A STUDY OF DISTRIBUTION OF NATURAL RADIONUCLIDES IN SOILS AND ASSESSMENT OF EXPOSURE HAZARDS FROM TERRESTRIAL γ-RADIATION IN THE REGION OF TSALKA (GEORGIA)

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Keywords: Natural radionuclides, absorbed dose rate, annual effective dose, radium equivalent activity, Tsalka region (Georgia).

Gamma-spectroscopy method has been used to determine the activity concentrations (in Bq kg^{-1}) of natural radionuclides such as ^{238}U, ^{232}Th, and ^{40}K in soil samples collected from Tsalka region of south Georgia. Based on which contents of radionuclides in soil (in g kg^{-1} and ppm) were calculated. In addition, concentrations of artificial radionuclide of ^{137}Cs were determined, which has shown contamination character of study area. Based on the results of the analysis, some crucial physical values have been calculated, which are necessary for assessment of radiation exposure hazards for the population. Relevant conclusions have been drawn by comparing the results with previous work and recommendations of the international organizations.

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Introduction

It is known that natural radioactive substances in the soil are constant sources of radiation (terrestrial radiation). According to periodic reports published by The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the average radiation from natural sources equals to 2.4 mSv y^{-1}, whereas the share of radiation from artificial sources is 0.8 mSv y^{-1}.[1,2] Thus, 75 % of total radiation affecting human health is due to natural radiation sources. Consequently, the great importance of studying the existing natural radiation of radioactive sources and assessment of radiation hazards is quite apparent. The major part of the soil radiation comes from the upper layer of the soil,[2,3] in which the sources of radioactivity are ^{238}U, ^{232}Th, their decay products, and radionuclide ^{40}K. Radiological impact of natural radionuclides on humans is mainly expressed by gamma radiation affecting the body, as well as by Radon and the processes caused by inhalation of its decay products.[3]

Aim of this research is to study spatial distribution of natural nuclides in the soils, based on the local geological characteristics of area under research, as well as determination of the contamination characteristics of the area due to artificial radionuclide ^{137}Cs.

Main tasks of the research are to determine concentrations of radionuclides in the soils, to calculate some crucial parameters assessing radiation exposure hazards for the population, namely absorbed dose rate in air, annual effective dose, radium equivalent activity and external hazard index and to compare obtained results with the relevant international monitoring data.

Experimental

Area under research

Natural radioactivity of the soil and ionizing gamma radiation coming from soil depends on the concentration of natural radionuclides it contains, while the latter depends on soil forming parent rock and other forming factors.[1,2,4,] In general, relatively increased radioactivity is associated with igneous rocks and the decreased one with sedimentary rocks. However, there are some exceptions, for instance, some shales and phosphates show relatively high content of radionuclides. Igneous rocks, namely, sialic rocks (especially granitoids) contain a relatively higher concentration of natural radionuclides than ultramafic and mafic rocks.[1,2]

In Georgia, granitoids are occurred in axial region of Caucasus Main Ridge, as well as in the crystal massifs of Dzirula, Khrami, and Loki. Presently, Khrami massif (Tsalka region) as a study area was selected for our research. During the selection, some other important factors, apart from the spread of granitoids, were considered, such as the existence of populated localities, agricultural and mining (of natural industrial materials) activities, etc.

The territory selected for this research covers approximately 20 km^2 of Tsalka municipality in Lower Kartli region (Figure 1). According to existing geological data[5] the most widely spread rocks here are late variscan granitoids building Khrami crystal massif, granodiorites, gneisses, adjacent and partly overlapping continental basaltic lava of neogene-quaternary of calc-alkaline series, continental and shallow marine volcanoclastic rocks, and other (Figure 2). As for soils, the most widely spread ones on the territory under research is black soil.[6]

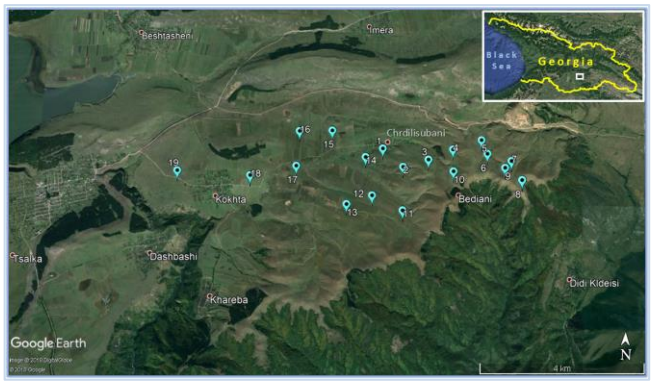

Figure 1. Area under study and sampling sites.

