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RADIOACTIVITY OF SOIL STRUCTURES IN THE BLACK SEA COASTAL STRIP (GEORGIA)

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ABSTRACT

One of the cardinal problems in the area of ecological researches is natural and anthropogenic radioactivity of environment. The main purpose of this work is determination of radioactivity in various types of soil in the Black Sea coastal strip in the West Georgia. Numerous settlements are located in this region which is a zone of sea resorts. Samples have been selected in 9 control points in this territory (soil types - alluvial soil, red soil), and also in 2 control points located outside of this zone (soil types - yellow soil and podzolic soil) for carrying out of the comparative analysis. Up to 22 radionuclides have been identified in these samples. Concentration of radionuclides of Th-232 family (in total 6 identified radionuclides) ranged from 12.5 to 32.5 Bq/kg with average value of 22.8 Bq/kg, U-238 family (in total 7 radionuclides) – from 13.4 to 28.3 Bq/kg with average value of 19.3 Bq/kg, U-235 family (in total 7 radionuclides) – from 0.62 to 1.31 Bq/kg with average value of 0.89 Bq/kg. Concentration of Pb-210 almost in all samples considerably exceeded equilibrium value. Also single radionuclides have been identified – Be-7 (activity up to 29.5 Bq/kg), K-40 (from 81.1 to 485 Bq/kg) and Cs-137 (from 8.8 to 191 Bq/kg). The value of radium equivalent activity varied in the range from 48.6 to 93.1 Bq/kg with average value of 74.0 Bq/kg, thus the greatest values were observed for alluvial soil and yellow soil, and the least value - for podzolic soil. The annual outdoor effective dose ranged from 29 to 56 μSv/y with average value of 44 μSv/y. Certain features in radionuclides distribution have been noted, and comparison with literary data has been carried out.

Key words: activity concentration, Georgia, radionuclides, soil

INTRODUCTION

Natural and man-made radioactivity of soil is one of the main components of the radioactive background of the Earth. According to the numerous researches, the radioactivity in various regions of the globe considerably differs – from units to hundreds of Bq/kg. This exposure to radiation constantly influences on the public and can be of human health hazard.

In many works activities ratios of various radionuclides are also investigated, which represent certain interest for understanding of the various geochemical processes taking place in rocks and soils. So, for example, activities ratio U-238/U-235, which is a constant value

21.7 in rocks and soils [1], is often investigated for the purpose of identification of technogenic uranium pollution. Also other activities ratios are investigated, for example, U-238/Th-232, Ra-226/U-238, Pb-210/Ra-226 reflecting disequilibrium in radioactive chain of U-238 (that is often observed in zones of hyper genesis (weathering)) [2] – [4]. Therefore such researches are important for each territorial region.

In the works [5] – [9] there were investigated soils of various types, including soil of potatoes, wheat, rye, oat in Poland, silty clay, sandy, sandy loam, silty sandstone in Northern India, anthrosol-type soil in Belgrade (Serbia), chestnut, chernozem and alluvial soils in Rostov region (Russia), beach sands of coastal lines in Ghana, soil around air base in Kuwait. In these works it was studied content of naturally occurring radionuclides Th-232, U-238, Ra-226, U-235, Pb-210, K-40, anthropogenic Cs-137. Based on the received data activities ratios of radionuclides U-238/U-235, U-238/Th-232, Ra-226/Th-232, Pb-210/Ra-226 have been calculated (concrete values are specified in the stated below table of literary data). Also various radiological indexes have been calculated. In particular, the radium equivalent activity of soil samples studied in the work [6] varied in the range 77.9-326 Bq/kg with average value of 199 Bq/kg, absorbed gamma dose rate – in the range 35.5-146 nGy/h with average value of 89.2 nGy/h, the annual effective dose – in the range 44-179 μSv/y with average value of 110 μSv/y. The following values have been received in work [9]: the radium equivalent activity – in the range 59.5-445 Bq/kg with average value of 101 Bq/kg, absorbed gamma dose rate – in the range 30.3-205 nGy/h with average value 0f 54.1 nGy/h, the annual effective dose – in the range 37- 251 μSv/y with average value of 66 μSv/y.

