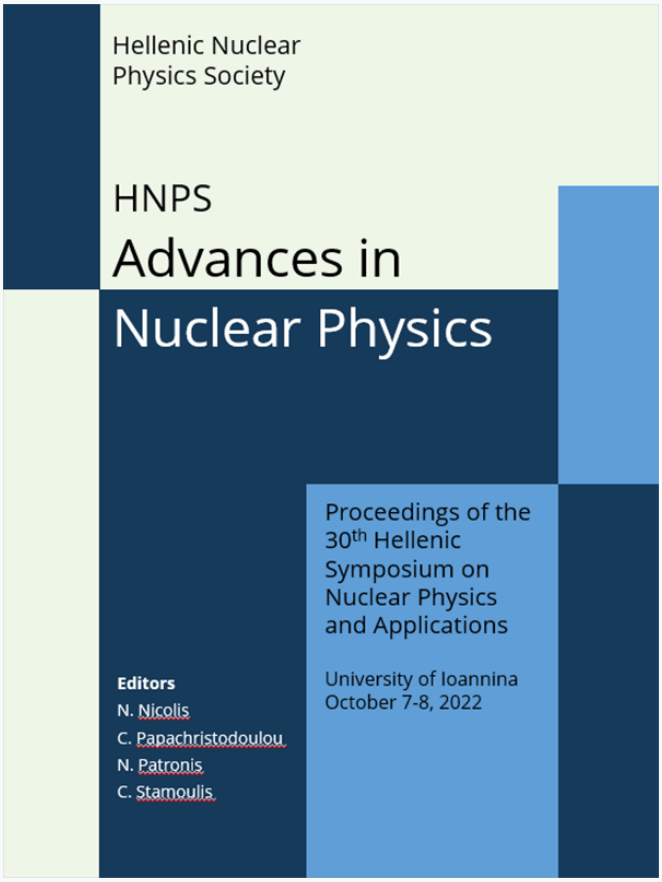
HNPS Advances in Nuclear Physics

Vol 29 (2023)

HNPS2022



Radioactivity measurements in eastern Lesvos, Greece

Filothei Pappa

doi: 10.12681/hnpsanp.5136

To cite this article:

Pappa, F. (2023). Radioactivity measurements in eastern Lesvos, Greece. *HNPS Advances in Nuclear Physics*, *29*, 144–148. https://doi.org/10.12681/hnpsanp.5136

Radioactivity and dose rate studies in eastern Lesvos, Greece

F.K. Pappa[1,2], D. Avgerinos[1], E. Kapilaris[1], O. Kremenioti[1], G. Poulis[1], G. Kuburas[1,3], C. Matsoukas[1*]

[1] *Department of Environment, School of Environment, University of the Aegean, University Hill, 81100 Mytilene, Greece,*
[2] *Institute of Oceanography, Hellenic Centre for Marine Research (HCMR), 46.7 km Athens-Sounion, Attica, Greece*
[3] *Environmental Radioactivity Laboratory, Institute of Nuclear and Radiological Sciences and Technology, Energy and Safety, National Centre for Scientific Research "Demokritos", 153 10 Aghia Paraskevi, Athens, Greece.*

Abstract The radioactive background of the eastern side of Lesvos Island in Greece, an island rich in natural radioactivity, was studied by means of gamma ray spectroscopy. Dose rates and concentrations of natural radionuclides (^{232}Th series, ^{226}Ra and ^{40}K) and ^{137}Cs were measured in-situ and in the laboratory, respectively. A total of twenty soil samples and ten beach sand samples was collected and processed according to the IAEA protocol. For the in-situ measurements and the dose rate determinations a portable NaI scintillation detector was utilized. The activity concentration calculations were performed in the laboratory, using a high-purity germanium detector. These activity concentrations were also used to estimate dose rates, so as to compare the obtained results with the in-situ measurements. The maximum detected values of activity concentrations of ^{232}Th series, ^{226}Ra, ^{40}K and ^{137}Cs were found to be 190, 90, 960 and 70 Bq kg^{-1}, respectively. As for the dose rates, both measured and estimated, the maximum values were 230 and 190 nGy h^{-1}, respectively. A significant difference regarding activity concentrations and dose rates was observed between the two matrices (soil, beach sand), with the values of soil samples being higher than those of beach sand samples. This can be attributed to the granulometry of each matrix. Furthermore, the study attempted to compare the radioactive background of the eastern side of Lesvos Island, studied in this work, with the western side. The higher values were found in the eastern part.

