CS-137 CONTAMINATION MEASUREMENTS OF TECHA RIVER BANK TERRITORY IN BRODOKALMAK SETTLEMENT

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ABSTRACT Cs-137 contamination mapping (with a scale 1:2,000) of one square kilometer of the Techa River bank territory inside the Brodokalmak settlement has been carried out. The electron maps of Cs-137 contamination distribution of bank landscapes have been created. Collimated scintillated detector technique was used for Cs-137 stock measurements. This method allows for determination of the total Cs-137 stock and the thickness of the soil layer containing more than 80% of total stock in-site. The RKG-09N device was used for these measurements. The Cs-137 contamination is very heterogeneous and the stock means are 10^7 Bq/m^2 at some places. The comparison of the above-mentioned technique and the traditional sampling method was carried out at specially chosen places. The gamma spectrometer laboratory data is in good agreement with site data. Additionally, the samples were investigated to determine soil surface activity of Sr-90. It was shown that Cs-137 contamination correlates with Sr-90 contamination within the bank territory of the settlement. The total Cs-137 stock contained at the investigated territory is near 6.6×10^{11} Bq. The estimated total Sr-90 stock here is near 2.2×10^{11} Bq.

KEYWORDS: Cs-137 contamination, gamma radiation, mapping, collimated scintillated detector, sample method

INTRODUCTION

The Brodokalmak settlement is located on both banks of the Techa River about 109 km downstream from a place of radioactive waste release from a production facility called “Mayak” [1]. At present the main dose contributing factor to inhabitants living in the settlement is the bank territory of the Techa River, since the level of soil Cs-137 contamination in the settlement does not exceed 0.1 μCi/m^2 and there are no another man-made gamma radiated radionuclides. The previous administration and environmental remediation work have decreased inhabitant doses but an adequate safety level of annual population dose has not been achieved [1, 2]. The main goal of the present work is to carry out detailed Cs-137 surface activity (stock) measurements and Cs-137 penetration depth inside the soil of the given territory to create large-scale maps (plans) of the distribution of contamination levels. The maps of Cs-137 stock distribution will be used as a base to work out remediation activity of the investigated territory and to detail the total stock of Cs-137 and Sr-90.

CS-137 STOCK MEASURING TECHNIQUE AND VALUATION OF CS-137 PENETRATION DEPTH INSIDE THE SOIL

The Cs-137 stock measurements were carried out by an RKG-09N device according to collimated detector technique [3]. The technique is based on registration by the collimated spectrometric detector of

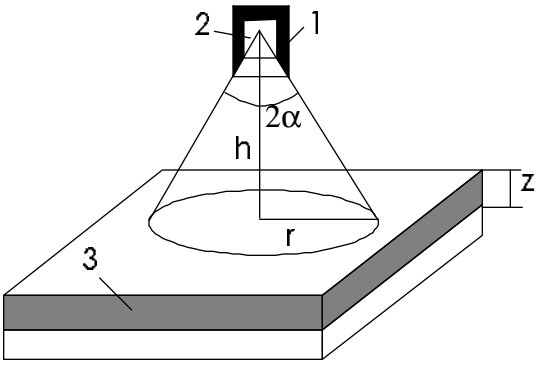

FIGURE 1. GEOMETRY OF MEASUREMENTS. 1—LEAD SHIELD AND COLLIMATOR; 2—SCINTILLATED CRYSTAL; 3—SOIL LAYER WITH THICKNESS Z CONTAMINATED BY CS-137.

the gamma-quantum flux, emitted by the contaminated soil surface.

It is known that the count rate, N, of the detector in the photo absorption peak is stipulated by registration of non-scattered radiation only. The reading of the detector with a collimator solid angle, Ω ($\Omega = \pi\alpha$, α = angle of collimator, Figure 1), is connected to surface activity, q, of the radionuclides by a simple equation,

$$N = A*q*\Omega , \quad (1)$$

where A = the calibration factor, which depends on the detector and energy spectrum of the contaminated surface. It follows from Equation 1 that surface activity, q, is defined by the count rate in the photo absorption peak. To take into account the background component, stipulated by passage of gamma-quanta through a lead shield, a standard procedure of a detector turning around a horizontal axis of 180º is used. The background count rate measured in this detector position is subtracted from N.

Thus, making two measurements at each point, the surface activity, q, averaged on the solid collimator angle, could be determined from the mean count rate in the photo absorption peak. However, this method of surface activity definition is only possible when radionuclides are in the top thin soil layer. In a real situation radionuclides penetrate the soil, the soil scatters the gamma radiation, and makes impossible the definition of the cesium stock using Equation 1. To measure the Cs-137 stock taking into account its penetration depth in soil it is necessary to determine the count rate in the Compton part of the spectrum in addition to one in the photo absorption peak. The optimum additional energy range of 400-560 keV was chosen on the basis of numerical Monte-Carlo calculations and experimental modeling with a standard volumetric Cs-137 source.