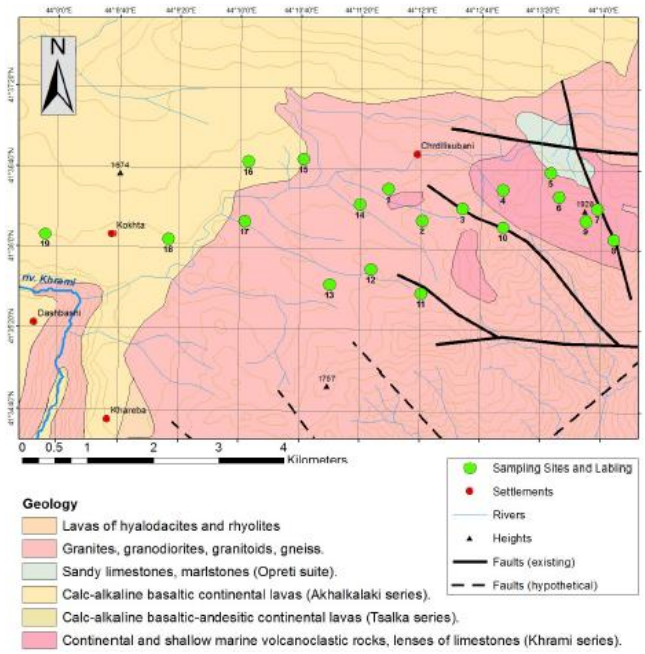

Figure 2. Sampling sites on the geological map.

Sampling and processing

The sampling scheme was selected according to spread of rocks, allowing the determination of the correlations between research parameters and geological and geographical features of the area.

In total, 19 samples were collected from the territory. All samples were taken in the distance from populated localities and buildings or other infrastructural constructions, in order to exclude the occurrence of ecdemic soil or any other materials in the samples to the greatest possible extent.

To get a generalized picture of radionuclide distribution and formation of background radiation by means of existing sampling methodology on the research territory, the so called "envelope" method (Figure 3) was selected,[7] according to which, five samples (30-40 m away from each other) in each sampling site were taken and averaged by means of mixing (i.e. in total 95 samples were taken).

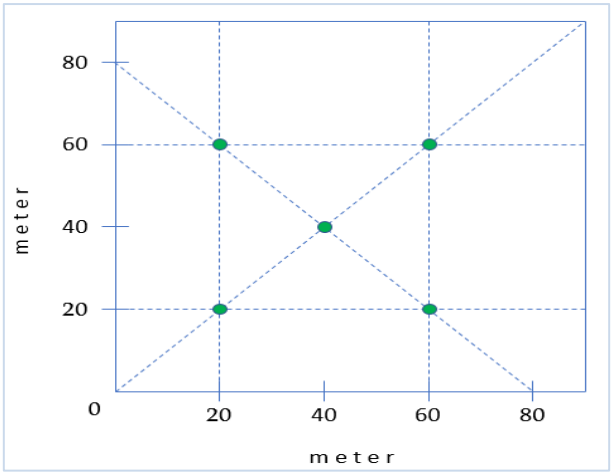

Figure 3. "Envelope" sampling method.

The distance between sampling sites was 600-800 m on an average. Sampling took place at the depth of 15-20 cm under the surface of the soil. The primary processing of samples took place on site (removing stones and roots from the soil samples) and 200-250 g of soil fractions were collected. Table 1 show geographical coordinates recorded on the central point of sampling site and shows agricultural purpose of the soils and parent material of the soil.

For laboratory measurements the samples were further prepared with well established methods.[2-4,8] At first, obtained samples were air dried at room temperature. After this, samples were sifted, first in a sift with 1.5 mm cells and then with 1mm cells and finally, samples were placed in hermetically sealed double polyethylene containers and stored for two months to attain radioactive equilibrium in decay series.

Laboratory research

A well-established gamma-spectroscopy method was used to determine activity concentration of natural radionuclide in soil samples, measurements were made with the use of semiconductor (detector), based on high-purity germanium (HPGe) crystal (manufacturer CANBERRA) and software packages Genie-2000 and ISOCS/LABOCS at Laboratory of Radiological Studies of the Applied Research Centre at the E. Andronikashvili Institute of Physics of the I. Javakhishvili Tbilisi State University.