Keywords: natural radioactivity, terrestrial, absorbed dose rate map

INTRODUCTION

During the last decades, a great effort has been made to produce a terrestrial gamma dose rate map in Europe for radiation protection reasons. This map reports the possible dose rate that a person will receive due to terrestrial radiation. The idea was proposed after the necessity to establish dose rate monitoring networks for emergency cases such as the Chernobyl accident. After the accident, the majority of the European countries established such networks and created a database contributing to the EUropean Radiological Data Exchange Platform (EURDEP) [1]. The purpose of the EURDEP system was early warning in radiological emergencies [1], however the continuous monitoring and the obtained spatio-temporal data could be also used for estimating radon fluxes and modelling radon emissions [2]. The complexity of the physical, geochemical and structural mechanisms involved in radon emission [3] lead to the introduction of new concepts, such as geogenic radon potential [4]. In order to characterize the region regarding radon potential, a number of factors must be measured, for instance gamma radiation from the ground, U concentration in soil and rock, radon concentration in soil gas and soil permeability [3]. Potential areas for such studies are those characterized by elevated level of natural radioactivity, like volcanic regions. Lesvos is such an area, being an island of volcanic origin with many thermal spas or springs.

The aim of this work was to produce a terrestrial map of absorbed dose rates by implementing two methodologies/approaches. The first approach regards the in-situ measurements of absorbed dose rates

* Corresponding author: matsoukas@aegean.gr

via a NaI scintillator detector (SpirID), while the second one determines the terrestrial absorbed dose rates by measuring ^{238}U decay series, ^{232}Th decay series and ^{40}K concentrations in soil and beach sand samples collected at the same points with the in-situ measurements. Finally, a comparison was also performed between the two approaches before the terrestrial map production.

STUDY AREA AND FIELD WORK

A total of 20 soil samples and 10 beach sand samples were collected from the eastern part of Lesvos Island, Greece, during May-June and October 2021, accordingly (Fig. 1). Each soil sample was a representative of a 1 km^2 area, meaning that the 1kg collected soil was a mixture of four soil samples from the four vertices of the 1 km x 1 km square region (i.e. 4 x 20 = 80 total sampling points). This sampling methodology was not followed for the beach sand samples due to the rocky characteristics of the beaches and the limited beach area. Therefore, each beach sand sample corresponds to one sampling point. Additionally, similarly to the sampling methodology, the in-situ dose rate measurements were performed. Namely for each sampling area, four in-situ measurements using a portable NaI detector (SpirID) were also performed - at the same points - to obtain absorbed dose rates data. Thus, the representative dose rate was the mean value of the four in-situ measurements. The probe of the SpirID system was always set in a vertical position facing the ground. The SpirID position was fixed by a belt to maintain the one meter distance from the ground in case of different detector operators. The representative soil data (in-situ dose rates and collected mass) correspond to the center of the square area. It should be noted that the soil sampling was focused on collecting ideally undisturbed ground by removing surface roughness (vegetation and pebbles). Moreover, both sampling and measurements were held under adverse conditions (lockdown restrictions due to the Covid-19 epidemic). The in-situ beach sand dose rates were obtained accordingly to the beach sand sampling.

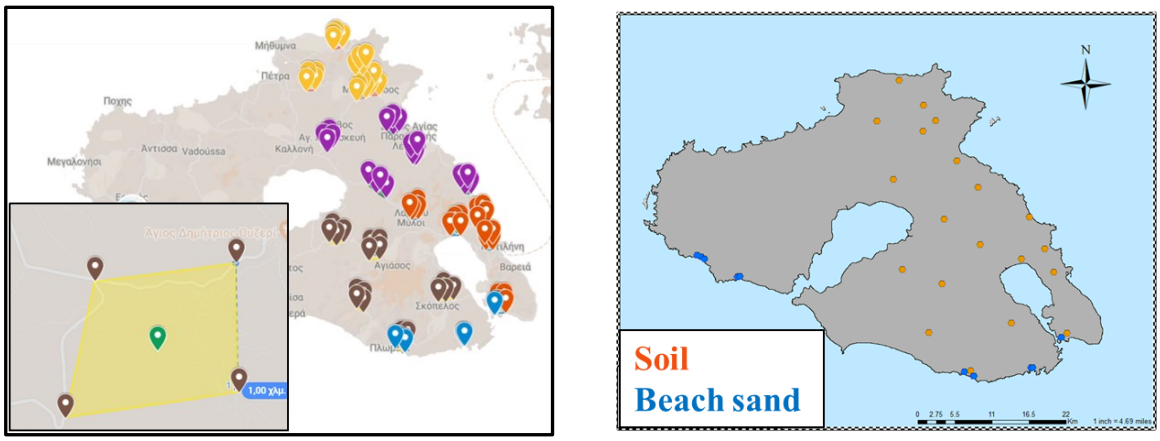


Figure 1. *The sampling methodology (four samples collected from a 1 km square area) on the left and the final representative sampling points on the right*

