QUANTIFYING NATURAL BACKGROUND RADIATION IN KORÇA: A COMPUTATIONAL APPROACH

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Abstract

This study investigates the environmental dose rate in the Korça district through extensive measurements conducted over three years. 25,000 measurements were performed using the Portable radiation monitoring device, Atomtex AT6101C device in various urban and rural areas. The dose rates ranged from 15 nSv/h to 210 nSv/h, averaging 54 nSv/h. Data analysis was carried out using the R programming language and GNU Octave. The initial analysis focused on summer data, followed by optimizing spatially distributed dose values using data clustering. A representative grid was then mapped in ArcGIS Pro and GNU Octave, and the Kriging method was applied to ensure complete area coverage. The distribution of values was fitted to known distributions, and the hypothesis was tested using log-likelihood and χ^2 tests. The findings confirm that natural radiation levels in the Korça district are very low and pose no health risk to the population (Ministria e Shëndetësisë, 2010; UNSCEAR, 2023).

Key words**:** *Dose rate, mapping, distribution, kriging interpolation.*

Përmbledhje

Ky studim trajton nivelin e fuqisë së dozës mjedisore në qytetin e Korçës, përmes një fushate të gjerë matjesh të realizuara gjatë një periudhe trevjeçare. Janë kryer mbi 25,000 matje në zona urbane dhe rurale, duke përdorur pajisjen Portable radiation monitoring device Atomtex AT6101C. Vlerat e shkallës së dozës ambientale varionin nga 15 nSv/h deri në 210 nSv/h, me një *mesatare aritmetike prej 54 nSv/h. Analiza statistikore e të dhënave u realizua në gjuhët e programimit R dhe GNU Octave. Fillimisht, vëmendja u përqendrua në analizën e të dhënave të mbledhura gjatë sezonit veror, pasuar nga faza e optimizimit hapësinor të matjeve përmes metodave të grupimit. Më pas, u projektua një rrjet hapësinor përfaqësues me qëllim mbulimin uniform të zonës së studimit nëpërmjet platformës ArcGIS Pro dhe GNU Octave, ku u aplikua metoda e interpolimit Kriging, me qëllim sigurimin e një mbulimi të plotë dhe të besueshëm të zonës së studiuar. Shpërndarja statistikore e vlerave të matura u testua ndaj shpërndarjeve teorike të njohura, përmes testeve të përshtatjes si testi i gjasës logaritmike dhe testi χ^2 (chi-katror). Rezultatet konfirmojnë se nivelet e rrezatimit natyror në qytetin e Korçës janë shumë të ulëta dhe nuk paraqesin rrezik për shëndetin e popullsisë, në përputhje me udhëzimet e Ministrisë së (Ministria e Shëndetësisë, 2010) (UNSCEAR, 2023).*

Fjalë kyçe: *Radioaktiviteti mjedisor, shkalla e dozës gama, sfondi i rrezatimit natyror në Korçë, pajisje portative e lëvizshme (Portable radiation monitoring device Atomtex AT6101C), interpolimi Kriging.*

Introduction

Korça is a city in southeastern Albania. Korça is also the center of the prefecture of the same name. It is one of the largest municipalities in the country, with approximately 60,000 registered inhabitants. (INSTAT, 2024) The areas of Korça have been inhabited since the Copper Age, which lasted from the third millennium to the second millennium BC. Until 650 BC, the area of the city of Korça under consideration was 1752 km², most of which lies in a valley surrounded by high mountains up to 2,300 meters. The study area lies between the coordinates of 40.61 degrees north latitude and 20.78 degrees east longitude, and an altitude of 850m above sea level. (Bërxholi, 2003). Despite this historical, geographical significance and tourist destination, large-scale gamma radiation measurements have not been conducted in recent years.