The count rate, N_1, in this energy range is proportional to the value of the cesium stock, q, and weakly depends on the value of penetration depth; i.e., for this energy range a relation, similar to Equation 1, takes place for the values of N_1 and q. The weak dependence of value N_1 on radionuclide penetration depth is connected with the fact that non-scattered radiation (first component) and radiation scattered in the soil (second component) contribute to the detector count rate in the 400-560 keV energy range. The registration of gamma-quanta unitary scattered in soil on small angles corresponds to the second component. With an increasing of radionuclide penetration depth, the first component decreases and the second increases. Thus both processes practically compensate one another, providing a weak dependence N_1 on the value of radionuclide penetration depth in soil.

It should be noted that for a small penetration depth (up to 3λ, where λ = a radiation free path in soil for gamma-

radiation of Cs-137 = 662 keV) the count rate in the indicated Compton part of the spectrum weakly depends not only on cesium penetration depth in soil, but also on its depth distribution. As mentioned above, the count rate in photo absorption peak N_2 strongly depends on penetration depth. N_1 and N_2 are proportional to cesium stock in soil; therefore, the relation of these values N_1/N_2 characterizes the degree of its penetration.

Results of the theoretical analysis show that using the relation N_1/N_2 it is possible to evaluate cesium penetration depth in soil, i.e., to determine the thickness of the soil layer which contains more than 80% of the total cesium stock. The error of surface cesium activity determination in a pointed layer is stipulated, *a priori*, because of unknown cesium depth distribution, but for the most probable—uniform, triangular, and exponential distributions—this error does not exceed 20%. This estimation of cesium penetration depth in soil is sufficient for acceptance of correct decisions on remediation of the contaminated territory. It is very important and necessary for accounts of exposed dose rates (EDR) on contaminated territories.

BRIEF DESCRIPTION OF RKG-09N DEVICE (CORAD)

To realize the technique described above, a new portable RKG-09N device, named "CORAD" (collimated radiometer), and an appropriate software were developed [4]. "CORAD" is intended mainly for mass investigation of contaminated territories and has been made in a weatherproof version. The simplicity of using this device is reached by application of a microprocessor and complete automation of measurements.

"CORAD" consists of a portable 256-channel analyzer and microprocessor. The software permits the device to accumulate a spectrum, to process it, and to calculate surface activity directly on-site. The modes of taking measurements and processing results are completely automated. According to the measuring technique of Cs-137 stock in soil, the three energy ranges are allocated: 400-560keV = the main measuring channel; 600-720keV = the first auxiliary channel; 740-900keV = the second auxiliary channel.

Count rates N_1, N_2, and N_3 in these channels (subtracting the background stipulated by radiation going through the lateral shield of the detector) are defined. Cesium stock in soil, $G = \alpha N_1$, is calculated from the count rate in the main measuring channel. The factor of proportionality, α, is determined at certification of the device using the flat standard Cs-137 source. N_2 corresponds to the photo absorption range (first auxiliary channel) and is defined as effective surface density of activity, $A = bN_2$. The factor b is chosen at calibration from condition G = A for a flat standard surface source. The count rate N_3 determines contribution in main and first auxiliary channels of background components stipulated by Cs-134 radiation, natural radionuclides of U-235, U-238, and Th-232 chains, and K-40. The ratio G/A determines the thickness of the soil layer containing more than 80% of the total cesium stock. In the latest versions of the algorithm the correction of the stock $G^* = K_{cor}(G/A)*G$, taking into account an existing weak dependence, G, on cesium penetration depth in soil, is incorporated. The functional dependencies of cesium penetration depth in soil and correction factor K_{cor} on G/A are determined by preliminary Monte-Carlo calculated data and results of laboratory experiments with a volumetric source.

The results of measurements and spectra can be saved in the memory and, using a communication interface RS-232, are transferred to any computer for subsequent processing. The radiometer software excludes any opportunity for deliberate result distortion and provides a control for measuring rule observance. The main version of the radiometer is manufactured with software, ensuring measurement of Cs-137 surface activity in the presence of natural radionuclides U and Th decay chains and K-40, irrespective of the character of Cs-137 distribution in the top soil layer for a thickness of up to 30 cm. The collimated detector is placed at a height of 80 cm over the ground surface and registers gamma radiation from the area of two square meters. The principle and order of measurement incorporated in the radiometer software correspond to the above-mentioned measuring technique [3].

The determination limit of the RKG-09N is 0.1 $\mu Ci/m^2$.

The "CORAD" device consists of a collimated scintillated detector with the NaI(Tl) crystal of sizes ϕ50 x 50 mm, control unit, preamplifier, unit of high-voltage and low-voltage supply, battery, spectrometric amplifier with programmed amplification, 256-channel digital converter, 80C31 microprocessor, RAM enabling it to store 44 spectra and 1,000 measuring results, as well as memory for processing software.