In Georgia researches of natural radioactivity (and also man-made radionuclides) using modern equipment and methodology has not almost been carried. Rather detailed researches of radioactivity in various environmental objects have been carried out i n 1986, after accident on the Chernobyl atomic power station and, basically, concerned in man-made radionuclides [10] – [12].It has been shown in these works that during this period in the territory of West Georgia (basically in a strip adjoining to the sea) the big concentrations of man-made radionuclides have been observed (in particular, Cs-137 concentration made from several hundred to some thousand of Bq/kg). In the works [13], [14] there are given results of research of radiation condition of Black Sea coastal soil during later period, in particular, 7 naturally occurring radionuclides (Ac-228, Ra-226, Bi-214, Pb-214, Pb-212, Pb-210, K-40) and one man-made radionuclide (Cs-137) have been fixed in soil in some regions of Ajara (Batumi, Gonio, Sarpi, Chakvi, Kvariati).

In the present work there are given results of radioactivity researches of soil of the various types, selected in 9 control points located in Black Sea coastal strip in West Georgia (beginning from Poti in the north and until settlement Gonio in the south – see Figure 1), and also in 2 control points out of this zone (Senaki and Kutaisi).

PROBLEM STATEMENT

Black Sea coastal part of the territory of Georgia, located between Poti and settlement Gonio, is the most perspective zone for the medicinal-health purposes in the country. Therefore research of

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radiation background – radionuclide content and activity concentration of naturally occurring, and also identification of man-made radionuclides – in soils of this region is an actual problem. In this strip (I) soils of two types – alluvial soil and red soil – are most widespread. 9 samples have been selected near the population aggregates – settlement Gonio (Gn), city Batumi (Bt), settlement Chakvi (Ch), city Kobuleti (Kb), village Grigoleti (Gr), city Poti (Pt), in particular, 5 samples in control points Bt-4, Bt-5, Kb, Gr, Pt – alluvial saturated soil (Al (St)), 2 samples in control points Bt-2, Bt-3 – alluvial acid soil (Al (Ac)), and 2 samples in control points Gn, Ch – red soil (Rd). For the comparative analysis 2 samples have been selected in the territory adjoining to Black Sea coastal strip (II) in control points Senaki (Sn) – approximately 30 km away from coast of Black Sea, and Kutaisi (Kt) – approximately 80 km away, in particular, 1 sample (from Senaki) – podzolic soil (Pz) and 1 sample (from Kutaisi) – yellow soil (Yl).

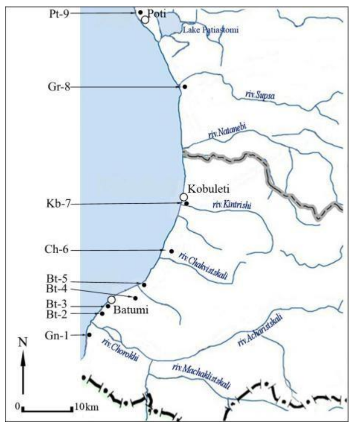

Figure 1. Layout chart of control points

METHODOLOGY

Sampling. Samples were selected using special auger directly in plastic containers (volume 2,0 L). After drying in laboratory conditions samples were crushed and sieved for the purpose of their homogenization. Samples were weighted, and their specific weight has been determined. These values were used at the description of sample geometry. The samples were sealed and stored for more than 4 weeks to achieve secular equilibrium between Rn-222 and Ra-226.

Measurement of gamma radiation activity. Measurements were carried out using gamma spectrometer Canberra GC2020 with semi-conductor germanium detector with relative efficiency 24 %. Gamma spectra acquisition time was 72 hour. For the analysis it was used software Genie-2000 S500 with additional modules, in particular, S506 – Interactive Fit Program. By means of this program, for example, in all spectra it was carried out “decomposition” of interference peak in the area of 186 keV (program identifies in this area one peak which is growing out of an interference of two closely spaced peaks of U-235 (185.715 keV) and Ra-226 (186.211 keV)). Using program S506C there is a mathematical processing of a spectral curve, therefore in this area two peaks with energies corresponding U-235 and Ra-226

