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INDOOR RADON CONCENTRATION RELATED TO GEOLOGICAL AREAS AT DIFFERENT WORKPLACES OF ALBANIA

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Abstract. *Radon exposure in the workplace is one of the main exposures to the population after that in dwellings. These workplaces are generally at the ground and/or first floor, where radon concentration is generally higher than at upper ones. This study deals with the measurements of indoor radon concentration in several workplaces located in different geological conditions. Measurements of indoor radon concentration have been carried out using passive bare detectors based on CR -39 in 50 workplaces, including one site at the Centre of Applied Nuclear Physics, Tirana. According to the principles of the methodology, the radon passive detectors have been located inside the workplaces for three months exposure, allowing the calculation of average values, which represent much better the true values of the radon concentration inside of a closed environment. The exposure time of detectors was performed during period January–April 2014. According to the assessment made by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), radon in the natural environment constitutes about 50% of the human exposure to natural radiation or 1.2 mSv/year. The measurements were used to calculate the effective dose due to the radon contribution (mSv/y). Based on the results of the measurements, the minimum value of the radon concentration found is 53 Bq/m^3 to 400 Bq/m^3 in workplaces, while the reference levels are 300 Bq/m^3. Around 90% of the radon concentration values are within reference levels. The results of this study represent a variation of radon concentration related to geological composition. More detailed studies are needed in areas with different geology and construction materials for a better spatial distribution of radon concentration, particularly in public places.*

Key words: *Indoor radon concentration, workplace, environmental radioactivity, passive detectors*

1. INTRODUCTION

The health risks from radon gas were first identified in mines and, initially, safety regulations concentrated on ensuring that underground workers were protected against radon [1]. Many studies [2], [6] have shown that radon levels in the above-ground workplaces are similar to those in nearby domestic housing [2], and that workers within the buildings can receive significant doses, which can be significantly greater than those received from occupational exposure to other radiation sources, such as the medical uses of X-rays. Concentrations of radon in a building vary with time both diurnally and seasonally. These variations are primarily due to the effect of meteorological changes on radon levels in soil gas and also to weather-related changes in practices for ventilating buildings [1]. Consequently, long term measurements over a period of several months are preferable to short-term ones.

Radon is recognized to be the second cause of lung cancer, after smoking [2], [7]. As reported to the recent European basic safety standards [3], epidemiological studies have shown an increase of lung cancer from prolonged exposure to indoor radon at levels of the order of 100 Bq/m^3 [3], [8]. In the last decades, there has been an increased concern in many countries regarding the establishment of national legislation on indoor radon concentration in dwellings and workplaces. For workplaces such as offices and factories in which Rn-222 exposure is treated as an existing exposure situation, the national authority should set a reference level for Rn-222 [1]. Based on an assumed equilibrium factor for Rn-222 of 0.4 and an occupancy rate of 2000 hours, this corresponds to an annual individual effective dose of the order of 10 mSv. The criteria for choosing the value of the reference level are the same as those that apply to dwellings, which is that the value chosen should be based on an evaluation of the distribution of the Rn-222 concentration in such workplaces. In Albania, only one national survey has been carried out that investigated the radon concentrations in dwellings in the recently 2014 which covered 10 % of all surface [4]. Subsequently, other studies have been performed on a local scale with different methods of measurement to determine the radon concentration in homes and workplaces in

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various Albanian regions [4]. According to the legislative framework in Albania [5], the reference level for indoor radon concentration for workplaces is considered to be 300 Bq/m3. When this Reference Level is exceeded, the employer must take measures for the protection of employees' health. Under the legislation, employers can be directed to have radon measurements carried out in their workplace.

2. MATERIALS AND METHODS

2.1. Studied area

The measurement of the level of radon concentration at workplaces is performed randomly in different regions of Albania. In this study, we present the results for 50 workplaces mainly in inhabited areas such as banks, different shops, and offices distributed at different cities of Albania such as Devolli in the south-east, Tirana and Fieri (Lushnje and Kucova) in the central part, Shkoder in the north, and Gjirokaster in the south of Albania. All these areas are characterized by different geological formations and climate conditions (Figure 1). From the geological point of view, the measurement sites are located in a geological formation dominated by: ATT unit, which is characterized by terrigenous sediments developed in flysch, limestone and dolomite rocks, show frequently relatively high radon concentration; the ION area presents the upper Triassic evaporation is the oldest rocks where the thick formations of limestone and bottom dolomite dolomites, as well as pelagic limestone strata, lie above them; the Mirdita and Krasta units (MIR and KRA) which consist of an ophiolite belt and flysch; Kruja unit (KRU) which is composed of neritic carbonate rocks overlain by flysch; and finally, the Periadriatic depression (PAD) a basin composed of sandy and clayey sediments.