To measure the activity concentrations of radionuclide i in Bq kg^{-1}, for the peak energy E, eqn. (1) was used,[2-4]

$$A_{\mathrm{Ei}} = \frac{C_{Ei}}{C_{\mathrm{eff}} \gamma m t} \qquad (1)$$

where C_{Ei} is the total count of a peak at energy E, C_{eff} is the detection efficiency at energy E, γ is the percentage of gamma emission probability of the radionuclide i for a transition at energy E, m is the mass in kg of the measured sample, and t is the counting time.

Table 1. Characteristics of sampling sites.

Site	Coordinates	Altitude (m)	Agricultural purpose	Geology
1	41°36.503'N 44°11.643'E	1637	Pasture	Granite
2	41°36.244'N 44°12.014'E	1681	Pasture	Granite
3	41°36.344'N 44°12.465'E	1799	Pasture	Granite
4	41°36.500'N 44°12.914'E	1779	Pasture	Granite
5	41°36.645'N 44°13.437'E	1771	Pasture	Volcanoclastic
6	41°36.447'N44°13.531'E	1839	Pasture	Volcanoclastic
7	41°36.350'N 44°13.953'E	1870	Pasture	Volcanoclastic
8	41°36.090'N 44°14.136'E	1873	Pasture	Granite
9	41°36.248'N44°13.828'E	1912	Pasture	Volcanoclastic
10	41°36.187'N 44°12.914'E	1813	Pasture	Granite
11	41°35.636'N 44°12.011'E	1687	Treated	Granite
12	41°35.833'N 44°11.458'E	1655	Treated	Granite
13	41°35.703'N 44°11.000'E	1624	Treated	Granite
14	41°36.375'N 44°11.329'E	1614	Old treated	Granite
15	41°36.746'N 44°10.701'E	1594	Old treated	Basalt/Granite
16	41°36.724'N 44°10.091'E	1597	Old treated	Basalt
17	41°36.225'N 44°10.056'E	1579	Old treated	Granite
18	41°36.070'N 44°09.216'E	1568	Old treated	Basalt
19	41°36.106'N 44°07.870'E	1573	Pasture	Basalt

Results

Concentrations of radionuclides

As a result of gamma spectrometry analysis for 19 samples activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in Bq kg^{-1} was determined and their contents in g kg^{-1} and in ppm were calculated. The results are provided in Table 2, where apart from natural sources it shows the concentration of ^{137}Cs, which is one of the most important radioactive artificial soil pollutants.

As it can be seen from Table 2, in our case the mean values of activity concentrations are 38.57, 53.18, and 879.76 Bq kg^{-1}, for ^{238}U, ^{232}Th, and ^{40}K, respectively, which exceeds the world mean values (also provided in Table 2) for ^{238}U by 3.57, for ^{232}Th by 18.18, and for ^{40}K by 479.76 Bq kg^{-1}.[1,3]

As for ^{137}Cs, as it can be seen from Table 2, activity concentration of ^{137}Cs fluctuates between 3.75 and 33.00 Bq kg^{-1} with the mean value of 10.53 Bq kg^{-1}.

If the activity concentrations of radionuclides in soil are known assuming that radionuclides are uniformly distributed in the soil, then exposure dose rate in air causing these radionuclides can be found.[1-3] The absorbed dose rate in air is calculated by eqn. (2),[1]

$$D = 0.4620A_U + 0.6040\,A_{Th} + 0.0417\,A_K \quad (2)$$

where D denotes the dose rate in the air at 1 m above the ground surface.

A_U, A_{Th}, and A_K are the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K, respectively, in the soil sample. 0.4620, 0.6040, and 0.0417 are dose conversion factors for ^{238}U, ^{232}Th, and ^{40}K, respectively.

The results calculated for absorbed dose rate in the air are presented in Table 3. The mean value of our results is equal to 86.63 nGy h^{-1}. That considerably exceeds the world mean value. which is 57 nGy h^{-1}.[2,8]

Annual effective dose rate (*E*)

When calculating the annual effective dose rate exposure to population, the following factors should be taken into account,[1-3] (a) coefficient of transferring from absorbed dose to effective dose (0.7 Sv Gy^{-1}) and (b) so called "occupation factor", i.e. how long a human stays outdoor and indoor.

