

Assessment of the Environmental Gamma Dose Rate in Macedonia

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Abstract. Assessment of the environmental gamma dose rate in Macedonia was conducted in 2010, 2015, and 2020 to establish baseline data of the gamma dose rate and observe potential changes over time. For the purpose, the gamma dose rate was measured at 68 locations in 2010, and 72 location in 2015 and 2020 using a portable dosimeter positioned 1 m above the ground surface. The gamma dose rates in the country were in the range 53 - 340 nSv/h in 2010, 38 - 360 nSv/h in 2015 and 41 - 300 nSv/h in 2020. It was found that the reason for a variation in the measured values is due to the geological factors and geological formations which are different in different parts of the country.

Keywords: gamma dose rate, portable dosimeter, geological formations, Macedonia

INTRODUCTION

Environmental radiation monitoring is critical to environmental science, public health, and safety. Gamma rays are of particular concern among various radiation types due to their high penetration power and potential health impacts. Gamma dose rates provide crucial information about environmental radiation levels and are essential for assessing natural background radiation and anthropogenic contributions. Understanding gamma radiation levels in some regions is crucial for several reasons: it aids in evaluating the impact of natural sources of radiation, monitoring potential contamination from human activities, and ensuring public safety.

This study presents a comprehensive analysis of in situ gamma dose rate measurements taken in Macedonia across three distinct time points: 2010, 2015, and 2020. These timeframes provide a historical perspective and allow for the assessment of temporal trends in environmental gamma radiation levels.

The objective of this research is twofold: to establish a baseline of gamma dose rates in Macedonia and to assess any fluctuations that may indicate environmental or anthropogenic influences. The results of this study will contribute to the broader understanding of radiation

including metamorphic, sedimentary, and volcanic types. This zone formed through a series of tectonic collisions and subductions and is younger than the Pelagonian Massif. In the northeastern part of the country lies the Serbo-Macedonian Massif (SMM), which is distinguished by its metamorphic and igneous rock formations and originated during the late Paleozoic and early Mesozoic eras. The West-Macedonian Zone (WMZ), located in the western part of Macedonia Macedonia, is characterized by its metamorphic rocks, including schists and gneisses, and features numerous thrust faults and folds. This zone was formed in the Mesozoic era. A simplified lithological map of Macedonia, highlighting these principal tectonic units, is presented in Fig. 1b. [4]

Sampling and analyses

Ambient radiation dose rate has been monitored at 68 locations in 2010 (Fig. 2a) and 72 locations in 2015 and 2020 (Fig. 2b) all around the country to estimate the rate of the absorbed radiation dose that arises from the terrestrial radiation exposed to open space. The dose rates have been measured by dose rate detector ATOMTEX AT1117M with BDGK-01 probe with a dose rate range from 0.01 $\mu\text{Sv/h}$ to 10 Sv/h. The energy interval in which the radiation was identified was from 60 keV to 3 MeV. The measurements of radiation dose rate were conducted at a height of one meter above the ground, following the guidelines of the Scientific Committee for the Effects of Atomic Radiation of the United Nations - UNSCEAR [2].

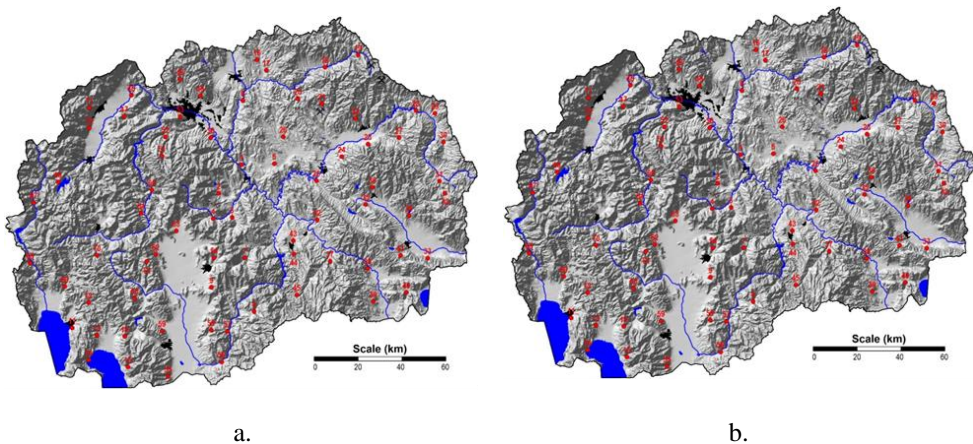


Figure 2. Locations of and radiation dose measurements points across Macedonia in 2010 (a) and in 2015 and 2020 (b)

RESULTS AND DISCUSSION

All data obtained from this investigation (processing, calculations, geostatistical data interpretation and visualization - (mapping) were processed using the following software:

Statistica (Stat Soft Inc.), Autodesk MAP 3D (Autodesk Inc.), QGIS (Open Source Geographic Information System) and Surfer (Golden Software Inc.).

The basic statistical parameters (mean, median, minimal and maximal content, standard deviation, percentile values, and coefficient of variation) of the data for the ambient dose rates are given in Table 1.

Table 1. Descriptive statistics. All the values in the table are given in nSv/h

Year	N	X	Md	X _{BC}	Min	Max	P ₁₀	P ₉₀	P ₂₅	P ₇₅	S	CV
2010	68	113	110	104	53	340	65	170	80	130	46	40
2015	72	110	110	102	38	360	56	158	80	142	48	43
2020	72	110	104	104	41	300	55	156	82	140	45	41

N- number of measurement locations; X - arithmetic mean; Md - median; X_{BC}- Median Box-Cox transformed values; Min - minimum; Max - maximum; P₁₀, P₉₀, P₂₅, and P₇₅ percentile values S - arithmetic standard deviation; CV - coefficient of variation.

