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Radon concentrations and exposure levels in the Trepça underground mine: A comparative study

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A B S T R A C T

This study presents the results of radon concentration measurements and radiation exposure levels in the Trepça (pronounced Trepcha) underground mine, which are important to assess the radiogenic hazards to occupational workers. Radon concentration measurements were carried out in selected locations of the Trepça mine using continuous radon monitor CRM-510 and portable radon monitor PRM-145. Results show that the radon gas concentration in the mine varied from 54 Bq/m^3 to 691 Bq/m^3. The radiation exposure doses of miners from radon and radon daughters were determined. The total annual effective doses varied from 0.4 mSv/y to 5 mSv/y. The effective dose has been found to be lower than the dose limits recommended by the International Commission of Radiation Protection. The comparison of indoor measurements shows that the highest time-dependent indoor values of radon concentration in the two lowest horizons decreased during the time period 2010–2015 and that their average values increased by about 10%. This means that five-year mining activities generated pathways for radon gas flow, causing the decreasing of the maximum values and increasing the average values.

1. Introduction

The human population is permanently exposed to ionising radiation from natural sources. About 50% of the total dose belongs to radon and its decay products (UNSCEAR, 2010). Radon is a radioactive gas and spontaneously decays into many short-lived daughter progenies, among which polonium-218 (Po-218) and polonium-214 (Po-214) are very high alpha emitters and are considered environmental health hazards (Sumner et al., 1991). Since radon and its progeny are easily inhaled and can penetrate deep into the airways of the lung, the alpha particles they emit carry enough energy to cause cell DNA damage within the airways and thereby increase lung cancer risk. Epidemiological studies have indicated that the presence of radon and its decay products in inhaled air causes a health risk for lung cancer (Darby et al., 2005). After reviewing numerous studies and data sources, the WHO reported that up to 15% of all lung cancers worldwide were caused by radon exposure (WHO, 2009). Some studies (Rosario and Wichmann, 2006) show that radiation exposure is also responsible for non-cancerous diseases like stroke, heart disease and those related to the respiratory and digestive systems.

Mining and especially underground mining have an impact to safety and occupational health of miners and people living near the mines, as well as environmental degradation and pollution (Damigos, 2006). Hence, many tools have been developed to detect and mitigate environmental effects focused in the framework of sustainable development in mining (Basu and van Zyl, 2006; Worrall et al., 2009). An important role in this aspect has national legislative and policy framework and other environmental measures relating to environmental management, as well as on the implementation capacity (Mutagwaba, 2006).

On the other hand, mining activities, has been identified as one of the potential sources of exposure to naturally occurring radioactive materials (UNSCEAR, 2000). Many surveys involving radon concentration measurements report a high radon risk in mines. The high values of radon concentrations measured in abandoned gold mines can reach about three times the upper action level recommended by the ICRP for workplaces (Anjos et al., 2010). Radon

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levels in the atmosphere of mines vary over time depending on the type of mine, geological formations, working conditions and parameters such as temperature, humidity and pressure (AGIR, 2009). Moreover, one of the most important factors responsible for radon concentration in the atmosphere of mines is ventilation (natural or mechanical). Ventilation is the most effective way of reducing the accumulation of radon gas concentrations in the mine's atmosphere (Zafrir et al., 2013). In mines radon is exhaled mainly from the mine walls, broken ores, backfill tailings and mine water (Sahu et al., 2014). When a miner inhales the mine's air, radon is exhaled along with the exhaled air. However, its daughter products, which are solid decay products, may be deposited in the lung, especially in the upper respiratory tract, and continue to irradiate the lung tissues. The high concentration of aerosols can significantly affect the value of the effective dose to which the miners can be exposed (Skubacz et al., 2016). The typical activities in mines are drilling, detonation, the transportation of materials and the maintenance of equipment and the mine structure. Some of these activities can result in the release of radon gas and its daughter products. Radon levels in the atmosphere of mines are considered a key indicator of the radiation hazards. National radon concentration surveys are essential in order to set reference levels, which, if exceeded, it is recommended to take action to reduce them. The national regulatory authorities of some countries have set reference levels for workplaces. The reference levels for the majority of countries are in the range of 400–3000 Bq/m^3 (Fig. 1) (Synnott and Fenton, 2005). An analysis of recent legislation in several European countries shows that recent regulation by some countries still continues to allow high reference levels in workplaces (Pacheco-Torgal, 2012).

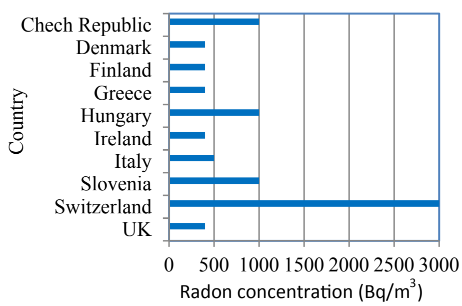

Fig. 1. Reference levels for radon gas in underground workplaces for some countries.