Environmental dose rate measurements are crucial to inform and shape regulatory decisions, guide political responses, and underpin public debate. High-quality data acquisition is essential for ensuring accurate assessments and enabling the delivery of evidence-based decisions. To achieve this goal, international quality assurance and control requirements, including those detailed by EURATOM, are scrupulously followed. Natural background radiation originates from terrestrial and cosmic sources. Terrestrial radiation is given off by the radioactive nuclides present in a region's air, soil, geological formations, water, and construction materials; their concentrations depend on the geological features of the region in question. Cosmic radiation refers to cosmic rays that come from outer space, and levels depend principally on altitude and geographic latitude (UNSCEAR, 2023). Anthropogenic activities like nuclear processes and accidents add to the increased background radiation. Traces of radioactive emissions from Fukushima spread across the entire northern hemisphere as a result of the serious damage caused to the Daichi power plant in Fukushima, Japan on 11 March 2011 by the double disaster of the 9.0 magnitude earthquake and tsunami. The dispersion of the radioactivity was first detected in Europe in Iceland on 19–20 March by the Icelandic Radiation Authority and by a monitoring station of the Comprehensive Nuclear-Test-Ban Treaty Organization (Potiriadis C, 2012).

There is a great need for a detailed assessment of environmental dose rate in regions such as Korça in Albania. Being an ancient city in southeastern Albania, its diverse geography thus really requires a comprehensive assessment of the ambient natural radiation levels. The main objective of this work is to assess the environmental dose rate in the Korça district using an advanced measurement technique and to compare the results obtained with both global and natural benchmarks. The data received will be used as basic information on gamma dose rates and will play a key role in public exposure level judgment. All previous efforts at mapping gamma dose rates in Albania, including those contributing to the European Terrestrial Gamma Dose Rate Map (Cinelli, 2019), represent but a minute fraction of the area. This represents a need for an extended and detailed mapping effort, hence the objective of the present work.

This study applies the ground-based gamma-ray spectrometry survey method noted for its much higher spatial resolution in overcoming the challenges imposed by regional variety in topography. Ordinary kriging of a single variable is the most robust and common geostatistical method and is used mostly to predict the variables at unknown locations (Webster, 2016). By incorporating advanced geostatistical methods in the form of ordinary kriging, this study predicts levels of gamma radiation at unsampled locations to further enhance the accuracy and better represent the radiation field throughout the

Korça district (Zhouzhou Song, 2023). The results obtained from this work will be relevant to land management, conservation planning, and public health, since one may clearly understand the radiation distribution in the area and point out zones exceeding any threshold values for necessary intervention.

Material and methods

The methodology used in this study focused on scanning many urban and rural roads within the city of Korça, to create a map describing the natural radiation levels. This will allow for the assessment of the natural radiation background in the territory of Korça and the identification of areas with higher radiation levels. After turning on the device and performing the auto-calibration procedure, the device was mounted at approximately 1 meter above ground level to simulate exposure at chest height. Then, a more in-depth investigation was carried out in the areas where we obtained a higher level, to determine the possible causes and the composition of the soil in that area. Also, to verify the accuracy of the measurement, a second measurement with the Flir identifier device was carried out at the points where the radiation level was highest. For measuring environmental doses, as well as scanning urban and rural roads in the Korça district, the Portable radiation monitoring device Atomex AT6101C device was used.

Figure 1. AT6101C detector used to conduct the study

The AT6101CE spectrometer (Atomtex), shown in Figure 1, is an advanced device for detecting and measuring gamma and neutron radiation sources. It provides an energy range from 20 keV to 3 MeV in spectrometric mode and from 50 keV to 3 MeV in dose-based mode. The device accurately measures environmental dose equivalents in the range of 0.03 – 150 μSv/h, ensuring high sensitivity to gamma radiation. Its typical sensitivity to gamma radiation is 15,000 cps/(μSv/h) for Am-241, 4,500 cps/(μSv/h) for Cs-137, and 2,400 cps/(μSv/h) for Co-60, allowing for precise identification of radionuclides at various energy intervals. The spectrometer is designed for rapid detection, triggering an alarm in less than 2 seconds upon identifying a radioactive source. It demonstrates high sensitivity to neutron radiation, with a detection rate of 20 counts per second (cps) for Cf-252 neutron sources. The device is capable of continuous operation for up to 20 hours, while providing real-time data logging with GPS reference. This functionality makes it ideal for environmental radiation monitoring and comprehensive data analysis. Its efficiency and precision make it an essential tool for detecting and mitigating radiological threats, as well as for the identification of complex radionuclide sources (Atomtex).