SOFTWARE ACTIV

To process all data received as a result of the radiation survey of the district, and to represent them in a kind of electronic map, the software ACTIV is used. The software ACTIV is an applied system developed for personal computers to work with measuring data of surface radioactivity and penetration depth, to construct maps of various radioactive contamination levels, and to calculate the exposition dose rate (EDR). The measuring data and coordinates of measuring points should be inputted into the computer as initial data for ACTIV.

ACTIV has three groups of executable programs. The first group executes a mapping of the surveyed district and automatically inputs data from the device on created maps. The second group of programs is connected to processing and data representation. It begins by Delone triangulation for a set of initial data. Delone triangulation permits one to proceed from local representation of data received to their continuous distribution. The continuous function, accepting in the measuring points a value of the measuring data, is under construction on a triangulation grid. The pass from a local to continuous measuring data distribution permits one to conduct various evident representations of measuring data. The programs in this package calculate isolines of given surface activity levels, shade, or color intervals between levels. Created maps may be presented as a hard copy by external devices—printers or plotters. The continuous representation of data enables one also to simulate removal of the top soil layer for possible decontamination, in order to receive valuation of removal efficiency.

The last group of programs calculates EDR, created by measured surface activity distribution. This part of the software calculates a space EDR distribution over a real soil surface with known surface and depth Cs-137 distribution [5].

The accumulated experimental material, received in results of long-term measurements in Bryansk and Tula regions of Russia, shows that use of the software

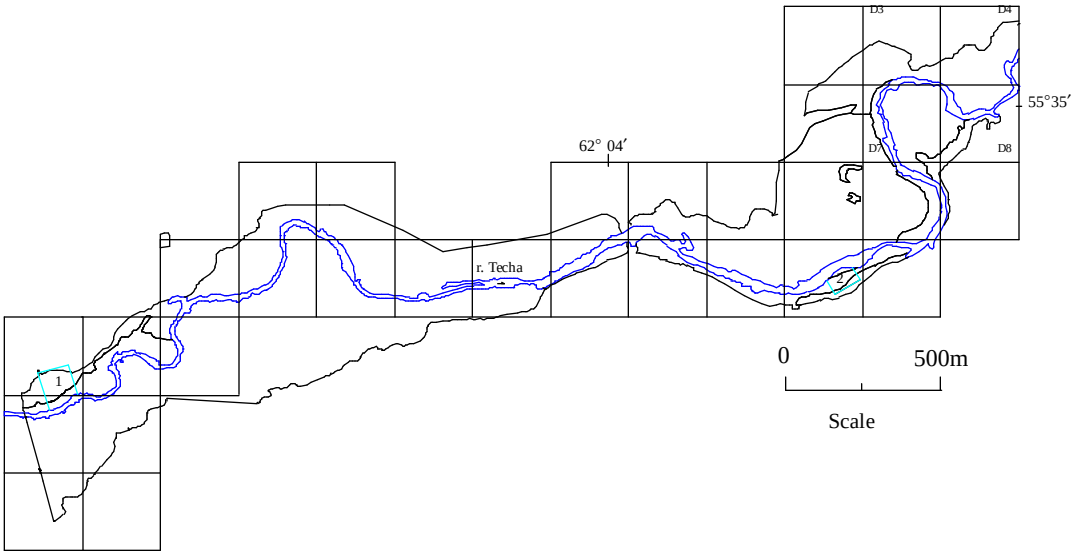

FIGURE 2. TERRITORY OF RADIOMETRIC SURVEY. 1—PLACE A; 2—PLACE B.

permits one to calculate EDR distribution for measured surface activity distribution in natural landscapes with an error not exceeding 20%.

CS-137 CONTAMINATION LEVELS OF THE TECHA RIVER BANK TERRITORY

A radiation survey of the bank territory of the Techa River in the Brodokalmak settlement was carried out in October 1994 and detailed in June 1995. The investigated territory (about one square kilometer), bordering to the bank of the river, is restricted by a prickly wire and has been legally taken out of economic and other activity. The extent of the river in its limits is more than 4.5 km; the width of the bank territory is from several tens up to several hundreds of meters (Figure 2).

The river bed in a given place is winding; slopes to the river are abrupt at some places. The bank territory includes small-sized old river bogs and marshes. The main goal of the survey is to find out whether the borders of the river bank have Cs-137 contamination of more than 1.0 $\mu Ci/m^2$. The measurements were begun at a one to two m distance from the water stream, as it existed at the moment of the survey, were carried out on profiles perpendicular to the bank line with a 5-10 m step, and were finished when the values of Cs-137 stock became less than 1.0 $\mu Ci/m^2$. The length of profiles varied from several meters up to several hundred meters. The distances between profiles was from 10 m up to 30 m and depended on the homogeneity of contamination distribution. The relative orientation of measuring points to the district was carried out according to photo plans (scale 1:2,000) and local landmarks (scale 1:50,000) and was checked by Global Position System Navstar.