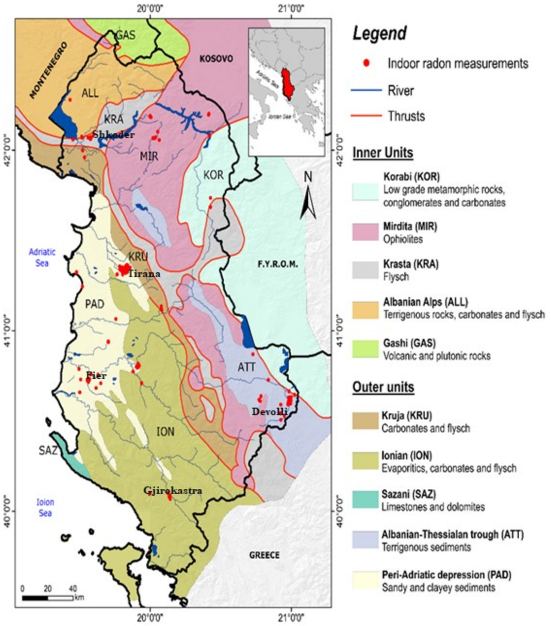

Figure 1. Simplified geological map of Albania modified from Havancsák et al. (2012). The red points represent the location of the radon measurements.

The number of employees in these areas was almost the same, 5–10 people. Most workplaces lacked a ventilation system.

2.2. The method for the measurement of radon concentration and calculation of the dose rate

To measure the time-integrated radon concentration, during this study, a passive device has been used. The Solid State Nuclear Track Detectors (SSNTD) Radtrak, CR- 39 detector is widely used as a passive device in radon survey, because it is suitable for the accumulation of the results over long periods which extend to one season.

The CR-39 diffusion cups were placed on the ground floor at approximately 1 to 2 m from the floor and as far away from the windows (when present) and doors as possible in order to avoid air currents. Each detector was exposed for three months (in the periods January–April) during the year 2014. The exposed CR-39 detectors were etched for approximately 10 hours in a NaOH (6M) solution at a temperature controlled by a thermostat ranging from 70°C to 75°C. The tracks were counted using digital optical microscope readings with zoom (x 150) based on random screenings of 30 areas (field of view of the microscope) of 0.75 mm². The activity concentration (in Bq/m3) was calculated from the superficial track density using the following equation [4]:

$$C_{Rn}(Bq^{-3}) = \frac{N - N_B}{\varepsilon \times t} \qquad (1)$$

where, N and N_B are respectively the gross and background track densities per unit area (track m^{-2}), ε is the calibration factor (track cm^{-2} $(Bq\ h\ m^{-3})^{-1}$) and t is the exposure time (h).

The minimum detection of indoor radon concentration was approximately 12 Bq/m3 for a three-month exposure time [9]. The annual effective dose (due to the exposure to radon (Rn-222) and its decay products) was calculated considering the exposure quantity of working level month (WLM) for a WL of approximately 170 h per month. One WLM equals 6.37 x 10^5 F^{-1} Bq h m^{-3}, which correspond to the time integral equivalent equilibrium concentration (EEC) of Rn-222 (radon gas) in air times the inverse of the equilibrium factor (F) generally assumed 0.4. From lifetime excess absolute risk calculations, ICRP Publication 103 (2007) adopted a nominal probability coefficient (fatality) of 5 x 10^{-4} WLM^{-1} for radon induced lung cancer in males and females. The dose conversion coefficients obtained were 12 mSv WLM^{-1} for workers and 9 mSv WLM^{-1} for members of the public, respectively [6].

3. RESULTS AND DISCUSSION

In the studied workplaces in some cities in the regions of Tirana, Shkodra, Gjirokaster, Devolli, and Fier (Kucova and Lushnja), indoor radon concentration varied in the interval from 53 to 400 Bq/m3.

Table 1 is shows the number of measurements for each city, the type of workplace with some specifications, the ranges (minimum and maximum) radon concentration for each group of workplaces and number of the data monitoring. Indoor radon concentrations were found to be significantly higher in two workplaces: one at an office in Tirana (360 Bq/m^3) and the other at a game-room in Bilisht (400 Bq/m^3).

The first value is observed due to several factors – this office is on the ground floor directly on the ground level, the windows are kept closed most of the time, and there is no ventilation system. The second value is taken due to the fact that this place is located in the basement where no ventilation system is present.