Results and discussion

The data processing began initially by visualizing the measured values of the city of Korça. The measured values according to the measured dose rate in nSv/h are, in many cases, superimposed. Some of the reasons are the different speeds of movement or standing for different mounts. The map was made using the ArcGIS Pro program, mainly used in the visualization of territorial studies. The unfiltered measurement values are placed on this map. As can be seen from the map in Figure 2, the coverage of the city of Korça with measurements is not the right one.

During the field survey, certain areas could not be accessed due to infrastructural and architectural limitations. Some roads were impassable, and many private house courtyards were inaccessible for measurement. A notable example is the typical construction layout in parts of Korça, where adjacent houses are built back-to-back, with their private courtyards facing in opposite directions. As a result, narrow cobblestone alleys between these dwellings often span up to 20 meters without direct measurement points.

These 20-meter gaps—where physical measurements could not be performed—were addressed through spatial interpolation techniques or, where necessary, simulation, to ensure continuity and coverage of the radiation map. For this purpose, we will initially identify and filter the unwanted or erroneous values.

Given the inadequate coverage of Korça, it was necessary to identify and filter out unwanted or incorrect values. To ensure meaningful analysis, we applied a Gaussian data filter using GNU OCTAVE (Nicolas Girodano, Hasao Nakanishi, 2005). This filtering method helps identify errors in measurement and measured values, although it is not entirely suitable for drawing definitive conclusions (Roxy Peck, Chris Olsen, Jay Devore).

Figure 2. Presents the map of Korçe with unfiltered

Figure 3 illustrates the spatial variation of measured ambient dose rates along urban and rural paths between successive measurements, denoted in yellow.

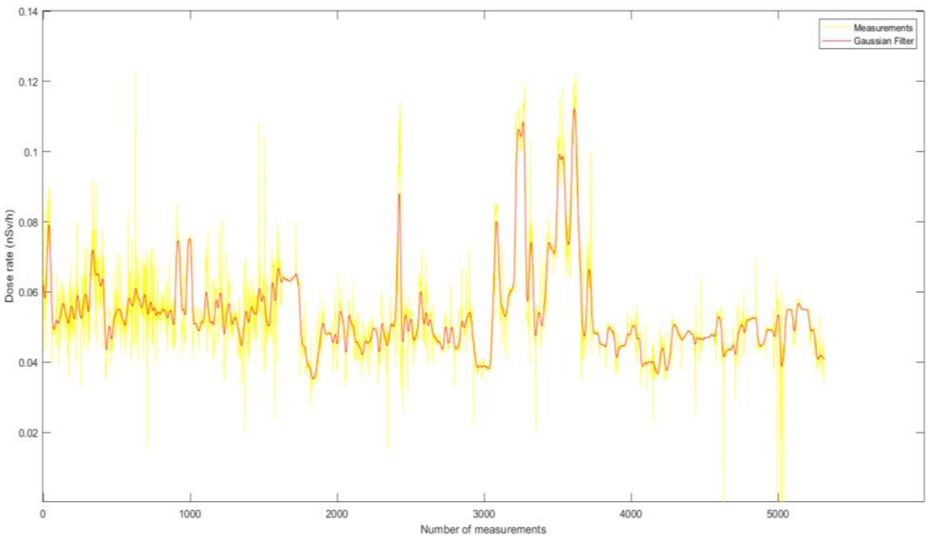

Figure 3. Application of Gaussian filtering on raw dose rate measurements to smooth extreme values and identify meaningful trends.