More than 4,000 measurements were taken. Spectra of soil gamma radiation were recorded at the most representative points to verify reliability of measurements. As an example, a characteristic apparatus spectrum of soil gamma radiation is shown in Figure 3. The spectrum indicates that the main gamma dose contributing radionuclide is Cs-137 and

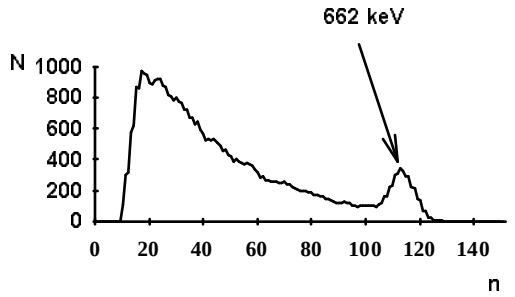

FIGURE 3. RKG-09N APPARATUS SPECTRUM OF SOIL GAMMA RADIATION IN POINT 3 AT PLACE A. N—DETECTOR'S COUNT RATE; n—CHANNEL NUMBER.

the contribution dose of another man-made gamma radiated radionuclide is negligible in comparison with this one at this territory.

The common area of investigated bank territory is 928,700 m^2; the total Cs-137 stock in soil is 17.8 Ci. The distribution of Cs-137 stock in the soil of the Techa River bank within the Brodokalmak settlement is presented in Table 1.

The area of 367,200 m^2 restricted inside the isoline of more than 10 $\mu Ci/m^2$ contains the main part of the activity (more than 97 %). Maximum measured Cs-137 stock value is 255 $\mu Ci/m^2$. The places contaminated more than 1 $\mu Ci/m^2$ outside the alienation zone were found in the eastern part of the surveyed territory only.

The contamination of the bank territory is non-uniform on the river current and is stipulated by physical-geographical particularities of the researched territory. The total Cs-137 stock changes from 0.4 Ci to 4.2 Ci on half-kilometer sections of the river. Even more strong heterogeneity is observed on shorter sites. As an example, in Figures 4 and 5 the maps of Cs-137 stock distribution in soil on sites "A" and "B" (Figure 2) are presented.

The samples of 20 cm top soil layer were taken along the profiles (directions and locations of profiles are shown in Figure 4 and Figure 5a) to determine independently the stock of radionuclides on both sites. The distance between the sample points is 5 m. The samples were investigated at the Rosgidromet laboratories. The comparison of results of sample laboratory gamma spectrometry and field radiometry (RKG-09N) are submitted in Tables 2 and 3. The site "A" (Figure 4) is located on the left-hand river bank. In the bank band at the level 0.5-0.8 m from the water stream, dense bushes grow, then there is an homogeneous elevation covered by long-term grasses. The low plateau (height about one meter) is west of the site. The site has an abrupt rise to the north. Three profiles were incorporated: the western (W), laid through the plateau; the main (C), on the border plateau; and the eastern (E), in a place of narrowing bank territory. The maximum density of activity is

TABLE 1. CONTAMINATED AREA WITHIN THE LIMITS OF BRODOKALMAK SETTLEMENT FOR VARIOUS VALUES OF CS-137 STOCK.

	Cs-137 Stock, $\mu Ci/m^2$						
	0.5-1	1-10	10-25	25-50	50-100	100-200	>200
Area, $1000m^2$	144.5	253.7	123.9	123.4	88.8	29.7	1.4
Area/Total Area, %	15.6	27.3	13.3	13.3	9.6	3.2	0.15
Stock/Total Stock, %	0.1	2.1	10.1	25.2	36.2	24.3	2.0