These factors are reported[1] to be 0.2 and 0.8 (a person spends 20 % of time outdoors and 80 % indoors). A summarized effective dose rate is calculated by means of the Eqn. (3),[2,4]

$$E = TQD \times 10^{-6} \quad (3)$$

where D is the absorbed dose rate in the air, Q is the conversion factor of 0.7 Sv Gy^{-1}, which converts the absorbed dose rate in the air to human effective dose received, and T is the time during a year, i.e. 8760 h. According to the results given in Table 3, in our case, the mean annual effective dose rate is 0.55 mSv Gy^{-1}, which is a little higher than world mean value[1,3] i.e., 0.48 mSv Gy^{-1}.

Table 2. Concentrations of radionuclides in soil samples.

Site #	Bq kg^{-1}				g kg^{-1}				ppm			
	^{238}U	^{232}Th	^{40}K	^{137}Cs	^{238}U	^{232}Th	^{40}K	^{137}Cs	^{238}U	^{232}Th	^{40}K	^{137}Cs
1	42.50	44.40	690.60	10.60	0.00345	0.01100	0.00267	3.30 x 10^{-12}	3.45	11.0	2.67	3.30 x 10^{-9}
2	39.40	53.80	745.80	9.60	0.00320	0.01330	0.00289	3.00 x 10^{-12}	3.20	13.3	2.89	3.00 x 10^{-9}
3	38.70	50.70	936.00	4.50	0.00314	0.01250	0.00362	1.40 x 10^{-12}	3.14	12.5	3.62	1.40 x 10^{-9}
4	38.30	51.40	933.00	11.50	0.00311	0.01266	0.00361	3.59 x 10^{-12}	3.11	12.66	3.61	3.59 x 10^{-9}
5	39.60	50.00	867.30	5.50	0.00321	0.01232	0.00336	1.72 x 10^{-12}	3.21	12.32	3.36	1.72 x 10^{-9}
6	40.67	50.50	933.00	3.75	0.00330	0.01240	0.00361	1.17 x 10^{-12}	3.30	12.4	3.61	1.17 x 10^{-9}
7	43.44	56.50	1008.00	12.26	0.00352	0.01392	0.00390	3.83 x 10^{-12}	3.52	13.92	3.90	3.83 x 10^{-9}
8	40.45	54.40	944.00	11.30	0.00328	0.01340	0.00365	3.53 x 10^{-12}	3.28	13.40	3.65	3.53 x 10^{-9}
9	38.00	60.20	1004.80	33.00	0.00308	0.01483	0.00389	1.00 x 10^{-11}	3.08	14.83	3.89	1.00 x 10^{-8}
10	33.00	48.90	956.00	8.50	0.00268	0.01205	0.00370	2.70 x 10^{-12}	2.68	12.05	3.70	2.70 x 10^{-9}
11	41.20	59.90	768.50	10.00	0.00334	0.01475	0.00297	3.20 x 10^{-12}	3.34	14.75	2.97	3.20 x 10^{-9}
12	35.70	52.00	784.20	10.20	0.00290	0.01280	0.00303	3.20 x 10^{-12}	2.90	12.80	3.03	3.20 x 10^{-9}
13	29.30	50.70	778.60	13.00	0.00238	0.01250	0.00301	4.10 x 10^{-12}	2.38	12.50	3.01	4.10 x 10^{-9}
14	36.00	54.50	957.50	10.00	0.00292	0.01340	0.00371	3.20 x 10^{-12}	2.92	13.40	3.71	3.20 x 10^{-9}
15	48.80	63.20	954.50	8.50	0.00396	0.01560	0.00369	2.70 x 10^{-12}	3.96	15.60	3.69	2.70 x 10^{-9}
16	44.30	53.90	837.50	10.70	0.00360	0.01330	0.00324	3.40 x 10^{-12}	3.60	13.30	3.24	3.40 x 10^{-9}
17	42.80	64.90	975.00	8.30	0.00343	0.01600	0.00377	2.60 x 10^{-12}	3.43	16.0	3.77	2.60 x 10^{-9}
18	34.90	51.00	918.40	13.30	0.00283	0.01260	0.00355	4.20 x 10^{-12}	2.83	12.60	3.55	4.20 x 10^{-9}
19	25.80	39.60	722.80	7.90	0.00210	0.00980	0.00280	2.50 x 10^{-12}	2.10	9.80	2.80	2.50 x 10^{-9}
Min.	25.80	39.60	690.60	3.75	0.00210	0.0098	0.00267	1.17 x 10^{-12}	2.10	9.8	2.67	1.17 x 10^{-9}
Max.	48.80	64.90	1008.00	33.00	0.00396	0.01600	0.00390	1.00 x 10^{-11}	3.96	16	3.9	1.00 x 10^{-8}
Mean	38.57	53.18	879.76	10.65	0.00313	0.01310	0.00340	3.33 x 10^{-12}	3.12	13.11	3.40	3.33 x 10^{-9}
World's Average[1]	35	30	400	–	0.00284	0.00739	0.00155	–	2.83	7.39	1.54	–

