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ANALYSIS OF ACTIVITY CONCENTRATION OF NATURAL RADIONUCLIDES IN THE SOIL OF THE INSTITUTE OF APPLIED NUCLEAR PHYSICS IN ALBANIA AND THE ASSESSMENT OF ANNUAL EFFECTIVE DOSE

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Abstract. *Terrestrial gamma radiation levels are significantly affected by the radionuclides that are present in the soil, which in turn can be used for the assessment of the terrestrial gamma dose rate. This study is important because the employees of this institute, in addition to professional exposure, will be familiar with the average annual effective dose equivalents (AEDEs) in soils that come from this area. The main radioactive materials are the long-lived radionuclides, such as ^{238}U, ^{232}Th and ^{40}K, known as NORMs (Naturally Occurring Radionuclide Materials). Natural radioactivity analysis has been done for the soil samples collected from the area of the Institute of Applied Nuclear Physics (IANP) in Tirana, Albania. The activity concentration of Radium (^{226}Ra), Thorium (^{232}Th) and Potassium (^{40}K) were measured in these samples using HPGe (High Purity Germanium) detector based on low background gamma-ray counting system. From the measured activity concentration of the above three natural radionuclides, the external gamma absorbed dose rate and the annual effective dose were calculated. The obtained mean values of gamma absorbed dose rate and annual effective dose in soil samples were found to be comparable with the worldwide average as reported by United Nations Scientific Committee on the Effects of Atomic Radiation. The natural radioactivity levels in soils of IANP area had never been studied before. This study aims to determine the dose rate in order to assess the health risks from the activity concentration of the natural radionuclides as ^{238}U, ^{232}Th and ^{40}K in the soil. Also, the Radium equivalent (Ra_{eq}) of the samples is calculated and compared with the similar data reported in literature. The values of the outdoor annual effective dose were in the range of 0.02 to 0.11 mSv, showing that the area of IANP was radiologically safe.*

Key words: *Natural radioactivity, HPGe detector, activity concentration, annual effective dose*

1. INTRODUCTION

Human beings have always been exposed to natural radiations arising from within and outside the earth. The main radioactive materials are long-lived radionuclides such as ^{238}U, ^{232}Th, and ^{40}K, known as NORMs (Naturally Occurring Radionuclide Materials). Gamma radiation emitted from primordial radionuclides and their progeny is one of the main external sources of radiation exposure to humans [1].

Terrestrial radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological formation and the soil type of the location; and these factors (geology and soil type) greatly influence the dose distribution from natural terrestrial radiation [2]. Total radiation dose to the world population has shown that approximately 86 percentage of the radiation to which humans are exposed is from natural radioactivity and the remaining 14 percentage is from anthropogenic radioactivity according to the UNSCEAR report (UNSCEAR, 2000) [3].

Since natural radiation is the largest contributor of external dose to the world population, the assessment of gamma radiation dose from natural sources is of particular importance [4]. Therefore, measurements of natural radioactivity in soil are of a great interest to many researchers throughout the world, which promoted worldwide national surveys in the last two decades.

We are working in collection of soil samples in different cities in Albania including here the city of Tirana and the area of IANP in order to produce a radiation map and to evaluate the public exposure.

To evaluate the terrestrial gamma-dose rate for outdoor occupations, it is very important to estimate the natural radioactivity level in soils. The natural radioactivity levels in soils of Institute of Applied Nuclear Physics (IANP) area in Tirana, Albania had never been studied before.

This study aims to determine the activity concentration of natural radionuclides such as ^{238}U, ^{232}Th and ^{40}K in the soil samples of IANP area, as well as the dose rate in order to assess the health risks. Also,

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the data obtained from the measured samples are compared with similar data reported in literature.

2. Materials and methods

2.1. Sampling and sample preparation

At the Institute of Applied Nuclear Physics (IANP) area, which is located in the Tirana city (Fig.1), ten soil samples were collected from different points. In this study the samples were taken from the upper 10 cm layer of soil and were packed in labelled polythene bags. The locations of the samples were recorded with a global positioning system. In the laboratory, the samples were first dried at 105 °C overnight for 24 h, cleared of stones and pebbles, crushed and ground to a fine powder, homogenized, weighted and packed in standard 500 mL Marinelli beakers. The Marinelli beakers are sealed (for at least 4 weeks) with PVC tape and carefully labelled to allow the radon gas in the soil to reach equilibrium.