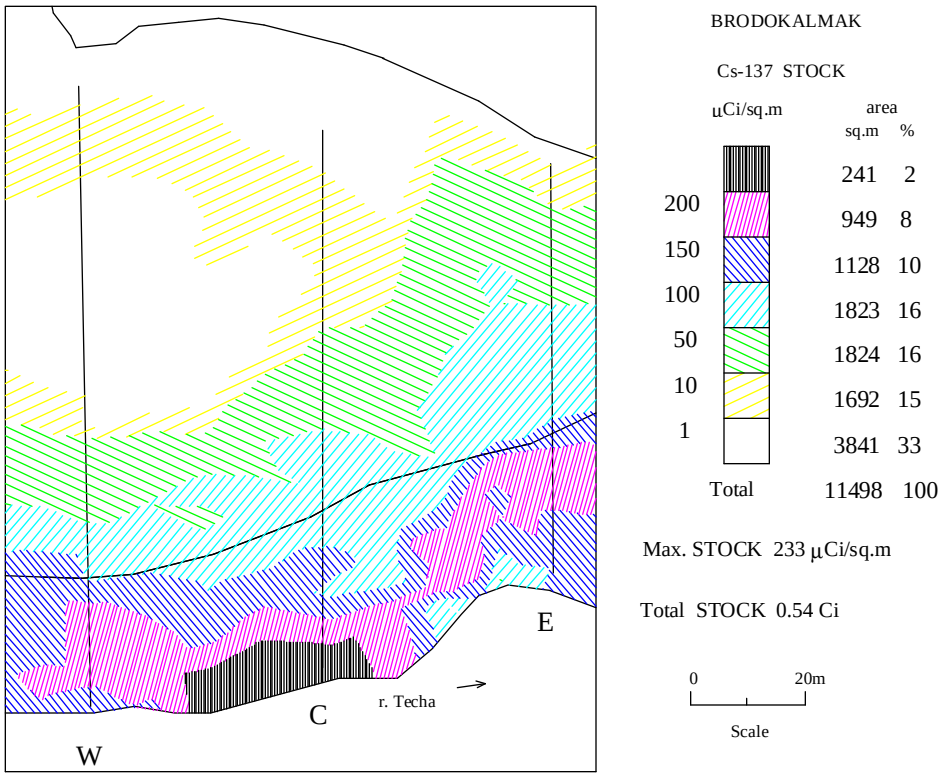

FIGURE 4. Cs-137 CONTAMINATION DISTRIBUTION AT PLACE A. W—WESTERN PROFILE; C—MAIN PROFILE; E—EASTERN PROFILE.

concentrated in the dense bushes; their border is marked by a solid line along the bank in Figure 4. This place floods practically every year; dense bushes promote braking of the water stream and sedimentation of floating particles. The formation of the most contaminated site (more than 200 µCi/m^2) in the main profile region is probably connected to the maximum fall of the water stream velocity here.

The river current begins to change its direction above the eastern profile. As a result, the primary contamination of the low bank territory is less here than it is on the main and western profiles. The destroying of the bank in this place results in the occurrence of activity (6.7 µCi/m^2) at the river bottom in a distance of one meter from the bank and secondary carrying of contamination along the river bed. The maximum contamination density of the eastern profile is removed from the water stream and placed in the microdown. The homogeneous decreasing of surface activity is observed at the more grassy part of the site. The plateau never floods or was formed in the 70 years since construction of the road bridge. Point No. 21 in Table 2 is a particularly fire-prone place and its contamination is connected to burning of bushes here.

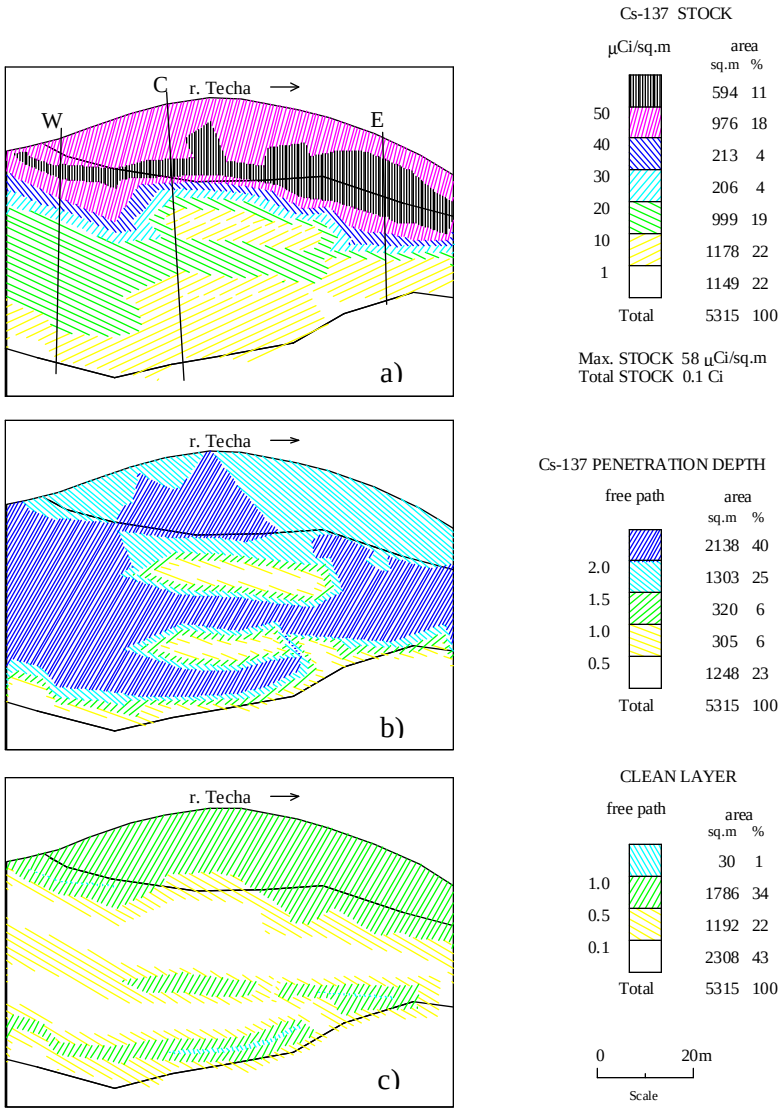

FIGURE 5. Cs-137 CONTAMINATION DISTRIBUTION AT PLACE B. W—WESTERN PROFILE; C—MAIN PROFILE; E—EASTERN PROFILE.