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are created. By the program identification of peaks tolerance value was established in such a manner that low-energy peak was compared only with U-235, and high-energy – only with Ra-226. As results have shown, in particular, determination uncertainty of activity concentration of Ra-226, mainly, was within 9-24 %. Its activity was compared with activity of its daughters – Pb-214 and Bi-214 which determination uncertainty laid in the limits from 3 to 9 %. Received values of activity of Ra-226, Pb-214 and Bi-214 not enough differed from each other. Thus, it is possible to consider, that determination uncertainty of Ra-226 concentration sufficiently satisfactory, and this method was used also for determination of U-235 activity concentration in the area of 185.715 keV. The received values of U-235 activity were compared to values of U-238 activity (which was determined in the area of 63.3 keV of Th-232 with uncertainty in the range 6.3-14 %). As criterion the value of their activities ratio was used which is considered as constant (21.7) for natural objects [1]. For determination of Th-232 activity there were used average values for Ac-228, Ra-224, Pb-212, Bi-212, Tl-208 which determination uncertainties laid in the limits from 1.4 to 7.0 %. Also activities ratios U-238/Th-232, Ra-226/U-238 and/Ra-226 were determined which are used for an estimation of the mechanism of various geochemical processes. In samples it was often observed super equilibrium (allochthonous) Pb-210 (Pbal) which value was determined by difference between the measured values of activities of Pb-210 and Ra-226. For radionuclides identification it was used special library containing lines of 41 radionuclides and other specific sources (in total 351 line). For activity (A) calculation background radiation of “substrate” was subtracted.

The assessment of values of radium equivalent activity Ra_{eq} (Bq/kg), absorbed dose rate D (nGy/h) and annual effective dose AEDE (mSv/y) was carried out under the formulas [15]:

$$Ra_{eq} = A_U + 1.43 A_{Th} + 0.07 A_K \quad (1)$$

where A_U, A_{Th}, and A_K are the activity concentrations (Bq/kg) of U-238, Th-232 and K-40, respectively;

$$D = k_U A_U + k_{Th} A_{Th} + k_K A_K \quad (2)$$

where k_U, k_{Th}, k_K – so-called dose coefficients which are equal to 0.462, 0.604 and 0.0417, respectively;

$$AEDE = D + N_h + k_1 + k_2 \quad (3)$$

where N_h is the number of hours in 1 y. (=8760 h), k_1 - the factor to convert effective dose rate into the absorbed dose rate in the air for adults, 0.7×10^6 μSv/Gy, k_2 - outdoor occupancy factor (the fraction of time spent in the open air) which equals to 0.2

RESULTS

More than 140 peaks (in some samples up to 170 and more peaks) were observed in spectra of soil samples, that is appreciable more than in background spectrum where it is observed no more than 40 peaks of rather low intensity (counts rate laid in the limits from 0.045 to 11.1 kcps).

There are essential changes in spectra of samples in comparison with background spectrum – intensity of background radiation of substrate considerably increases (especially in low-energy area of a spectrum), also peak intensity considerably increases in the same energy areas and there is a considerable quantity of peaks in energy areas in which they were not observed earlier. The highest counts rate is observed for peak in the area of 1461 keV (sufficiently high counts rate are observed also for peaks in the areas of 661, 609, 351, 216, 323 keV etc.).

By results of the analysis of gamma spectra in soil samples it is identified up to 22 radionuclides, in particular, of Th-232 family– Ac-228, Th-228, Ra-224, Pb-212, Bi-212, Tl-208 (in total 6 radionuclides); of U-238 family – Th-234, Pa-234, Th-230, Ra- 226, Pb-214, Bi-214, Pb-210 (in total 7 radionuclides); of U-235 family – U-235, Th-231, Th-227, Ra-223, Rn-219, Pb-211 (in total 6 radionuclides); single naturally occurring radionuclides – Be-7, K-40; man-made radionuclide – Cs-137 (some specific lines are also identified which incipient as result of interaction of cosmic rays with material of the detector or the sample).

Some parameters of radionuclides are given in the tables (Table 1 - Table 3), in particular – activity concentration (A), radium equivalent activity with no account taken of allochthonic Pb-210al (Raeq) and taking into account allochthonic Pb-210al (Raeq-al), activities ratios (ARs) of radionuclides U-238/U-235, U-238/Th-232, Ra-226/U-238, Pb-210/Ra-226, absorbed dose rate, annual effective dose, generalized data – average (av), minimal (mn) and maximal (mx) values.