METHODOLOGY

Both for sampling and sample preparation, the IAEA protocol [5] was followed. Briefly, the main steps of sample preparation include removing the remaining vegetation (e.g. twigs, grass or other foreign bodies), sieving (2 mm sieve grid), oven drying at 100ºC for 24 h or until to achieve dry mass, pulverization and sealing the pulverized sample in a 40 ml container for 20 days to reach secular equilibrium within the ^{238}U and ^{232}Th decay series. A similar procedure was followed for the beach sand samples. After the sample preparation, gamma-ray analysis was performed to determine the activity concentrations of natural radionuclides (^{238}U decay series (^{226}Ra, ^{214}Pb, ^{214}Bi), ^{232}Th decay series (^{228}Ac,

^{212}Pb, ^{208}Tl) and ^{40}K) and ^{137}Cs. The radionuclide measurements were performed via a HPGE detector with an efficiency of 45% relative to a 3´´ X 3´´ NaI scintillator having a 1.8 keV resolution (FWHM) at the 1.332 MeV gamma ray of ^{60}Co with the acquisition time set to 24 h. The appropriate calibrations and corrections (e.g. True Coincidence Summing effects) were also taken into account. In the uncertainty budget the photopeak-counts statistical uncertainty, the gamma-rays intensity, the detector efficiency and the sample mass were taken into consideration. All radionuclide measurements were held at the environmental radioactivity facility of the Water and Air Quality Laboratory, Department of Environment, University of the Aegean.

The obtained mean activity concentrations of ^{238}U decay series, ^{232}Th decay series and ^{40}K were utilized to calculate absorbed dose rates (nGy h^{-1}), according to [6] (see equations 1 and 2). Additionally, the equivalent dose rates (nSv h^{-1}) obtained in-situ via SpirID detector and software, were converted to absorbed dose rates using a factor of 1.

$$D=A\cdot{}^{40}K + B\cdot{}^{238}U + C\cdot{}^{232}Th \quad \text{(Eq. 1)}$$

$$\delta D = \sqrt{(A\cdot\delta^{40}K)^2 + \left(B\cdot\delta^{226}Ra\right)^2 + (C\cdot\delta^{232}Th)^2} \quad \text{(Eq. 2)}$$

where, D is the dose rate (nGy h^{-1}), ^{40}K, ^{238}U and ^{232}Th are the activity concentrations of the aforementioned radionuclides (Bq kg^{-1}) and A = 0.0417, B = 0.462 and C = 0.604 are constants (nGy h^{-1} per Bq kg^{-1}) proposed by [6].

RESULTS AND DISCUSSION

The obtained activity concentrations of ^{226}Ra, ^{232}Th series, ^{40}K and ^{137}Cs in soil samples are presented in Fig. 2. The relative uncertainty of the aforementioned radionuclides was found to be 4%, 3%, 2% and 7%, respectively. The presented results of ^{226}Ra correspond to the mean activity concentration of ^{214}Pb and ^{214}Bi, as the secular equilibrium was achieved among the aforementioned radionuclides. However, the ^{226}Ra data cannot be representative of ^{238}U, as the equilibrium between ^{238}U and ^{226}Ra is not secured. Regarding the ^{232}Th series, ^{232}Th can be assumed to be in secular equilibrium with its daughters, as the latter (i.e. ^{228}Ac, ^{212}Pb, ^{208}Tl) gave similar results. The spatial distribution of ^{226}Ra and ^{232}Th series shows elevated values above 50 Bq kg^{-1} at the north-eastern part of Lesvos (S12-S20). The high activity concentrations reflect the volcanic background of the island. Additionally, the artificial radionuclide ^{137}Cs, exhibited similar values (5-50 Bq kg^{-1}) for all study areas, with the highest value (70 Bq kg^{-1}) observed at a high altitude area (S19) compared to the other points.