According to the data shown in Table 1, it can be concluded that the ambient radiation dose rate in Macedonia ranged from 53 nSv/h to 340 nSv/h in 2010, from 38 nSv/h to 360 nSv/h in 2015 and from 41 nSv/h to 300 nSv/h in 2020. The average dose were assessed to be 113 nSv/h in 2010 and 110 nSv/h in 2015 and 2020. Notable difference are not observed in the median values for the measurements in the three surveys also. The results for the ambient dose rate measurements done in many regions in the world reveal that the mean values varied from 24 nSv/h to 160 nSv/h. The world average for the ambient radiation rate was determined at 57 nSv/h [2].

Following the Box-Cox transformation of the data, bivariate statistics was used to detect the correlations or relationships between the data obtained in each of the measurement campaigns. For that objective, the Pearson correlation coefficient r reflecting the strength and direction of the linear dependence (correlation degree), between two random variables or sets of random variables was determined. The results from bivariate statistics are displayed in the matrix of the correlation coefficient in Table 2. The values within the range of 0.7-1.0 are considered to show a strong connection between the variables which is the case in this situation. This can be interpreted as the constant origin of the radiation on the territory of Macedonia in the studied period.

Table 2. Pearson correlation coefficient. Values are in the range 0.7-1.0 showing strong association; Box-Cox transformed values were used.

2010	1.00		
2015	0.78	1.00	
2020	0.76	0.84	1.00
	2010	2015	2020

The observed radiation dose distribution for 2010, 2015 and 2020, in Macedonia is shown in Figure 3. From the analysis of the geological map of Macedonia Fig 1b, and the results obtained for the ambient dose rate at each of the locations it was evident that the highest ambient dose rates were observed at the places where volcanic and magmatic rocks were most present in the Western-Macedonian zone (regions of Kičevo and Bitola) and in the Vardar zone of Mariovo, Kožuf, Kratovo and Radoviš region as well as smaller regions. Furthermore, regions extensively covered by Precambrian granites in the Serbian-

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Macedonian massif and Pelagonian Massif have shown elevated dose rates. High ambient dose rates were measured in the Pelagonia Valley, and that can be further explained by the emission of dust from the uranium-enriched ore mine and fly ash from the thermoelectric power station near the town of Bitola [5-8].

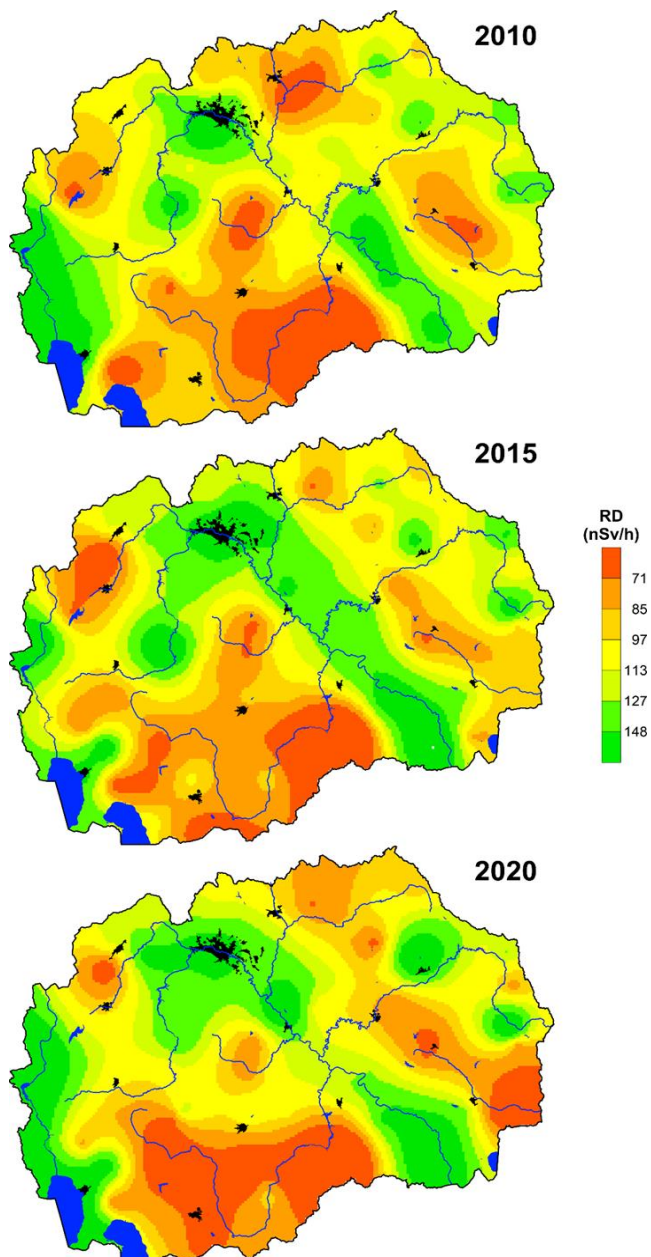


Fig 2. Spatial distribution of measured radiation dose rates in 2010, 2015 and 2020.

CONCLUSION

The results from this study show that the results obtained in the in situ environmental dose rate measurements in Macedonia made in 2010, 2015 and 2020 are strongly influenced by the geology of the country and the highest values are locations where volcanic and magmatic rocks were most present. Higher values are observed also in the Pelagonia Valley, which can be explained by the emission of dust from the uranium-enriched ore mine and fly ash from the thermoelectric power station situated near the town of Bitola

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