ANALYSIS

Apparently from the received activity values of radionuclides of families it is possible to note the following main features and regularities:

•activity of radionuclides of families varies rather in a narrow range: Th-232 – from 12.5 (sample 193) to 32.5 Bq/kg (sample 212), on the average – 22.8 Bq/kg; U-238 – from 13.4 (sample 281) to 28.3 Bq/kg (sample 212), on the average 22.4 Bq/kg, U-235 – from 0.62 (sample 281) to 1.31 Bq/kg (sample 212), on the average 0.89 Bq/kg (more than 10 times less than Th- 232 and U-238);

Radium equivalent activity ranged from 48.6 (sample 281) to 93.1 Bq/kg (sample 182), on the average 74.0 Bq/kg; all received values of ARs U-238/U-235 correspond (within 10 %) to the value 21.7 (accepted for natural objects);

•for characteristic properties of ARs inside U-238 family:

1 U-238/Th-232: the small deviation (more than 10 %) from average value of 0.81 (for the closed systems) was observed for a number of samples as towards increase (samples 178, 180 and 195) and towards decrease (samples 181 and 207);

2 Ra-226/U-238: appreciable (more than 10 %) prevalence of daughter product is observed in 6 samples (samples 208, 181, 207, 212, 182 and 204), and that of parent radionuclide – in 2 samples (samples 178 and 180);

3 Pb-210/Ra-226: except for 2 samples (samples 181 and 207) in all samples it is observed appreciable prevalence (more than 20 %1) of daughter product (the greatest value – 4.01);

4 inside chain Th-232 - Tl-208, basically, it is observed balance (except for Th-228, which determination uncertainty is appreciable more than for other radionuclides of family);

5 the greatest values of Raeq, D and AEDE are observed for the sample 182 selected in control point Gn-1, and minimal – for the sample 180 selected in control point Ch-6;

6 concentration of radionuclide Be-7 varies over a wide range – from values less than Minimal Detectable Activity (MDA) to 29.5 Bq/kg; it is not observed any regularity in distribution;

7 concentration of radionuclide K-40 is the highest among all radionuclides – 485 Bq/kg; considerably the low value (81.1 Bq/kg) is observed for the sample in control point Ch-6;

8 man-made radionuclide Cs-137 is fixed in all samples – activity from 8.76 to 191 Bq/kg (in control point Kb-7).

Note. For the sample selected in Senaki region (podzolic soil), radium equivalent activity of radionuclides approximately correspond to the average values received for soil of the coastal strip, and results (53.0 Bq/kg) for the sample selected in Kutaisi region (yellow soil), more correspond to the minimal values.

Table 1. Some key parameters of radionuclides of investigated soil samples (designations are in text)

#	SN	SR	ST	CP	Th-232	U-238	Ra-226	Pb-210	U-235	Be-7	K-40	Cs-137	Pb_{al}	Ra_{eq}	Ra_{eq}-al	U-238/U-235	U-238/Th-232	Ra-226/U-238	Pb-210/Ra-226	D, nGy/h	AEDE, µSv/y
1	208	I	Al (St)	Pt-9	22.6	17.2	22.1	33.6	0.81	< M	436	61.4	11.4	80.1	91.4	21.3	0.76	1.29	1.52	39.8	49
2	181		-"-	Gr-8	32.4	16.7	22.3	17.4	0.80	2.16	292	8.8	-4.83	83.5	78.7	20.9	0.50	1.33	0.78	39.5	49
3	178		-"-	Kb-7	18.7	20.7	16.3	65.5	0.92	5.35	485	191	49.1	81.4	130	22.5	1.12	0.79	4.01	41.1	51
4	180		Rd	Ch-6	23.5	23.7	19.7	51.1	1.08	16.3	81.1	66.0	31.4	62.9	93.9	21.9	0.98	0.83	2.60	28.5	35
5	207		Al (St)	Bt-5	24.3	17.2	28.7	27.1	0.80	10.1	328	56.9	-1.6	75.0	73.4	21.6	0.68	1.66	0.94	36.3	45

