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# Radon concentration and gamma exposure in some Kosovo underground mines

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► ***Short report***

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## ABSTRACT

***Background:*** In this study are submitted the radon concentration measurement results of four underground mines: Stanterg, Artana, Hajvali and Badovc, which are owned by Trepça Enterprise, Kosovo. The mines have the same geological formation and from these mines are extracted ores rich with lead, zinc, silver, and gold. The radiation exposures caused by radon and radon daughters was determined and gamma dose measurements were also performed in the same time. ***Materials and Methods:*** The measurement of radon concentrations in the environment of mines is carried out by CRM 510, a portable device which continuously made measurement for four consecutive days. The gamma exposure was determined using fully portable handheld instrument GR-130 Exploranium. The detector consisted of a 65 $cm^3$ sodium iodide NaI(Tl) and a GM tube. The system was calibrated against a $^{137}Cs$ standard and checked for stability using a low-activity 9 kBq radioactive source. ***Results:*** The radon gas concentration for underground mines under study varied from minimal values 60 Bqm-3 to maximal recorded value 748 Bqm-3. The average radon concentration for mines Stanterg, Artana, Hajvali and Badovc are 301.6, 191.4, 463.2 and 527.2 Bqm-3, respectively. ***Conclusion:*** The average of total annual effective doses from radon concentration and radon decay products for miners under the study is 2.67 mSv and just from gamma ray exposure is 0.26 mSv. The average values for radon concentration and radon decay products to mines under the study are lower than action level 1000 Bq m-3 given by IAEA.

***Keywords:*** *Radon concentration, underground mines, effective dose, workplace, ore.*



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## INTRODUCTION

Humanity is always exposed to ionizing radiation from natural sources. It is well established that the inhalation of Radon ($^{222}Rn$) and mainly its radioactive decay products, contributes more than 50% of the total radiation dose to the world population from natural sources (UNSCEAR, 2000)[1].

Mining activity results in the release of radon gas and its daughter products. This is particularly important in underground mines. Miners may be exposed to radon as well to long-lived radionuclide in ore dust and to external gamma and beta radiations [2].

Human exposure to radon and radon progeny occurs out of several sources. Underground mining material is one of most important factor, with contribution to the occupational health risk. The ore dust contains the radionuclides of the uranium and thorium decay series and is spread through galleries by water or air circulation during mining operations. Epidemiological studies have indicated that the presence of radon and its decay products in inhaled air causes a health risk for lung cancer [3,4]. Although there exist large uncertainties associated with risk estimates, studies, especially on uranium mines, have shown that the relative risk for lung cancer increases almost linearly [5,6] with value of the working level month-WLM. Radon is present in the mine's air released by the mineralized working front and the walls of the tunnels and channels throughout the mine [7]. Radon concentrations vary substantially in the atmosphere of underground mines depending by the type of mine, geological formation, working conditions and natural and artificial ventilation systems.

In worldwide average annual effective dose for non-coal miners is estimated to be 2.7 mSv [8]. The average annual effective dose to underground non-coal miners from radon in the UK was reported to be about 4.5 mSv in 1991 [1].

Purpose of this study was to assess health risk of workers for Kosovo (figure 1) underground miners from natural radiation and whether if it is necessary to take measures for the improvement of working conditions. Such a comprehensive study has not been done before in our country. Also drawn conclusions from this study will serve as a reference for management of the mine.

## MATERIALS AND METHODS

Monitoring of radiation in workplace for some underground Kosovo mines is the main topic of this work. The majority of the radon measurements are performed under mining conditions, i.e. underground, high temperatures, wet, dust, high humidity and darkness.

All of mines under the study are with same geological formation, from these mines extracted ores rich with lead, zinc, silver, and gold.

Measurements were made in the workplaces, which in most cases have been in the end of the channels, near of the extracted ore and in some case after long walks and climbs.

For measurement of radon concentrations in the environment of mines was used instrument CRM 510 (Continuous Radon Measurements -510). CRM-510 is portable device and performs continuous measurements for four consecutive days. At the same time, with radon-222, are measured air humidity, temperature and barometric pressure. Every measurement point represented here has take at last three days nonstop recording data for radon and other parameters.

Underground miners are also the subject of the external gamma radiation. The gamma exposure (dose rate) was determined using fully


**Figure 1.** Location map of Kosovo underground mines under the study.

portable handheld instrument GR-130, from Exploranium Co. Ltd. Canada.

The instrumentation consisted of a 65 $cm^3$ sodium iodide NaI(Tl) detector equipped with GM tube to extend the dynamic range in the survey mode to measure high dose rates. The readings are presented in terms of nanosieverts per hour (nSv $h^{-1}$). The system was calibrated against a 137Cs standard and checked daily for stability using a low-activity (9 kBq) radioactive source of $^{137}Cs$.

Measuments were made in four underground mines. In horizons that weren't exploited due to safety there were no measurements. XLSTAT software was used for data analysis.

## RESULTS AND DISCUSSION

Based in the given results for radon concentration, is represented a graphic of frequency distribution of all mines under the study: Stanterg, Artana Badovc and Hajvali (figure 2). The underground mines of this study are located in northeast of Kosovo.