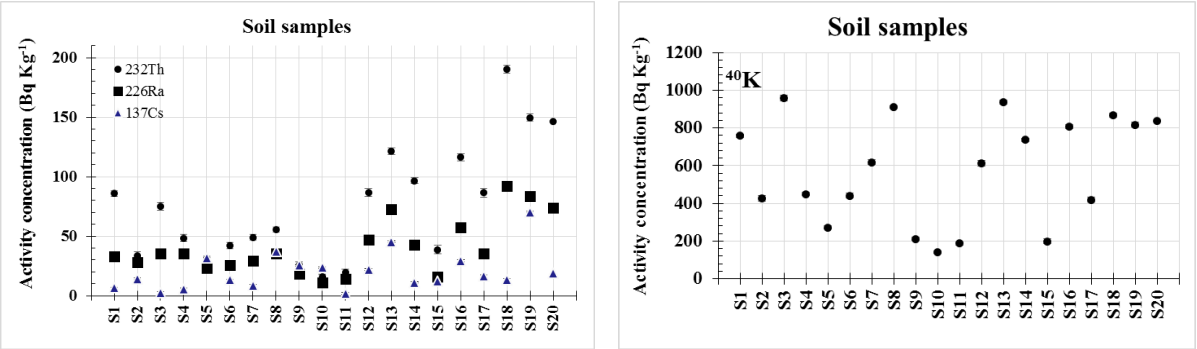


Figure 2. *The activity concentrations at the soil*

The beach sand samples exhibited 50% lower values of natural radioactivity compared with those for the soil (Fig. 3). The sand sample activity concentration of ^{137}Cs was well below the detection limit (1 Bq kg^{-1}) of the high purity germanium detector used, thus it is not presented in this work. Additionally, the activity concentrations of ^{232}Th series were two times higher than those of ^{226}Ra. The spatial distribution of the studied natural radionuclides (^{226}Ra, ^{232}Th series, ^{40}K) showed that the south-east beaches of Lesvos were characterized by high concentrations (BS6-BS9), compared to the south-west. This may be attributed to the granulometry of the beaches and the rocky characteristics of each beach. In our samples, the particle size of sand in the south-west coast was generally coarser than in the south-east side.

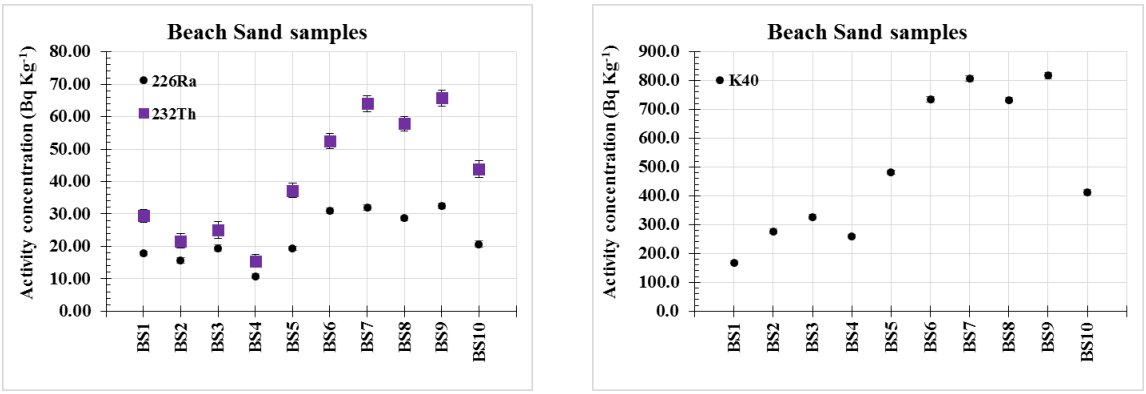


Figure 3. *The activity concentrations at the beach sand*

The measured (in-situ methodology) and the calculated (lab-based methodology) absorbed dose rates for the soil matrix are presented in Fig. 4. Both methodologies were in good agreement and discrepancies up to only 20% were found. The results for beach sands are not presented for the sake of brevity. As expected from the measured activity concentrations, the dose rates at the soil were higher than those at the beach sand and the elevated values were found in the north-east part of Lesvos (S12-S20). Furthermore, the high dose rates observed in this work were higher than the mean value for Greece (56 nGy h^{-1}) and reported ranges (30-109 nGy h^{-1}) [6]. The preliminary produced absorbed dose rate map is also presented in Fig. 4. The map was produced based on the data of this work, as well as others [7]. Different colouring (from green to red) was selected to show low and high absorbed dose rates. The map reveals that the northern part of Lesvos, above Kalloni Gulf, is characterized by elevated concentrations and thus dose rates. This observation is related to the volcanic origin of the island, as such high concentrations were also obtained for other volcanic islands of Greece (e.g. Milos) [8,9]. The results of this work are in accordance with those obtained previously [10] but this work was more accurate due to the use of a HPGe detector instead of NaI detector.