6	212		-"-	Bt-4	32.5	28.3	34.8	55.2	1.31	29.5	195	47.6	20.4	88.4	108	21.6	0.82	1.23	1.59	40.8	50
7	211		Al (Ac)	Bt-3	20.8	19.3	20.0	56.7	0.89	23.5	259	95.1	36.7	67.2	103	21.7	0.87	1.04	2.83	32.3	40
8	281		-"-	Bt-2	15.2	13.4	14.0	43.6	0.62	4.92	192	21.1	29.6	48.6	77.8	21.5	0.85	1.04	3.12	23.4	29
9	182		Rd	Gn-1	26.3	22.5	28.8	53.6	1.04	6.71	471	83.7	24.8	93.1	117	21.7	0.83	1.28	1.86	45.9	56
10	195	II	Yl	Kt-11	12.5	15.5	14.0	35.3	0.71	11.4	357	43.2	21.3	58.4	79.4	22.0	1.21	0.90	2.52	29.6	36
11	204		Pz	Sn-10	21.8	18.4	32.6	50.4	0.84	—	374	112	17.8	75.7	93.2	21.9	0.83	1.78	1.54	37.2	46
				av	22.8	19.3	23.0	44.5	0.89	12.2	316	71.5	21.5	74.0	95.2	21.7	0.86	1.20	2.12	35.9	44
				mn	12.5	13.4	14.0	17.4	0.62	< M	81.1	8.8	-4.83	48.6	73.4	20.9	0.50	0.79	0.78	23.4	29
				mx	32.5	28.3	34.8	65.5	1.31	29.5	485	191	49.1	93.1	130	22.5	1.21	1.78	4.01	45.9	56

Note. SN – sample number; SR – studied region; ST – soil type; CP – control points.

Table 2. Generalized data for some radionuclides depending on the soil type (designations are in the text)

#	SR	ST	Th-232			U-238			Ra-226			Pb-210			U-235			Be-7			K-40			Cs-137		
			av	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*
1	I	Al(St)	26.1	18.7	32.5	20.0	16.7	28.3	24.8	16.3	34.8	39.7	17.4	65.5	0.93	0.80	1.31	11.8	2.2	29.5	347	195	485	73.1	8.8	191
2		Al(Ac)	18.0	15.2	32.4	16.3	13.4	19.3	17.0	14.0	20.0	50.2	43.6	56.7	0.75	0.62	0.89	14.2	4.9	23.5	226	192	259	58.1	21.1	95.1
3		Rd	24.9	23.5	26.3	23.1	22.5	23.7	24.2	19.7	28.8	52.3	51.1	53.6	1.06	1.04	1.08	11.5	6.7	16.3	276	81	471	74.8	66.0	83.7
4	II	Yl	12.5	-	-	15.5	-	-	14.0	-	-	35.3	-	-	0.71	-	-	11.4	-	-	357	-	-	43.2	-	-
5		Pz	21.8	-	-	18.4	-	-	32.6	-	-	50.4	-	-	0.84	-	-	—	-	-	374	-	-	112	-	-

Table 3. Generalized data for some parameters depending on the soil type (designations are in the text)

#	SR	ST	Ra_{eq}			Ra_{eq-al}			U-238/U-235			U-238/Th-232			Ra-226/U-238			Pb-210/Ra-226			D, nGy/h			AEDE, µSv/y		
			av	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*	*av*	*mn*	*mx*
1	I	Al(St)	81.7	75.0	88.4	96.4	73.4	130	21.6	20.9	22.5	0.78	0.50	1.12	1.26	0.79	1.66	1.77	0.78	4.01	39.5	36.3	41.1	49	45	51
2		Al(Ac)	57.9	48.6	67.2	90.5	77.8	103	21.6	21.5	21.7	0.86	0.85	0.87	1.04	1.04	1.04	2.98	2.83	3.12	27.8	23.4	32.3	34	29	40
3		Rd	78.0	62.9	93.1	106	93.9	117	21.8	21.7	21.9	0.90	0.83	0.98	1.06	0.83	1.28	2.23	1.86	2.60	37.2	28.5	45.9	46	35	56
4	II	Yl	58.4	-	-	79.4	-	-	22.0	-	-	1.21	-	-	0.90	-	-	2.52	-	-	29.6	-	-	0.036	-	-

Apparently from the received results, in all spectra of soil samples in comparison with a background spectrum it is observed the appreciable quantity of new peaks and increase in intensity of the existing peaks. It unequivocally testifies that their sources are investigated samples.