The detailed consideration of data in Tables 2 and 3 shows a divergence in definition of Cs-137 stock between the laboratory sample method and field radiometry in some points (for example, Nos. 5, 11, 27, 32, etc.). The main reason for this divergence is an essential difference between analyzed areas. The RKG-09N device integrates a quantum flux from 2.0 m^2 of the soil and the sample has a total square near 0.01 m^2. Secondly, the RKG-09N reliably registers quanta from the soil layer to a depth of not less than 30 cm, and the samples were taken up to 20 cm in depth.

The divergences of determination of Cs-137 stock between the sample method and the collimated device can be reduced up to several percents if the area and depth of samples are increased.

The significant divergences of Cs-137 stock determination for the level of 0.2 μCi/m^2 (N 18-26, Table 2) are connected to a small exposure time (60 sec) for RKG-09N measurements. The selected exposure time keeps the statistical error of measurements at a contamination level of 0.5 μCi/m^2 from exceeding 50%. And on the other side it allows one to solve the main task (see above)—realization of radiation survey of the bank territory.

The availability of secondary carrying

TABLE 2. (CONTINUED ON NEXT PAGE) CHARACTERISTICS OF SOIL Cs-137 CONTAMINATION ON LEFT-HAND BANK (SITE "A").

	Sample Method		Field Radiometry (RKG 09N)					Ratio	EDR
N	Density	Stock	Stock	Part of Stock in 3 g/cm^2	Radiation Thickness, g/cm^2				
	g/cm^3	μCi/m^2	μCi/ m^2		80-100%	Clear Layer	Contam. Layer		μR/h
Main profile									
1		220.1	215.	0	25.	9.	16.	1.02	139
2		199.5	153.	.0	39.	.1	39.	1.31	166
3		92.5	86.	16.	25.	.0	25.	1.08	106
4		124.8	116.	15.	26.	.0	26.	1.07	120
5		154.5	79.	19.	22.	.0	22.	1.95	99
6		34.4	55.	32.	13.	.0	13.	.62	103
7		37.2	61.	20.	21.	.0	21.	.61	110
8		44.5	49.	26.	17.	.0	17.	.91	85
9		17.2	25.	23.	19.	.0	19.	.67	54
10		10.8.	17.	23.	19.	.0	19.	.64	42
11		4.4	10.	15.	26.	.0	26.	.44	23
12		3.5	9.	14.	27.	.0	27.	.38	15
13		3.5	5.0	.0	23.	10.	13.	.69	19
14		2.4	3.9	18.	23.	.0	23.	.62	14
Western profile									
15		.15	.4	.0	26.	13.	13.	.39	20
16		1.9	2.8	19.	22.	.0	22.	.67	
17		4.1	5.1	17.	24.	.0	24.	.80	
18		.47	.47	100.	.0	0.	.0	1.00	15
19	1.15	.58	.19	100.	.0	.0	.0	3.05	13
20	.70	.18	.05	100.	.0	.0	.0	3.60	12
21	.70	.23	.49	12.	31.	.0	31.	.47	16
22	.75	.16	.05	100.	.0	.0	.0	3.20	12
23	.80	.13	.09	100.	.0	.0	.0	1.44	15
24	1.00	.12	.06	100.	.0	.0	.0	2.00	15
25	.75	.13	.05	100.	.0	.0	.0	3.20	17
26	1.00	.20	.05	100.	.0	.0	.0	4.00	26
27	.70	10.4	26.	13.	29.	.0	29.	.40	48
28	.75	14.8	29.	39.	11.	.0	11.	.52	76
29	.80	40.5	43.	18.	23.	.0	23.	.95	91
30	.75	58.5	89.	24.	18.	.0	18.	.66	121
31	1.20	58.1	96.	15.	26.	.0	26.	.61	133
32	.75	61.4	149.	12.	30.	.0	30.	.41	167
33	1.10	94.3	146.	11.	32.	.0	32.	.65	165
34	.85	122.6	157.	12.	31.	.0	31.	.78	161
35	.80	78.9	122.	13.	29.	.0	29.	.65	

confirms also an availability in some places of a purer sedimentation over more contaminated soil layers (see Figure 5). The Cs-137 soil stock distribution on site “B” is presented in Figure 5a; the total depth of its penetration in soil (thickness of the layer containing more than 80% of Cs-137 stock) is shown in Figure 5b; and thickness of the pure soil layer over the contaminated one is shown in Figure 5c. The last two characteristics are given in radiation-free path, λ, in the soil of 662keV gamma-quantum energy. To calculate a soil thickness in cm it is possible to use the formula $L(cm) = L(\lambda)*12.9(g/cm^2)/\rho(g/cm^3)$, where ρ = the soil density. Thus, one radiation-free path for 1.0 g/cm^3 soil density corresponds to 12.9 cm.

The maximum contamination levels on site “A” are observed at a level of average bank territory (near 1.5 m from the water level), but the character of contamination distribution essentially differs throughout site “A.” There are a lot of channels here, the contamination of which is removed in flood-time (they are especially appreciable on the distribution of penetration depth and on thickness of the pure sedimentation layer). In channels the contamination has surface character; the sedimentation pure soil is carried away by floods, and earlier latent contamination is exposed, which impacts contamination levels in the channels below neighboring sites of the bank.