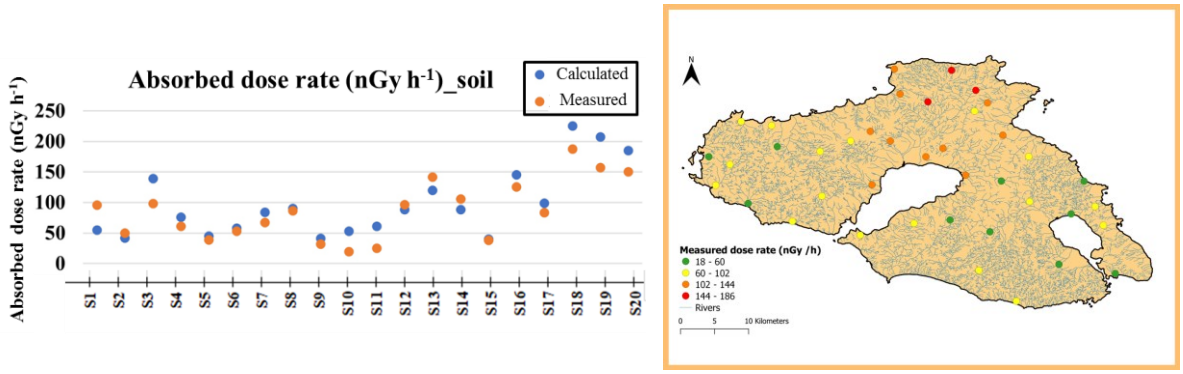


Figure 4. *The measured and calculated absorbed dose rates (in-situ and lab measurements, respectively) for soil samples, on the left. The preliminary produced absorbed dose rate map at Lesvos island, on the right.*

CONCLUSIONS

In this work, the volcanic radiological background of Lesvos Island was observed by the measured and calculated absorbed dose rates. Namely, the elevated natural radioactivity concentrations and dose rates were similar with other Greek volcanic areas and well above the Greek mean value [6]. Moreover, both methodologies were in good agreement and natural radioactivity concentrations were well above the artificial (^{137}Cs), thus the proposed methodology by [6] to calculate absorbed dose rates from activity concentrations proved to be a good approximation. Larger concentrations were found for the soil compared to the sand samples. A preliminary absorbed dose rate map was achieved in this work, nevertheless a more detailed geostatistical map in relevance with geology will be produced for the future. Finally, the application of this methodology to other areas (e.g. neighboring islands) not characterized by high natural radioactivity values is another future option.

Acknowledgments

The authors acknowledge support of this work by the project “Center of Sustainable and Circular Bioeconomy [Aegean_BIOECONOMY]” (MIS 5045851) which is implemented under the Action “Reinforcement of the Research and Innovation Infrastructure”, funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

Moreover, the authors acknowledge support of this work by the project "Equipment for the Water and Air Quality Laboratory, University of the Aegean and their application to the hot springs of Lesvos, upgrading the services and the radiological protection of personnel and visitors" (MIS 5021528) which is implemented under the Action "Research, Technological Development and Innovation", funded by the Regional Operational Programme "North Aegean" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

References

[1] P. Bossew et al., J. Environ. Radioact. 166, 296 (2017)
[2] T. Szegvary et al., Radiat. Meas. 42, 1561 (2007)
[3] G. Cinelli et al., Radiat. Eff. Defects Solids. 175, 54 (2020)
[4] L. Pásztor et al., Sci. Total Environ. 544, 883 (2016)
[5] U. Barnekow et al., IAEA TRS 486 (2019)
[6] UNSCEAR, Report, Vol. 1: Sources of ionizing radiation (2000)
[7] Kremenioti, Bachelor thesis, University of the Aegean, Department of Environment (2020)
[8] H. Florou et al., J. Environ. Radioact. 93, 74 (2007)
[9] H. Florou and P. Kritidis, Radiat. Prot. Dosimetry 45, 277 (1992)
[10] A.B. Petalas, Radiat. Prot. Dosimetry 113, 336 (2005)