Many radon investigations have been performed in indoor environments or working places in Kosovo (Bekteshi et al., 2011). However, studies of the concentration levels of radon and its progeny in mines are few (Hodolli et al., 2015). The aim of the present study was to measure radon concentrations in the Trepça mine and to estimate the annual exposure of the workers. By comparing five-year span measurements, we intend also to study the temporal and spatial dependence of radon distribution in the mine.

2. Description and geology of study area

The study area, the Trepça mine in Stan Terg, located in northern Kosovo, is one of the most ramified and deep mines in Kosovo and region (Fig. 2, left) (SGA, 2016). Within the Vardar Zone of Dinaride, the Stan Terg deposit is situated in the centre of the so-called Trepça Mineral Belt, which is one of the largest lead and zinc ore areas in Europe, The ore mineralogy of the deposit is dominated by pyrite, pyrrhotite, sphalerite and galena, with typical carbonate gangue minerals and minor quartz. The ore bodies have a strike extension of 1200 m (Fig. 2, right) (Hyseni et al., 2010).

3. Materials and methods

Measurements were carried out in the Trepça mine at different locations, particularly in horizons and workplaces where large number of workers frequent them. The sites selected for sampling consist of the active areas of each horizon, in which it is expected

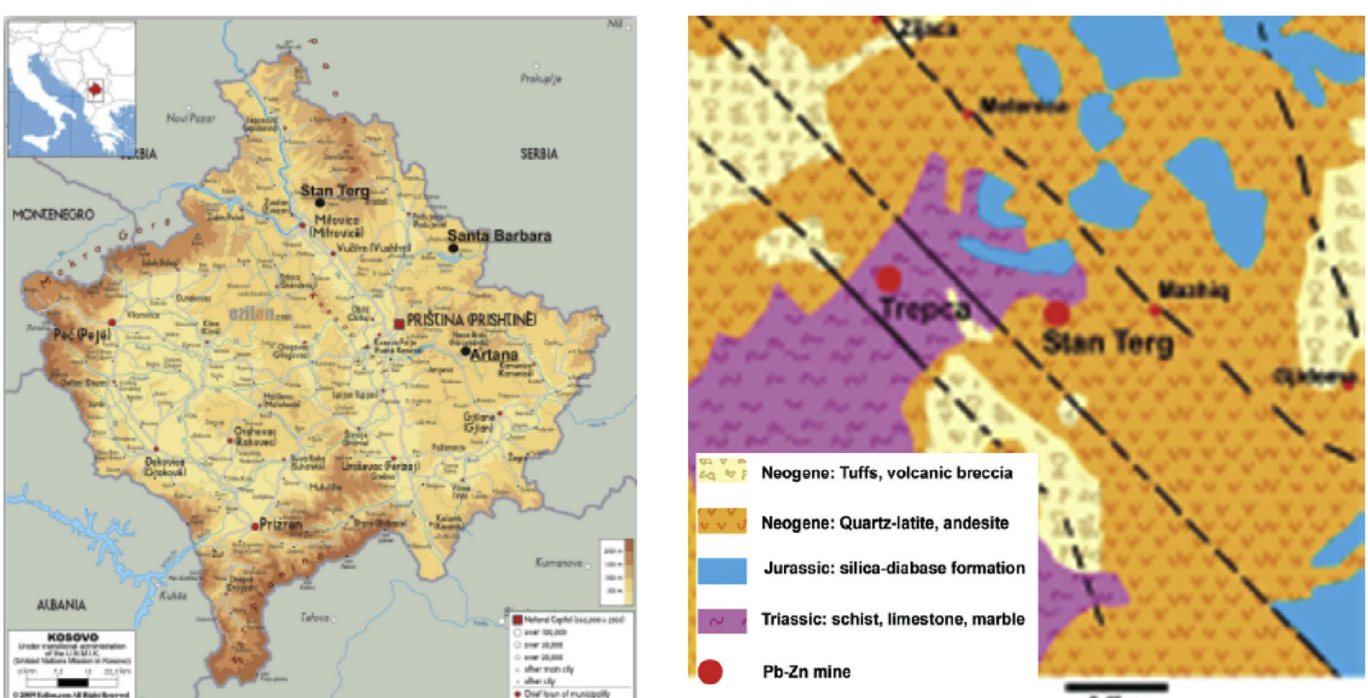

Fig. 2. Geographic map of Kosovo locating StanTerg (Pb-Zn-Ag) underground mine (left); Stan Terg regional geology (right).