Radium equivalent activity (Ra$_{eq}$)

Radium equivalent activity is calculated by considering the hazards that are connected with the use of building and other types of industrial materials containing ^{238}U, ^{232}Th, and ^{40}K. Assuming that 10 Bq kg^{-1} of ^{238}U, 7 Bq kg^{-1} of ^{232}Th, and 130 Bq kg^{-1} of ^{40}K generate approximately the equal amount of gamma-radiation, the total activity concentration of ^{238}U, ^{232}Th, and ^{40}K is to be calculated. For calculations we use eqn. (4),[3]

$$Ra_{eq} = A_U + 1\,.\,430\,A_{Th} + 0.077\,A_K \qquad (4)$$

where A_U, A_{Th}, and A_K denote activity concentrations for ^{238}U, ^{232}Th, and ^{40}K, respectively. To avoid the expected risks of exposure, the material which contains more than 370 Bq kg^{-1} radium-equivalent activity should not be used for industrial purposes.[2,4] From Table 3, it can be observed that the mean value of radium-equivalent activity according to our results equals to 182.37 Bq kg^{-1}, which is considerably less than above mentioned recommended maximum value.

External hazard index (H_{ex})

One of the characteristics of irradiation risk for the population is considered the so called external hazard index, which is calculated by eqn. (5),[3]

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \qquad (5)$$

where A_U, A_{Th}, and A_K are activity concentrations of ^{238}U, ^{232}Th, and ^{40}K, respectively. To avoid the expected risks the external hazard index should be less than 1, which corresponds to maximally admissible radium-equivalent activity 370 Bq kg^{-1}.[3,8] In our case the mean value of external hazard index is 0.49 (Table 3), which is less than the recommended limit.

Correlations

Table 4 shows correlations of radionuclide concentrations (in ppm) ^{232}Th/^{238}U, ^{232}Th/^{40}K and ^{238}U/^{40}K, while the Figures 4-6 present them graphically.

Table 3. Absorbed dose rate, annual effective dose rate, radium equivalent activity, and external hazard index.

Site #	Absorbed γ-dose rate in air (nGy h^{-1})	Annual effective dose rate (mSv y^{-1})	Radium equivalent activity (Bq kg^{-1})	External hazard index
1	77.24	0.47	159.17	0.43
2	84.51	0.52	173.76	0.47
3	90.34	0.55	183.27	0.49
4	90.50	0.55	183.64	0.50
5	87.30	0.54	177.88	0.48
6	90.92	0.56	184.73	0.5
7	99.30	0.61	201.85	0.55
8	93.88	0.58	190.93	0.52
9	99.28	0.61	201.46	0.54
10	87.57	0.54	176.54	0.48
11	90.29	0.55	186.03	0.5
12	83.39	0.51	170.44	0.46
13	79.55	0.49	161.75	0.44
14	92.62	0.57	187.66	0.51
15	103.72	0.64	212.67	0.57
16	90.61	0.56	185.86	0.50
17	103.16	0.63	210.68	0.57
18	88.16	0.54	178.55	0.48
19	68.31	0.42	138.08	0.37
Min.	68.31	0.42	138.08	0.37
Max.	103.72	0.64	212.67	0.57
Mean	89.51	0.55	182.37	0.49

Table 4. Correlations between natural radionuclides (ppm ratio).