The observed measurements are centred around 60 nSv/h, with fluctuations occurring both above and below this average. However, certain values appear to lack physical relevance, potentially arising from measurement errors or misinterpretations during data acquisition.

Consequently, it is critical to implement data filtering techniques to refine the analysis and address both the distribution and the presence of outliers in the dataset. Additionally, the figure incorporates a Gaussian filter (represented in red), which serves to mitigate the influence of extreme values, particularly those resulting from abrupt, anomalous shifts in the data.

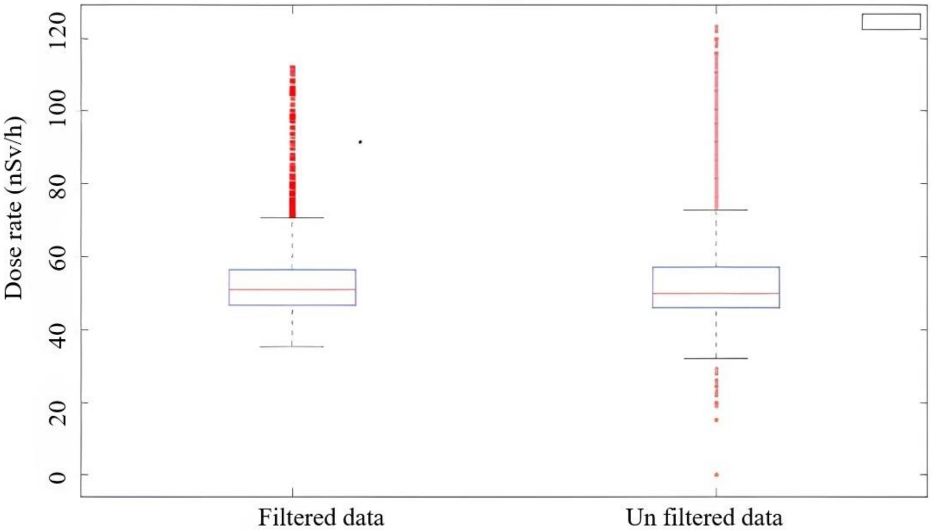

Figure 4. Boxplot of filtered and unfiltered data.

In Figure 4, we attempted to identify outliers or erroneous measurements that may result from instruments producing values without physical meaning. The figure presents box plots with interquartile range (Whaley, 2005), generated in GNU OCTAVE, based on both unfiltered and filtered measurements using a Gaussian filter (a moving average filter was also available and could be used). In the filtered data, zero values have been eliminated, while high values remain. However, since these do not appear as sudden jumps but rather as smoother increases, the Gaussian filter only softens them without fully removing them.

This suggests that a significant number of measurements recorded high values in a specific area, indicating elevated radiation levels in that zone. However, since the dose rate is not significantly higher than the natural background radiation, these elevated values may reflect environmental or geological variations rather than instrumental error, potentially influenced by the composition of the soil, pavement stones, or asphalt, rather than measurement errors. Thus, they do not indicate areas of high radiation risk. The instrument measures and records dose rate values uniformly and periodically. Depending on the movement speed, it registers values at varying distances, considering stops and obstacles along the route. From Figure 1 and data analysis, there have been instances where multiple measurements were recorded at the same location due to stops, which can affect the overall assessment. Therefore, an additional spatial filtering process is necessary, alongside dose rate filtering. As a result, data selection and clustering become essential. Using GNU OCTAVE, data points were selected based on their spatial distance. The selection followed a rule ensuring that considered measurements were at least 50 meters apart, as closer measurements could influence the distribution of values. This clustering or selection process produces the following map.