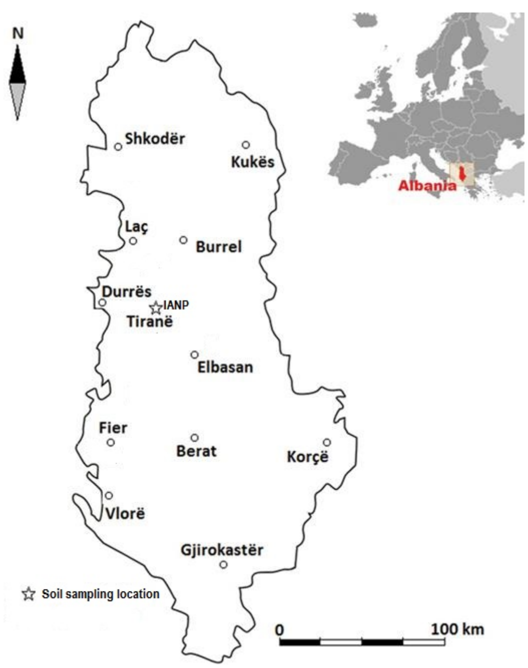

Figure 1. Simple map of Albania cities and the IANP soil sampling location

2.2. High-resolution gamma-ray spectrometry measurements

The radioactivities of the prepared samples were measured using a high-resolution gamma-ray spectrometry system with a coaxial high purity germanium detector with a relative efficiency of 40 %, and a resolution of 1.8 keV for the 1332 keV gamma ray emission of ^{60}Co. The HPGe γ –ray detector (GC4018-7500 SL) is a Broad Energy Ge (BEGe) detector equipped with a composite carbon window and coupled with a digital spectrum analyzer, DSA-1000. The detector was well-shielded to minimize the γ -ray background to be able to measure low radioactivity. For the analysis of spectra, Genie 2000 (VI.3.2.1) software from Canberra was used. Counting time interval was 86400 seconds for each sample. Energy was calibrated using different point sources, whereas efficiency was calibrated using a 500 mL multi-nuclide standard solution of: ^{241}Am, ^{109}Cd, ^{139}Ce, ^{57}Co, ^{60}Co, ^{137}Cs, ^{113}Sn, ^{85}Sr, ^{88}Y, ^{203}Hg, ^{54}Mn, ^{65}Zn and interpolated in the energy range of 60 keV to 2000 keV.

The combined uncertainty in the intrinsic detector efficiency calibration combining Type A and B uncertainties was found to be less than 10 %. The uncertainty in the full energy peak count rate which is determined by Type A evaluation will influence the precision of the fit, whereas uncertainties estimated using Type B evaluations will not.

The uncertainties in calibration source activity, gamma-energy intensities, linear attenuation coefficients and source-to-detector distance are all obtained using Type B evaluations.

The activity of ^{226}Ra was determined based on gamma ray emissions of ^{214}Pb (295.21 and 352 keV) and ^{214}Bi (609 and 1120.29 keV), ^{232}Th was determined based on the emissions of ^{228}Ac (911.07 and 968.9 keV) and that of ^{40}K was determined from the emission at 1461.8 keV. The Minimum Detectable Activity (MDA) of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K, calculated according to Currie formula [5], was 0.6 Bq kg^{-1}, 0.4 Bq kg^{-1} and 13 Bq kg^{-1}.

3. Results and discussion

3.1. Activity concentrations

The activity concentrations of ^{226}Ra ^{232}Th and ^{40}K are reported in Table 1. The average activity concentrations of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K, were respectively 26.2 ± 1.1 Bq kg^{-1}, 25.2 ± 1.5 Bq kg^{-1} and 408.2 ± 5.1 Bq kg^{-1} in the soil samples. The activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in the soil were found to be lower or comparable within 1σ to the typical average activity concentrations in world, which are respectively 420 Bq kg^{-1}, 33 Bq kg^{-1} and 45 Bq kg^{-1}. In Table 2 and Figure 1, what is shown is the level of natural radioactivity in IANP soil compared with those in other countries as given in UNSCEAR (2000). There is a normal distribution of activity concentration in representative samples. No regular trend in the variation of radioactivity has been observed.

Table 1. Activity concentrations of ^{40}K, ^{238}U (^{226}Ra) and ^{232}Th in the soil sample

ID	^{40}K (Bq/kg)	σ ^{40}K (Bq/kg)	^{238}U (Bq/Kg)	σ ^{238}U (Bq/kg)	^{232}Th (Bq/Kg)	σ ^{232}Th (Bq/kg)
IANP 1	332.6	16.6	22.4	1.6	27.8	2.2
IANP 2	504.9	25.2	28.3	1.7	36.2	2.9
IANP 3	473.6	0.2	33.7	1.5	31.1	1.6
IANP 4	466.2	0.2	27.5	0.6	30.1	1.6
IANP 5	410.7	0.2	22.3	0.7	17.8	1.0
IANP 6	518.0	0.3	56.6	1.6	72.8	3.1
IANP 7	140.6	7.3	9.0	0.4	6.5	0.8
IANP 8	407.0	0.2	31.0	0.7	25.8	1.8
IANP 9	414.4	0.2	28.8	1.4	1.7	0.1
IANP 10	414.4	0.2	2.24	1.1	1.9	0.1
Average	**408.2**	**5.1**	**26.2**	**1.1**	**25.2**	**1.5**

