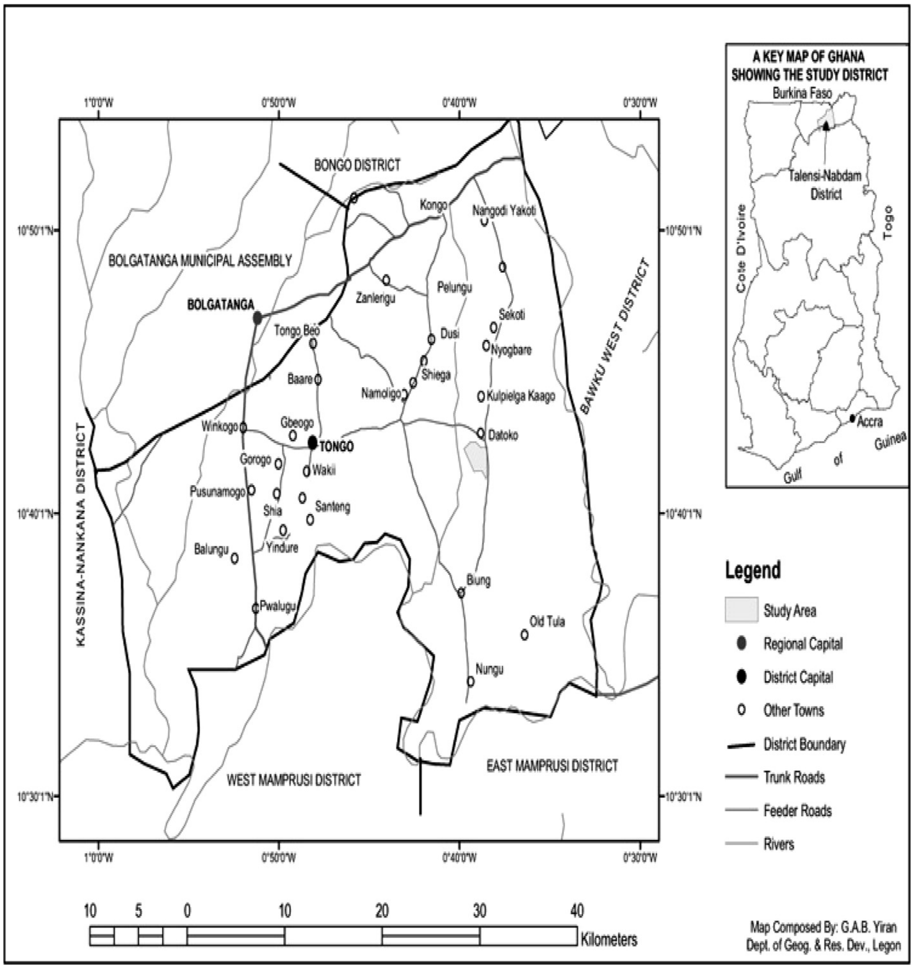

Fig. 1. Map of Talensi-Nabdam District showing the study area. [Awumbila et al. (2006)].

relative concentration of each of the radionuclides depends on the type of mine, working conditions particularly the degree of ventilation (Hewson, 1990), mineralogy and local geochemistry or geological structure (Chang et al., 2008).

1.1. Study area

Tongo is an artisanal mining community in the Talensi-Nabdam district of the Upper East Region. Mining settlements were named after large towns, mining communities in southern Ghana or rich institutions. Awumbila et al. (2006) have reported that settlements were given names such as Accra (the national capital), Kejetia, Bantama (large commercial centres in Kumasi, Ashanti Region), Obuasi, Tarkwa (well known large gold mining towns in the Southern Ghana), Gold Coast (former name of Ghana), World Bank and Croatia. Kejetia is the oldest community in this cluster. It was so crowded when mining started that it looked like Kejetia market, the largest market in Kumasi in the Ashanti Region and hence its name. Names of settlements appeared to convey the size and population of the new mining area when it opened. Each name also tried to outdo the one before it. There was rivalry among settlements as to which started first, which was larger in population size and which had the richest ore deposits. In-depth interviews revealed that although initially mining started in Croatia around 1995 for a brief period, Kejetia was the oldest settlement in terms of historical age and size of population. However, Tarkwa appeared to be the most important settlement at the time of the research because its central location had helped to make it the commercial centre of the cluster of settlements. The politics and rivalry in the naming as well as disagreements about the age of settlements was an illustration of aspirations and the potential promise of mining for improving the livelihoods of people in the district (Awumbila et al, 2006).

The mines are accessed by crawling through holes big enough to accommodate an adult. Miners use dry cell powered torchlights to aid visibility. There is no mechanised ventilation system to the underground mines hence the only means of air passage into the mines is by natural circulation of air from the open entrance of the mines. The mines which are several metres deep open into other mines connecting into several tunnels beneath. Here, miners chip at the rock samples which they haul to the surface in sacks.

1.2. Geology and relief of Tongo

The entire area is associated with the Pre-Cambrian Granite and Metamorphic rocks, belonging to the Guinean shield of West Africa. The granitic formation is mainly composed of granites, granodiorites and granite gneisses. However, small patches of metamorphosed volcanic schists and phyllites of the Birrimain formation are located across the southern and central parts. The relief of the area is much influenced by the geology but sub-aerial processes have reduced the area to a generally flat and gently rolling topography with slopes of less than 2%. Average elevation is