The other probable explanation of the marked position of the contamination maximum (~1.5 m) may be storage of radioactive sedimentation in flood-time. This assumption is confirmed by the fact that the width of maximum contamination sites depends on the steepness of the bank. The most narrow highly contaminated sites are observed at the steepest bank line places. The bank territory located in the easternmost part of the settlement shows confirmation of the above (Figure 6). The river in this place sharply changes direction; the high-altitude character of contamination strongly depends on the steepness of the bank. The band of maximum contamination is wider where the bank line is more sloped (compare, for example, the width on the right- and left-

TABLE 2. (CONTINUED FROM PREVIOUS PAGE)

Eastern profile									
36		1.17	1.17	.0	27.	15.	13.	1.00	24
37		6.19	7.2	45.	9.	.0	9.	.87	30
38		11.8	21.1	12.	30.	.0	30.	.56	43
39		10.2	17.5	38.	12.	.0	12.	.58	56
40	1.00	37.1	38.2	22.	19.	.0	19.	.97	57
41	1.15	46.4	68.	15.	26.	.0	26.	.68	110
42	1.10	31.3	55.	39.	11.	.0	11.	.57	115
43	1.30	52.5	71.	26.	17.	.0	17.	.73	117
44	1.45	94.4.	91.	13.	28.	0.	28.	1.04	117
45	1.25	99.1	143.	.0	28.	7.	21.	.69	124
46	1.55	139.4	198.	.0	24.	11.	13.	.70	151
47	1.05	161.8	177.	.0	24.	13.	13.	.91	123
48	1.70	47.9	122.	.0	24.	11.	13.	.39	86
49	1.90	114.2	154.	.0	25.	12.	13.	.74	110
50	1.15	49.9	110.	.0	29.	16.	13.	.45	68
51	1.00	47.2	102.	.0	31.	18.	13.	.46	54

hand banks).

The surface Sr-90 activity was measured on samples taken from site “B.” The definition of the correlation factor for radionuclides of Cs-137 and Sr-90 in the limits of Brodokalmak for the 20-25 cm soil layer (layer of the soil in which Sr-90 is in a biologically accessible form) allows one to evaluate the total Sr-90 stock from Cs-137 stock measurements. The means of Sr-90 stock in site “B” are presented in Table 3. The relation of Cs-137 stock (measured by the RKG-09N device) to density of Sr-90 contamination in the top 20 cm of soil varies in limits from 1.7 up to 5.6 and is stipulated by the structure of depth contamination distribution. In places where a covering purer layer of sedimentation does not exist over the contaminated one (Nos. 57-58, 68, 73, etc.), the ratio of the stocks Cs-137/Sr-90 changes in limits from two up to 3, and in points, where the pure layer is brightly expressed, this ratio is in an interval from 3 to 5.6. The analysis of ratios shows that

TABLE 3. CHARACTERISTICS OF SOIL Cs-137 AND Sr-90 CONTAMINATION ON RIGHT-HAND BANK (SITE “B”).

	Sample Method			Field Radiometry (RKG 09N)					Ratio	EDR
N	Density	Cs-137 Stock	Sr-90 Stock	Stock	Part of Stock in 3 g/cm^2	Radiation Thickness, g/cm^2				
	g/sm^3	μCi/m^2	μCi/m^2	μCi/m^2		80-100%	Clear Layer	Cont. Layer		μR/h
Main profile										
52	1.40	23.3	10.6	40.	.0	24.	11.	13.	.57	31
53	1.50	60.3	15.9	46.	.0	25.	12.	13.	1.30	33
54	1.40	43.1	12.6	41.	.0	27.	8.	19.	1.05	42
55	1.35	71.1	19.7	58.	.0	30.	6.	24.	1.22	53
56	1.50	15.7	13.4	22.	18.	23.	.0	23.	.73	46
57		14.0	6.6	14.	14.	28.	.0	28.	1.10	32
58		7.3	3.0	13.	14.	28.	.0	28.	.52	25
59		3.9	1.0	11.	.0	26.	13.	13.	.37	20
60		.43	0.3	.53	100.	.0	.0	.0	.81	14
61	1.05	12.2	2.4	7.5	15.	26.	.0	26.	1.63	19
62	1.95	10.6	1.4	7.8	.0	27.	14.	13.	1.36	13
Eastern profile										
63	.90	47.4	9.5	49.	.0	25.	12.	13.	.96	36
64	1.25	80.0	18.0	58.	.0	24.	11.	13.	1.25	49
65	1.70	68.5	12.6	59.	.0	25.	12.	13.	1.16	48
66	1.45	55.9	26.2	51.	:.0	30.	6.	24.	1.10	50
67	1.70	23.8	9.3	34.	.0	38.	.8	37.	.70	41
68	1.85	1.2	0.8	2.1	12.	31.	.0	31.	.55	21
69	1.90	.43	0.4	.19	100.0	.0	.0	.0	2.26	15
Western profile										
70	1.60	36.5	13.4	42.	.0	26.	9.	17.	.87	30
71	1.70	32.5	26.4	54.	.0	26.	13.	13.	.61	47
72	1.60	48.9	9.6	40.	14.	27.	.0	27.	1.21	49
73	1.55	17.2	8.5	17.	14.	28.	.0	28.	1.01	32
74	1.25	13.3	4.1	20.	.0	30.	6.	24.	.68	30
75	1.50	15.3	4.1	11.	12.	30.	.0	30.	1.36	25
76		7.4	2.8	12.	14.	28.	.0	28.	.63	22
77	1.25	1.8	1.5	9.4	.0	25.	9.	16.	.19	18