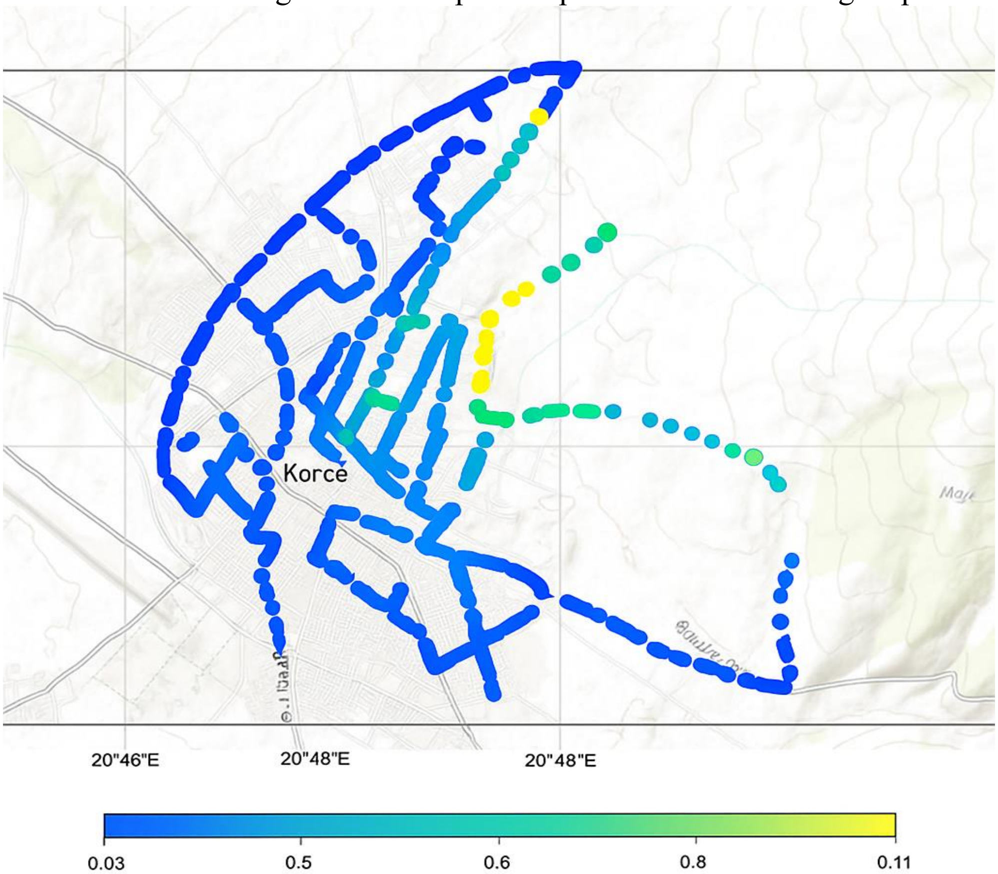

Figure 5. Spatial distribution of gamma dose rates in Korça after applying data filtering. The legend indicates dose rate values in nSv/h, ranging from low (blue) to high (red)

Using GNU OCTAVE (MENKE, 2021), we visualized the distribution of the measured values and optimized the bin width using Freedman and Diaconis's (David Freedman, Persi Diaconis, 1981) rule, adapting it to known distributions. With the EasyFit software (Schittkowski, 2000), we ranked the most suitable known distributions for our data. The best-fitting distributions were identified as the Generalized Extreme Value and Lognormal distributions.

To verify this, we conducted statistical tests, including the Chi-squared test and the Anderson-Darling test with a significance level of $\alpha = 0.05$. The statistical analysis indicates that the distribution does not perfectly conform to any single known distribution. However, it closely aligns with the Generalized Extreme Value distribution. The dataset has a mean value of 54 nSv/h, a maximum value of 210 nSv/h, and a minimum value of 15 nSv/h.