Site #	$^{232}Th/^{238}U$	$^{232}Th/^{40}K$	$^{238}U/^{40}K$
1	3.19	4.12	1.29
2	4.16	4.60	1.11
3	3.98	3.45	0.87
4	4.07	3.51	0.86
5	3.84	3.67	0.96
6	3.76	3.43	0.91
7	3.95	3.57	0.90
8	4.09	3.67	0.90
9	4.89	3.81	0.79
10	4.50	3.26	0.72
11	4.42	4.97	1.12
12	4.41	4.22	0.96
13	5.25	4.15	0.79
14	4.59	3.61	0.79
15	3.94	4.23	1.07
16	3.69	4.1	1.11
17	4.67	4.24	0.91
18	4.45	3.55	0.80
19	4.67	3.50	0.75
Min.	3.19	3.26	0.72
Max.	5.25	4.97	1.29
Mean	4.23	3.88	0.93

Figure 7 shows the correlation of annual effective dose rates with parent rocks according to sampling sites. In the results presented it can be observed increased concentrations. For instance, an increased concentration of ^{238}U isotope is at point 15, which is one of the main water catchment areas.

Figure 8 shows the correlation of ^{238}U, ^{232}Th, and ^{40}K natural radionuclide concentrations with absorbed dose rates in the air according to sampling sites.

With the aim of taking into consideration geochemical factor during the process of soil formation, Digital Elevation Model (DEM) of the relief in a geo-informational system ArcGIS–10.4.1 has been developed, water flow has been modelled and a combined scheme of natural radionuclide distribution in the soil and geological structure have been created (Figure 9).

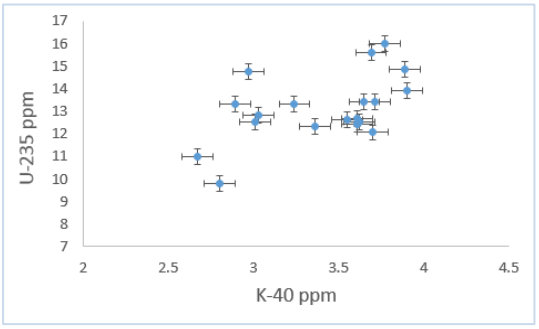

Figure 4. Correlation $^{238}U/^{40}K$.

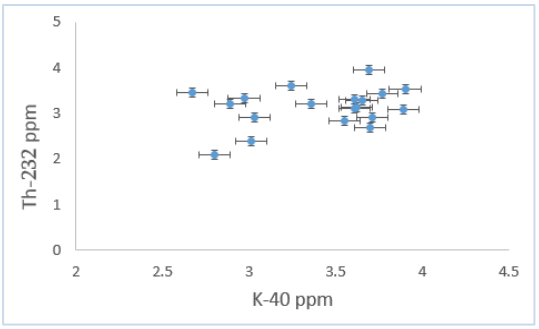

Figure 5. Correlation $^{232}Th/^{40}K$.

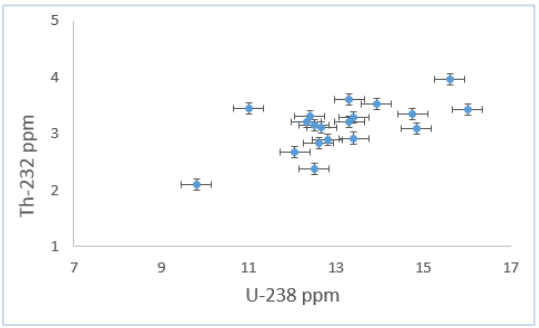

Figure 6. Correlation $^{232}Th/^{238}U$.

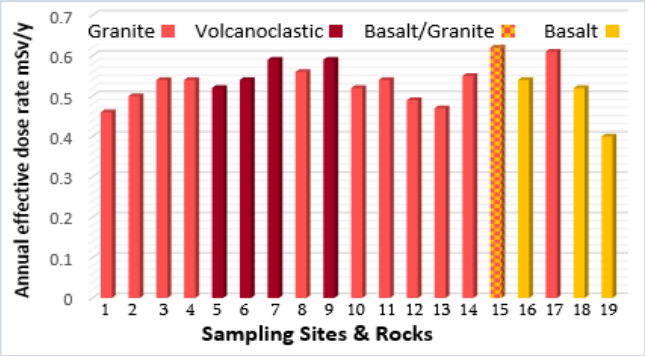

Figure 7. Correlation between annual effective dose and geology of area.