As is known, concentration of radioactive elements in soils is formed by radioactivity of bedrocks and combination of the subsequent processes of soil formation. Content and concentration of naturally occurring radionuclides identified in samples, in general, correspond usually observable for various soils [2].

All these radionuclides, except for Cs-137, are naturally occurring. They are characteristic for the region of East Georgia also, in particular, for soil in the strip of the river Mtkvari [16] and some other regions [14].

The observable some decrease in concentration of radionuclides of families in samples of alluvial soil in comparison with samples of red soil can be connected with peculiarities of conditions of formation of genetic types of soil that can affect the content of radionuclides elements in them. Certain soil type dependence of radionuclides is noted in the work [2], in particular, it is shown that the average content of naturally occurring radioactive elements decreases from primitive grey desert soils and grey-brown soils to sod-swampy and marshy soils. This decrease as if reflects depth of biochemical processing of initial soil- forming rocks. Also it is marked the role of factors of leaching, humification, eluvial and alluvial moving, determining final radioactivity of soil layer in different types of soils. Probably these factors influence the results of activity received for the samples of podzolic and yellow soils, selected in regions of Senaki and Kutaisi.

Observed peculiarities of activities ratios, in particular, deviation from the average value of ratio U-238/Th-232 and equilibrium value Ra-226/U-238, are connected, as it was marked above, with various geochemical processes. So, for example, in works [2],

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[3] it is noticed, that Th isotopes in environments occur in nature only in the tetravalent form; compounds are practically insoluble in waters and they are transferred mechanically in the form of stable minerals while U isotopes occur in nature in tetravalent form as well as in hexavalent form – in tetravalent form by chemical properties are close to Th, and in hexavalent form differ by the big chemical activity, and in the form of water solutions migrate on the big distances. Ra isotope is easy leached and washed away by waters: in natural formations Ra-226 often accumulates in quantities exceeding equilibrium with uranium. Combinations of these and other geochemical factors can lead to appreciable variations of activities ratios of these radionuclides, causing their deviation in the big or smaller party from average and equilibrium values. The investigated region is characterized by diverse climatic conditions (in particular, meteorological) which can cause the processes noted above and lead to the deviations of ARs values noted in the work.

Observed in samples prominent feature in activities ratio Pb-210/Ra-226 – appreciable excess of equilibrium value of activity value in the majority of samples – apparently, points to appreciable effect of the exhalation factor of radioactive gas radon from soil deep layers. Radon in soil air during migration process to the top layers of soil (and further in atmospheric air) decays; its decay products (including Pb-210) deposit on solid particles of soil. This process can lead to occurrence of “nonequilibrium” concentration of Pb-210 (so-called “allochthonic” Pb-210 [17]).

Also is of interest, that practically in all samples it is observed radionuclide Be-7 which is formed in an upper atmosphere as a result of interaction with cosmic rays, and then gets together with deposits into soil. Frequent and plentiful deposits are characteristic for the given region that can cause its accumulation in soil in appreciable quantities. On the other hand, its half- decay period is rather small (54 days). These circumstances cause a wide dispersion of its concentration in various samples.

Distribution of naturally occurring radionuclide K-40, basically, is close to values observed in the work [16]. Rather low value for the sample in control point Ch-6 can be connected with its more intensive washing away from soil (in this point the most intensive rain precipitations in the whole West Georgia are observed).

Data for man-made radionuclide Cs-137 are of the special interest. As is known, Cs-137 is formed at nuclear tests which had regular character in the past, and as a result its certain background (equilibrium) concentration was formed. By data series, in particular, according to monitoring for the region of East Georgia [16], values of Cs-137 background activity now are, basically, in the range 1-10 Bq/kg. With certain degree of convention it is possible to consider this level as the background value for the whole territory of Georgia connected with result of nuclear tests. However, there were cases (for example, as a result of Chernobyl accident) when the increase of man-made radionuclides, in particular Cs-137, had extreme character. For the last period activity of Cs-137 has considerably decreased, apparently, basically, as the result of processes of washing away from soil or migration in deeper layers. In so doing as a result of non-uniform precipitations during accident, appreciable non-uniformity of its concentration on investigated territory took place which, in certain degree, has remained till now. This circumstance could cause a wide dispersion of its activity in the samples selected in various points.