Table 1. Description of the relevant type of workplaces in different cities under investigation. The ranges of radon concentrations (in Bq/m^3) are reported.

Cities	**Type of workplaces monitoring**	**Range (Bq/m^3)**
Kucove	Offices, around 5 workers, 8 hours of work, natural ventilation, 4 data	63-138
Devoll	Banks, around 6 workers, 9 hours of work, artificial ventilation, 5 data	96-137
	Shops, around 4 workers, 10 hours of work, natural ventilation, 8 data	73-400
Lushnje	Shops, around 2 workers, 10 hours of work, natural ventilation, 4 data	81-170
Gjirokaster	Offices, around 10 workers, 8 hours of work, artificial ventilation, 7 data	81-138
Shkoder	Offices, around 10 workers, 8 hours of work, natural ventilation, 7 data	99-204
Tirane	Offices, around 10 workers, 8 hours of work, natural ventilation, 15 data	53-360

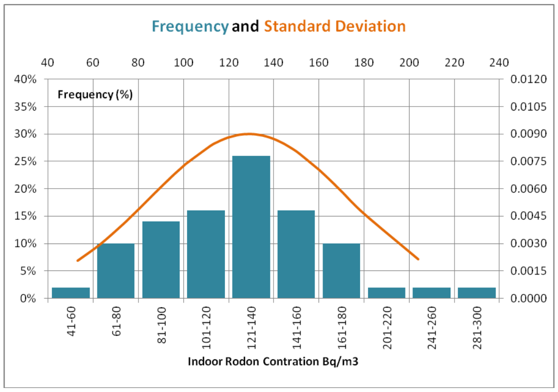

Figure 2. The distribution of radon concentrations (Bq/m^3) in 50 workplaces in Albania

The highest indoor radon concentrations were found in Tirana and Devoll districts, respectively PAD and ATT geological formations. It is observed to be a general correlation with the geological formations in increase order PAD, MIR, ATT, KRU and ION, which need to be investigated with more statistics in the future. The descriptive analysis shows a positively skewed Table 2 and peaked distribution indicating that the radon concentration records follow a log-normal distribution (Figure 2), checked by the Kolmogorov–Smirnov test.

The arithmetic mean (AM) is found to be 130±44 Bq/m^3. These results are consistent with the indoor radon concentration in dwellings measured in Albania, which is found to have an arithmetic mean (AM) of 120±67 Bq/m^3 and a geometrical mean (GM) of 103 Bq/m^3. Moreover, they are also higher than the indoor radon concentration in dwellings measured in the Tirana region, which is found to have an arithmetic mean (AM) of 112 ± 83 Bq/m^3 (Bode et al. 2015).

Table 2. Statistical data on the indoor radon concentration (Bq m^{-3}) for all data and classified for different geological formations.

Statistical data	**Radon concentration (Bq/m^3)**
Range	53-400
Average (AM)	130
Median (GM)	127
Standard deviation	44
Skewness	2
Kurtosis	4

The overall results show that approximately 90% of the workplaces are within the reference level of 300 Bq/m^3.

The calculated values of the effective dose rate varied from 0.38 to 2.16 mSv/y with an average of 0.9 mSv/y. The average dose is almost the same as the worldwide indoor average annual effective dose rate of 1.2 mSv/y (UNSCEAR 2000).

5. CONCLUSION

Considering the hazardous effects of radon in this study presented 50 measurements were performed in random workplaces in different regions of Albania. About 90% of the radon concentration values are within the national reference levels of 300 Bq/m^3. The distribution of indoor radon concentration was found to be log-normal distribution.

The results show high values of radon concentration in the Tirana and Shkoder regions, where the average values come to 146 ±14 and 134±13 Bq/m^3, respectively. The city of Tirana can be considered a place with a medium and high risk of radon concentration; as such, it requires broader studies in the future. The same situation is presented for the Shkodra region, where the results are compatible with the values reported in another study [10] and the radon concentration levels with an active method vary from 115 up to 224 Bq/m^3 with a mean value of 169 Bq/m^3.

Based on these results was calculated the annual effective dose rate, which was found to be from 0.38 to

2.16 mSv/y. These results highlighted the necessity to increase the control in workplaces with high occupancy (like, banks, shops, schools and hospitals) to ensure protection against exposure to the public as well as to the staff working inside. We recommend that the institutions where these measurements were performed ventilate the workplaces regularly in order to alter the results and measurements of radon concentration in different seasons.

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