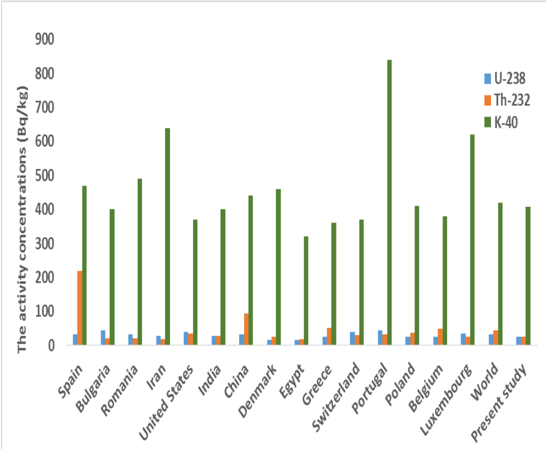

Figure 2. Comparison of natural radioactivity levels in IANP soil with those in others countries

3.2. Outdoor absorbed gamma dose rate and corresponding annual effective dose

Table 2. Comparison of natural radioactivity levels in IANP soil with those in others countries as given in UNSCEAR (2000)

Country	Concentration in soil (Bq/kg)					
	^{238}U		^{232}Th		^{40}K	
	Mean	Range	Mean	Range	Mean	Range
Spain	32	6-250	221	35-125	470	25-1650
Bulgaria	45	12-210	21	4-77	400	40-800
Romania	32	8-60	21	1-190	490	250-1100
Iran	28	8-55	19	8-30	640	250-980
United States	40	8-160	35	4-130	370	100-700
India	29	7-81	28	22-88	400	38-760
China	32	2-440	95	16-200	440	9-1800
Denmark	17	9-29	27	5-50	460	240-610
Egypt	17	5-64	18	2-96	320	29-650
Greece	25	1-240	51	22-100	360	12-1570
Switzerland	40	10-900	30	7-160	370	40-1000
Portugal	44	8-65	33	2-210	840	220-1230
Poland	26	5-120	38	11-75	410	110-970
Belgium	26	5-50	50	7-70	380	70-900
Luxembourg	35	6-52	25	4-70	620	80-1800
World	33	-	45	-	420	-
Present study	**26**	**2-57**	**25**	**2-73**	**408**	**141-518**

The external gamma dose rate in outdoor air can be evaluated from the activity concentrations of the ^{238}U, ^{232}Th and ^{40}K measured in soil samples. For natural gamma sources uniformly distributed in the ground, the outdoor absorbed gamma dose rate in air at a height of 1 m above the ground surface can be calculated by using the following formula [6]:

$$D_{ROUT}(nGy/h)=0.462 \cdot A_{Ra}+0.604 \cdot A_{Th}+0.0417 \cdot A_K \quad (1)$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, respectively.

The annual effective dose equivalent, AEDE (mSv/y) rate is calculated considering the conversion coefficient from the absorbed dose in air to an effective dose. The annual, estimated, average, effective dose equivalent received by a member is calculated using a conversion factor of 0.7 Sv Gy^{-1}, which is used to convert the absorbed rate to the human effective dose equivalent with an outdoor occupancy of 20% [3].

$$AEDE_{Outdoor}\ (nSv) = (absorbed\ dose)nGy^{-1} \cdot 8760\ h \cdot 0.2 \cdot 0.7\ Sv\ Gy^{-1} \quad (2)$$

Considering the worst case with an outdoor occupancy factor of 5h/d for people working in the IANP area, the corresponding average annual effective dose equivalent (AEDEs) value is 0.06 mSv/year.

Table 3. Characterization of radiological hazard

ID_IANP	Absorbed dose rate in air D (nGy/h)	AEDE Outdoor (mSv)
IANP_1	41.01	0.05
IANP _2	55.99	0.07
IANP _3	54.10	0.07
IANP _4	50.33	0.06
IANP_5	38.18	0.05
IANP _6	91.72	0.11
IANP _7	13.97	0.02
IANP _8	46.88	0.06
IANP _9	31.61	0.04
IANP_10	19.48	0.02
Average	**44.3**	**0.06**

4. Conclusion

The radioactivity content of ^{40}K, ^{226}Ra and ^{232}Th were measured in soil samples. The average activity concentrations of ^{238}U (^{226}Ra) , ^{232}Th and ^{40}K, were respectively 26.2 ± 1.1 Bq kg-1, 25.2 ± 1.5 Bq kg-1 and 408.2 ± 5.1 Bq kg-1 in the soil samples.

These activity concentrations were found to be lower or comparable with the reported results from other studies in the world. In the present study, the activity concentration of natural radionuclides, such as ^{238}U, ^{232}Th and ^{40}K, in soil samples of IANP area is determined, as well as the dose rate in order to assess the health risks. The samples are calculated and compared with similar data reported in literature.

The values of outdoor annual effective doses, which ranged from 0.02 to 0.11 mSv, with the average of 0.06 mSv, have shown that the Institute of Applied Nuclear Physics (IANP) area was radiologically safe.

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