In Stanterg underground mine there are actually in use 4 horizons from 13, XI horizon is located at 15 meter below sea elevation, while the first horizon and last are in 760 meter and -105 meters comparing by sea level. All levels have natural and artificial ventilations [9]. Each of the horizons has natural and artificial system ventilation, which are quite good and this has lead the average radon concentration for the three horizons to be 276 $Bqm^{-3}$. In Artana underground mine measurements were done in some different workshops of V horizon, geology composition, and extracted ore from this mine is similar of the Stanterg and the results obtained do not differ so much.

The Badovc and Hajvali underground mines currently are not in exploitation, even Hajvali underground mine is almost submerged by water. The measurements for Hajvali were made at several points near the mine entrance (about 50 m from entrance of underground mine), because there were no artificial ventilation and natural ventilation was so poor.

Results of radon concentration and dose rate of mines are shown in table 1. The highest value of radon concentration that was found is in Badovc 526 Bq $m^{-3}$ and the second is in Hajvali 463 Bq $m^{-3}$. Percentage of frequency distribution for radon concentration is presented in figure 2, only eleven percent of all measured values are higher than 500 Bq/$m^{-3}$.

The measurements reveal that radon concentration in all of the measurement points are below the action level of 1000 Bq $m^{-3}$ for workplaces defined by International Atomic Energy Agency [10]. This value is at the midpoint of the range 500 – 1500 Bq $m^{-3}$ recommended by International Commission of Radiation Protection (ICRP – 65)[11]. The annual effective dose was calculated in accordance with report of UNSCEAR 2000. The occupancy in the mines was taken to be 2000 $hy^{-1}$ for workers with 0.4 as average equilibrium factor, dose conversion factor of effective dose was 9 nSv per Bq h $m^{-3}$. Conversion factors of 5 mSv per WLM and 1.43 mSv per mJ h $m^{-3}$ at work, suggested by the ICRP-65.

After being calculated the exposure to radon and radon progeny decay the annual equivalent dose for workers of Stanterg, Artana, Hajvali and Badovc are 2.17, 1.38, 3.33 and 3.79 mSv respectively.

In the underground mines that have studied in this work the highest exposure dose was recorded in Badovc with 0.76 WLM $y^{-1}$ and the lowest is 0.28 WLM $y^{-1}$ in Aratana mine. This is

**Table 1.** Total annual effective dose due the exposure radon, radon product (RDP) and gamma rays in four underground mines in Kosovo.

| Mine | N | Radon concentration (Bq $m^{-3}$) | Annual effective dose (mSv) | | Total annual effective doses (mSv) |
|---|---|---|---|---|---|
| | | | Radon and RDP | Gamma rays | |
| Stanterg | 138 | 301.6 ± 20.5 | 2.17 | 0.291 | 2.461 |
| Artana | 89 | 191.4 ± 5.8 | 1.38 | 0.239 | 1.619 |
| Hajvali | 53 | 463.2 ± 19.4 | 3.34 | 0.262 | 3.602 |
| Badovc | 66 | 527.2 ± 34.9 | 3.79 | 0.264 | 4.054 |
| Average | | | 2.67 | 0.264 | 2.934 |

N – Number of measurements, RDP-Radon Decay Product.





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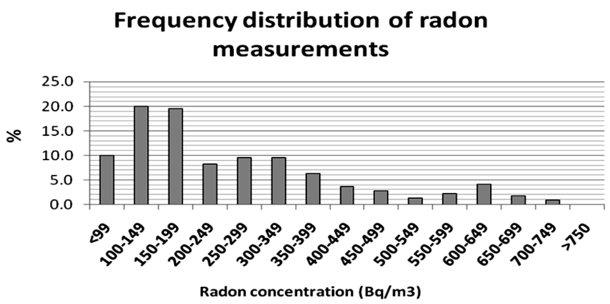


**Figure 2.** Frequency distribution of radon measurements.

lower than limiting value given by ICRP [12]. But our measurements show that underground mines in: Stanterg, Hajvali and Badovc has higher value than the EPA report [13], the mean annual radon decay product exposure is estimated as 0.3 WLM $y^{-1}$ for non-uranium mine.

Geological layers of the four mines under the study were approximately the same, but the higher exposure from radon and its progeny are present in Hajvali and Badovc underground mines than others, because in those mines actually ventilation systems are not working. It caused increasing of the radon concentration and its daughters.

Reduction of radon exposure due to improved ventilation is documented for Turkey mines, also in New Mexico mines [14] when in 1967 was 5.40 WLM while in 1980 was 0.5 WLM and subsequently stayed at this level [15].

## CONCLUSION

The radon level and gamma exposure rate have been estimated in four underground mines in Republic of Kosovo. The average radon concentration in the Stanterg, Artana, Hajvali and Badovc were 301.6, 191.4, 463.2 and 527.2 Bq $m^{-3}$, respectively. The average values for radon concentration and radon decay products to mines under the study are lower than action level of 1000 Bq $m^{-3}$ given by IAEA.

The value of the annual effective dose limit for mine-worker shall be strictly controlled, not exceeding the limit of effective dose, which is determined 20 mSv per year, averaged over five consecutive years. The data obtained shows that no one of surveyed mines has exceeded this limit. From obtained results it is concluded that annual effective doses is low due to the natural and artificial ventilation systems.

Finally, it is proved that concentration of radon, radon decay products and exposure of gamma rays in surveyed mines are generally safe in terms of health risk.

***Conflicts of interest:*** *none to declare.*

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