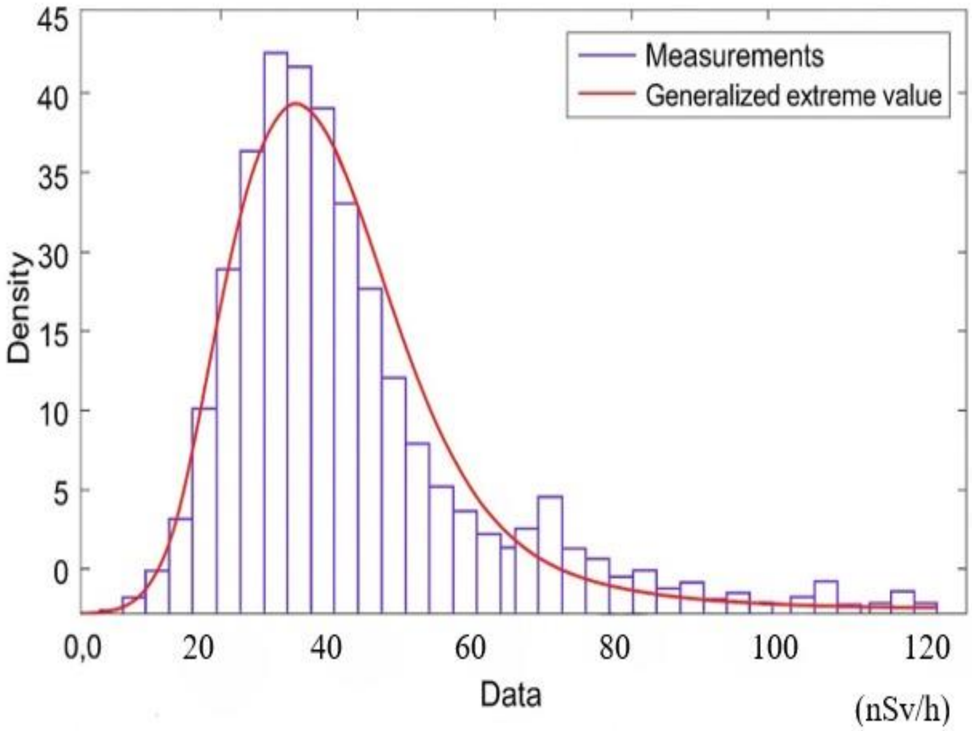

Figure 6. Distribution and fitting with one known distribution

Figure 5 illustrates the spatial variation of measured ambient dose rates along urban and rural pathsDistribution fitting was conducted using EasyFit, testing 23 known probabilistic models. The Generalized Extreme Value and Lognormal distributions showed and ranked according to Table 1.

Table 1. Distribution Fitting Results

Distribution	Kolmogorov Smirnov		Anderson Darling		Chi Squared	
	Stat	Rank	Stat	Rank	Stat	Rank
Generalized Extreme Value	0.05637	1	3.4695	1	33.895	1
Log Normal	0.07982	2	7.7548	2	102.97	2

Using the filtered data, interpolation was performed using the kriging method, which estimates values in areas with missing measurements by considering nearby data points.

Figure 7 displays the complete interpolated map, generated in ArcGIS Pro using the kriging method (MENKE, 2021) after applying the necessary data filters selected where the distance between measurement points was optimized, making it the most suitable for interpolation.

In contrast, outside this region, the spacing between measurement points becomes irregular, compromising the kriging method's accuracy in those areas.