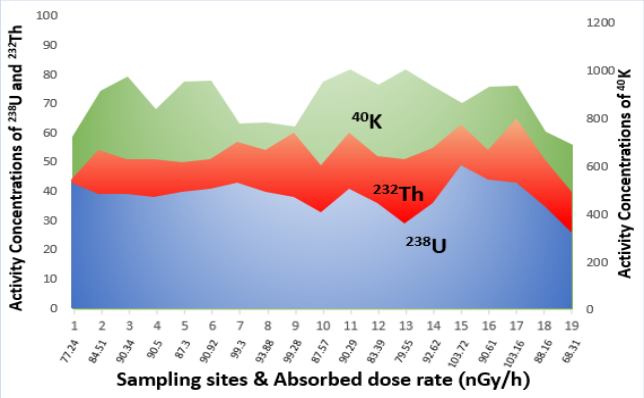

Figure 8. Correlation between activity concentrations and absorbed dose rate.

Discussions

As it can be seen from the Figure 9, the increased concentrations of natural radionuclides are in a certain correlation with the direction of water flows. Increased concentrations can be observed at their gathering points. Besides, as the combined scheme shows, the distributions of natural radionuclides are obviously related to the type of parent rock. Namely, the soils emerged at the expense of late variscan granitoids of Khrami massif, reveal higher natural radioactivity compared to neogene-quaternary lavas.

Mean value of absorbed dose rate in the air calculated according to natural radionuclide concentrations in the soil, in our case equals to 89.51 nGy h^{-1}. The obtained result is considerably higher (by 32.5 nGy h^{-1}) than the world mean value (Figure 10), which is 57 nGy h^{-1}.[1,2] But as it was mentioned above, our research covers Khrami massif, and where due to the spread of granitoids natural radioactive factors must have been increased.

Mean value of annual effective dose rate of 0.55 mSv h^{-1} is slightly higher than the world mean value (Figure 11), which is 0.48 mSv h^{-1}.[1,3] But the obtained value is less than the recommended limit established by ICRP, which is 1 mSv h^{-1}.[2,3] However, as it is known during the formation of the total radiation hazard, to gamma radiation portion generated by natural radionuclides is added some other significant components such as the portion caused by the spread of artificial pollutants, cosmic radiation, radon inhalation, spread of natural and artificial pollutants and their concentration in drinking water and food, as well as professional activities, radiation impact in medical sphere etc.[1]

Mean value for radium-equivalent activity according to our results is 182.37 370 Bq kg^{-1}, which is less than maximally admissible limit set by UNSCEAR, which is 370 370 Bq kg^{-1}.[2,3] This indicates that the territory under this research is free from the threats caused by radium and its decay product radon, especially that there are no regional deep faults on the territory.[5]

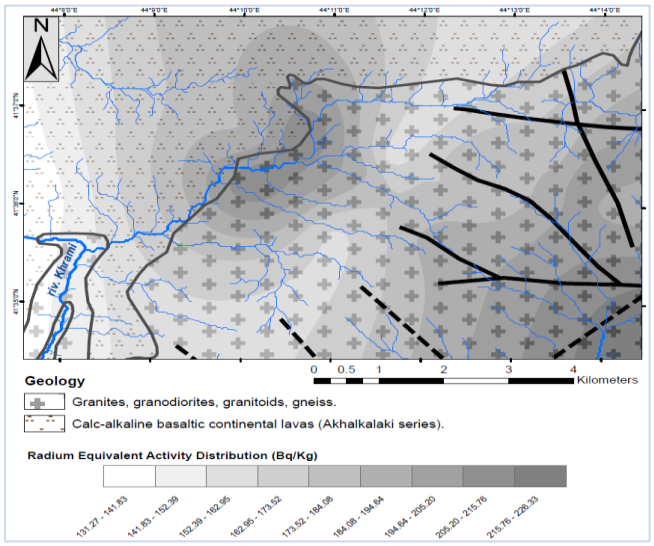

Figure 9. Interconnection of radium-equivalent activities, soil parent materials, and water flows.

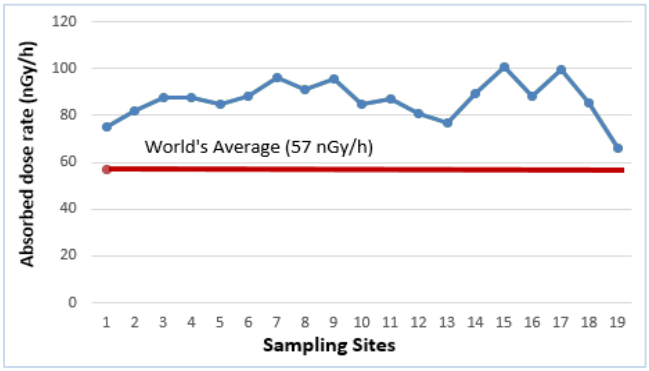

Figure 10. Comparison of obtained values of absorbed dose rate with world mean values.