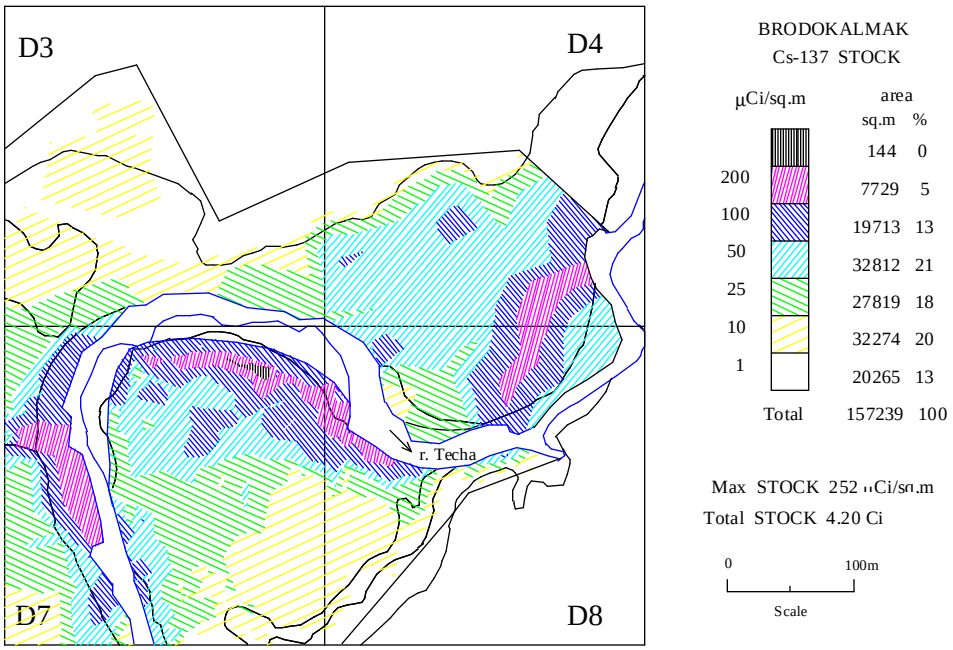

FIGURE 6. THE CONTAMINATION DISTRIBUTION IN EAST PART OF SURVEY TERRITORY.

measured values of Sr-90 stock in the presence of the pure layer over the contaminated one are obviously decreased.

Thus, the received maps of the Cs-137 stock distribution in a zero approximation within the limits of a limited river site can be considered to be maps of Sr-90 stock distribution in view of the constant factor, which for Brodokalmak is within the frame of 0.3-0.5. In particular, from the value of total Cs-137 stock, ~17.8 Ci on the investigated territory (4.5 km site of Techa River with a total bank territory area of about one square kilometer), the Sr-90 total stock can be evaluated. Its mean for the given district is ~9.0 Ci.

As a result of measurements, the electronic database of surface Cs-137 stock distribution and its penetration depth has been created; the maps of contamination distribution in the bank territory of the Techa River in the Brodokalmak settlement have been made.

CONCLUSIONS

The developed technique of definition of surface Cs-137 activity in view of its penetration depth in the soil by the collimated radiometer is the most effective way of large-scale mapping of the contaminated district to date. The technique permits one to detail the borders of contaminated places according to established criteria and to determine the total Cs-137 stock on the surveyed territory. The analysis of received data enables one to establish places of accumulation, removing of gamma radiating radionuclides, and places of sedimentation of a “pure” soil layer over a contaminated one. The results of the radiation survey permit one to analyze the character of contamination distribution in the bank territory, to predict probable processes of Cs-137 transport along the river bed, to simulate the changing of radiation conditions during various remediation measures, and to define their efficiency.

The computer database of Cs-137 stock distribution has been created for the bank territory of the Techa River within the borders of the Brodokalmak settlement. The values of Cs-137 stock are connected to the particularities of the bank territory structure and vary along the river in wide limits. When Cs-137 penetration depth in soil exceeds 25 cm in most places, it is necessary to plan to carry out decontamination. Availability of separate local places with increased Cs-137 stock in the top soil layer, as well as more "pure" sedimentation, depends on intensive river bed processes. The received maps of distribution of Cs-137 stock may be considered as the basis for valuation of Sr-90 stock.

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