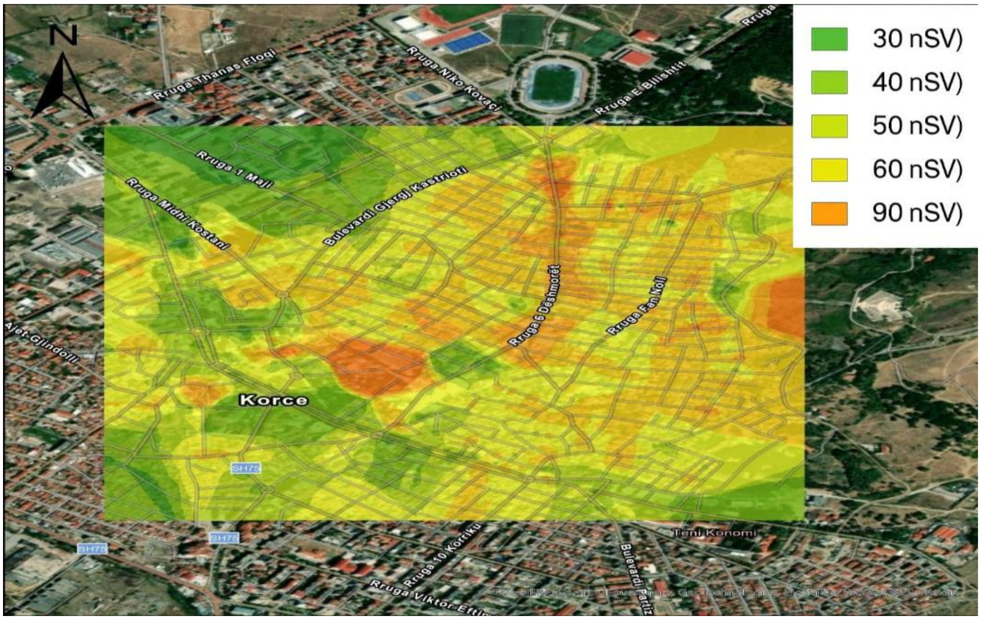

Figure 7. Interpolation with the Kriging method. The legend indicates dose rate values in nSv/h, ranging from low (yellow) to high (red).

The study also considered gamma dose rate values for neighbouring countries of Albania. (Bërxholi, 2003).

Table 2. Comparison of Gamma Dose Rates in Korça and Neighboring Countries.

Country	Average (nSv/h)	Reference
Korça, Albania	54	Our measurements
Montenegro and Serbia	66.8	(S. Dragovic´, 2006)
Bosnia and Herzegovina	111	(Davorin Samek, 2003)
Bulgaria	157	(Cinelli, 2019)
Greece	71	(Cinelli, 2019)

The measured in Montenegro and Serbia range from 34.5 nSv/h to 97.6 nSv/h, with an arithmetic mean of 66.8 nSv/h (S. Dragovic´, 2006). In Bosnia and Herzegovina, the average is 81.8 ± 17.9 nSv/h (Davorin Samek, 2003), while in Bulgaria, it is 157 nSv/h (Cinelli, 2019).

For Romania, Moldova, and Greece, the average dose rate is approximately 71 nSv/h, with the highest recorded value of 489 nSv/h at Ammolofoi Beach. In contrast, our measurement in Korça have an average dose rate of 54 nSv/h. While the average radiation levels in Korça are lower than those in most other Balkan countries, the maximum recorded value exceeds those found in Serbia, Montenegro, and Bosnia and Herzegovina. However, it is important to note that Korça's maximum value, although higher than those recorded in these neighboring countries, remains significantly below the European average.

Conclusions

This study provides a comprehensive assessment of environmental dose rate in the Korça district based on an extensive dataset collected over three years and processed using advanced spatial and statistical techniques. Average gamma dose rate is 54nSv/h. The application of data filtering, clustering, and geostatistical interpolation (Kriging) enabled a precise spatial representation of ambient dose rate distribution.

Although certain zones exhibited slightly elevated radiation values, all measurements remained well below internationally recommended safety thresholds, indicating no radiological concern for the population. The resulting radiation map serves as a valuable baseline for future radiological monitoring, environmental health assessments, and urban planning initiatives in the Korça region.

Contributions of the authors

The following statement specify individual contributions of the authors. "Conceptualization, J.Sh. and E.B.; Methodology, J.Sh.; Software, E.G.; Validation, E.B., P.M. and B.D.; Formal Analysis, E.G.; Investigation, J.Sh.; Resources, J.Sh.; Data Curation, E.G.; Writing – Original Draft Preparation, J.Sh.; Writing – Review & Editing, J.Sh and E.G.; Visualization, E.G.; Supervision, E.B.; Project Administration, E.B.

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