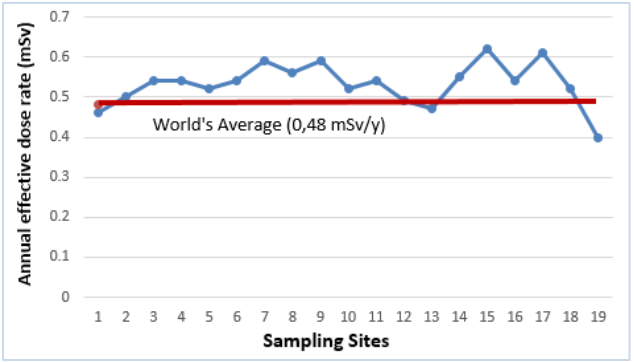

Figure 11. Comparison of obtained values of annual effective dose rate with world mean values.

Figure 12. The 9th site of sampling.

Table 5. Comparison of current results for concentrations of ^{137}Cs with data available in literature.

No.	Country	Bq kg^{-1}
1	Ordu, Turkey	171.35
2	Venezuela	5.00
3	Bangladesh	6.50
4	Majorca, Spain	35.00
5	Inshass, Cairo, Egypt	10.35
6	Algeria	25.00
7	Louisiana, USA)	31.50
8	Montenegrin Coast, Montenegro	14.95
9	Sudan	9.25
10	North-Western Libya	1.30
11	Riyadh, Saudi Arabia)	1.00
12	Northern Taiwan	14.24
13	Punjab – 1, Pakistan	2.80
14	Pakka Anna, Pakistan	3.60
15	Southern Punjab, Pakistan	1.60
16	Mid-Rechna, Pakistan	3.50
17	Punjab – 2, Pakistan	2.18
18	Charsaddah, Pakistan	7.10
19	Mirpur ,Azad Kashmir, Pakistan	1.39
20	Khrami Array, Georgia – present study	10.65

For external radiation index all mean values are below 1, which means that the populated localities on the territory are not exposed to radiation hazard that exceeds the limit.

The maximum concentration of ^{137}Cs (33 370 Bq kg^{-1}) was found at the 9th point (Table 2, Figure 12), which was sampled between the points located at a maximum altitude ASL (Table 1). A comparison of the results for ^{137}Cs obtained in studies conducted in various countries are given in Table 5.[5] As seen in **Table 5** in a number of cases ^{137}Cs concentrations is relatively high, which in our opinion indicates the trace left after the Chernobyl accident in 1986 and nuclear tests during the "Cold War" period. In general, the spread and sedimentation of artificial pollutants (radioisotopes) during the Chernobyl accident fallout depended on the strength of atmospheric motions and their directions. However, due to relatively high intensity of precipitation, pollution in mountainous regions was higher than in the plain, which is proved by corresponding studies carried out for instance, in France and Poland.[10,11]

Conclusion

Results of our research have shown that concentrations of natural radionuclide in the soils of the area under study considerably differ. In our opinion this must be conditioned by specific character of soils and their formation in which the forming parent rock plays a significant role and the factor of geochemical migration of substances is less important. Research results have indirectly revealed that sialic igneous rocks of Khrami massif, namely the soils that have emerged as a result of weathering of granitoids are indeed characterized by relatively high concentrations of natural radionuclides.

In this investigation, radiation character of a specific region of Georgia has been studied and explained according the geological features and correlation factors of the different characteristics have been observed. Although, the research has shown relatively high radioactivity level of the soils in the study area, but all parameters of assessing radiation exposure hazards are below the international limits.

We expect that this investigation and methodology used will stimulate similar study of other regions of Georgia, as well as of whole of south Caucasus. This may lead to a creation of useful generalized analytical information of terrestrial natural and artificial radioactivity of the region.

Acknowledgements

The authors express their gratitude to E. Andronikashvili Institute of Physics of the I. Javakhishvili Tbilisi State University and Ilia State University colleagues for the rendered assistance and support in the process of conducting the presented research.

Paper was presented at the 5th International Conference "Nanotechnologies", November 19–22, 2018, Tbilisi, Georgia (Nano–2018).

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Received: 04.07.2019.
Accepted: 16.08.2019.