Some literary data by results of the researches carried out in other regions of the world are given in the table (Table 4). Apparently from the table, the values received in the present work, on the average, are much lower than in other regions, and also in comparison with worldwide average values. Also it is necessary to notice, that value of radium equivalent activity which ranged from 48.6 to 93.1 Bq/kg, is appreciable below the recommended value of 370 Bq/kg, and annual effective dose which changes in the range 29-56 μSv/y, is below limiting value of 1 mSv/y [18], [19], [20].

Table 4. Activity concentration (Bq/kg) and activities ratios of radionuclides in soil in various regions of the world

Regi-ons	ST	Th-232	U-238	Ra-226	Pb-210	U-235	K-40	Cs-137	U-238/ U-235	U-238/ Th-232	Ra-226/ U-238	Pb-210/ Ra-226	Ref.
1		83.0 30.2-136	50.5 22.6-116	54.1 19.5-96.1			338 189-508				1.05 0.56-1.79		[6]
2		15.4 12.3-23.5	19.1 15.1-27.6			1.07 0.77-1.51	441 361-512	1.15 0.43-5.7		1.23 1.17-1.38			[21]
3									1.7-4.1	1.6-6.1	0.55-7.14		[22]
4	Bs	42.6 16.8-231	20.1 11.1-31.8	31.4 10.9-104		0.91 0.51-1.5	110 68.3-184		22.2 18.9-31.3	0.79 0.11-1.56	1.27 0.42-4.2		[9]
5	Ag	20.1 8.9-35.1		45.1 25.6-67.9	25.5 14.1-37.1		408 211-667	15.2 9.8-22.9				0.57 0.49-0.69	[5]
6		19.6-68.4	1.8-240	12.3-92.6	174-342		200-962						[8]
7	An	53.1 45-62	67.4 49-90	48.1 39-59		3.6 2.7-4.6	642 565-755						[7]
8		29-60	28-70	32-77			310-420						[23]
9		10-56	26-50	15-35			60-180						-“-
10		45	33	32			412						-“-

11	Al (St)	26.1 18.7-32.5	20.0 16.7-28.3	24.8 16.3-34.8	39.7 17.4-65.5	0.93 0.80-1.31	347 195-485	73.1 8.8-191	21.6 20.9-22.5	0.78 0.50-1.12	1.26 0.79-1.66	1.77 0.78-4.0	Present study
-“-	Al (Ac)	18.0 15.2-32.4	16.3 13.4-19.3	17.0 14.0-20.0	50.2 43.6-56.7	0.75 0.62-0.89	226 192-259	58.1 21.1-95.1	21.6 21.5-21.7	0.86 0.85-0.87	1.04 1.04-1.04	2.98 2.83-3.12	-“-
-“-	Rd	24.9 23.5-26.3	23.1 22.5-23.7	24.2 19.7-28.8	52.3 51.1-53.6	1.06 1.04-1.08	276 81-471	74.8 66.0-83.7	21.8 21.7-21.9	0.90 0.83-0.98	1.06 0.83-1.28	2.23 1.86-2.60	-“-
12	Yl	12.5	15.5	14.0	35.3	0.71	357	43.2	22.0	1.21	0.90	2.52	-“-
13	Pz	21.8	18.4	32.6	50.4	0.84	374	112	21.9	0.83	1.78	1.54	-“-

Note. 1) Regions: 1 – northern India; 2 – Al-Jahra, Kuwait; 3 – Russia; 4 – Greater Accra region, Ghana; 5 – middle-eastern Poland; 6 – Rostov region, Russia; 7 – Belgrade, Serbia; 8 – Armenia; 9 – Azerbaijan; 10 - Worldwide average values; 11 - Black Sea coastal strip, Georgia; 12 – Kutaisi region, Georgia; 13 – Senaki region, Georgia.2) Soil types: Bs – beach sand; Ag – agriculture soil (soil of potatoes, wheat, rye, oat); An – anthrosol-type soil. In conclusion it is necessary to notice, that the received results represent doubtless scientific and applied interest for the investigated region that confirms an urgency of such researches and necessity of their regular character.

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