Akaki Tsereteli State University
Faculty of Engineering and Technology

MAKA KHETSURIANI

RADIOECOLOGICAL INVESTIGATION IN THE CITY OF KUTAISI AND IN ADJACENT LANDSCAPES

The Author's Abstract
of the Doctoral Thesis Nominated for Ph Doctor Degree
in Environmental Engineering and Safety (0413)

KUTAISI
2013

The given work is executed at the Department of Chemical Engineering of the Faculty of Engineering and Technology at the Akaki Tsereteli State University.

Scientific Adviser: Dr. **Zaur Chankseliani**, Doctor of Agricultural Science, Academician of the Academy of Agricultural Sciences

Reviewers: **Tinatin Dzadzamia**, Senior Scientist of Hydrology and Engineering Geology of Georgian Technical University. Doctor of Agricultural Science

Revaz Melkadze, Researcher of Technical and Technological Sciences Scientific Studies Direction of ATSU Scientific Research Centre;Coordinator of the Direction; Doctor of Technical Sciences.

Defense of a thesis will be held on February ---, 2013 at the session of the Dissertation Commission created by Dissertation Council of the Faculty of Engineering and Technology. Address: Auditorium №111450, Building 1, 59 Tamar Mepe Street, 4600, Kutaisi.

Dissertation is available in the library of the Akaki Tsereteli State University at the address: 59 Tamar Mepe Street, 4600, Kutaisi
The Author's Abstract had been sent out „___"_____

Dissertation Council
Secretary _____ /_____/

General Description of Research

Topicality of Research

Under conditions of contemporary technogenesis, the radioactive sources play a large role in environmental pollution. In industrial production, when using the fertilizers in agricultural sector as well as due to the nuclear explosion and radiological accidents there are appeared the radionuclides, which release into the ground, plants, animals, water, human organisms and then they become a part of ecological cycle in kind of a food chain.

Georgia is a country with high natural radiation background that is conditioned by its geological and geophysical position. Also, due to the same factors, release of artificial radionuclides takes place on its territory. And the latter one, in turn, increases radiation background of the environment. Consequently, there is a risk of growing the dose of irradiation for population.

The proposed research is even more topical since the geographical location of Kutaisi area facilitates the spreading of artificial radionuclides that takes place in even without that high natural radiation background conditions. A special emphasis must be placed on fact that despite the topicality of this issue, it was never carried out such research before.

Goals and Objectives of Research

The proposed research is aimed to determine the content of radionuclides, study the natural radiation background and search for probable out of control radioactive sources in the City of Kutaisi and its adjacent landscapes (in river waters, plants and grounds of territories adjacent to main industrial enterprises and facilities), including the areas of former home station of former Soviet army in Kutaisi, as well as to design mathematical model for investigation of the migration of radionuclides in ground waters.

Main Results and Novelty of Research

For the first time ever there have been: determined the content of radionuclides and radiation background in the City of Kutaisi and adjacent landscapes; drawn up the radioecological maps of grounds and natural radiation background in Kutaisi area (at depths to 0.5 sm and 5.20 sm); designed the mathematical model of radionuclide migration in ground waters; developed several preventive and rehabilitation activities.

Practical Bearing and Implementation

In terms of practical application the essential provisions and conclusions of the proposed dissertation can be used in developing the various facilities (schools, kindergartens, foodservice facilities and so on) and in the process for the development of agricultural lands in the City of Kutaisi and its surroundings.

It is reasonable that the results of this research should be applied by scientists and researchers in the future. Based on the results of the proposed research, this research enables to develop the state and regional programs intended for further study of mentioned territories as well as for developing the rehabilitation activities.

With a view to providing the population with potable water, the considerable aspect of the regional planning is the development of mathematical model for radionuclide migration in ground waters and then its analysis as well.

The research results may be applied for the environmental components (soils, rivers and plants) for determination of the permissible regulatory limits of radionuclides.

The Provisions Brought to Defense

The determined content of radionuclides (^{40}K, ^{224}Ra, ^{226}Ra, ^{212}Pb, ^{214}Pb, ^{211}Bi, ^{214}Bi, ^{208}Ta, ^{235}U, ^{228}Ac, ^{137}Cs and others) in the grounds, rivers, river sediments and plants in the city of Kutaisi and its adjucent landcapes; the determined content of radionuclides in the grounds (at depth to 0.5 sm) and plants of areas of former home station of former Soviet army in Kutaisi; the natural radiation background in Kutaisi area.

The radiological maps of natural radiation background and soils (at depths to 0.5 sm and 5.20 sm) in the City of Kutaisi and its adjacent landscapes, which are drawn up on the basis of the research work performed.

The mathematical model of radionuclide migration in ground waters.

Approbation of Work

The basic provisions of dissertation are presented at the following conferences:

1. International Scientific Conference "Radiological and Agro-Ecological Investigations", Tbilisi, 2010. The Radiology and Ecology Institute;

2. International Scientific Conference "Radiological and Agro-Ecological Investigations", Tbilisi, 2010. The Radiology and Ecology Institute;
3. International Scientific-Practical Conference "Innovative Technologies and Environmental Protection, Kutaisi, 2012, Akaki Tsereteli State University;

Publication of research results: Basic part of dissertation.

There are published 15 scientific works.

Volume and Structure of Dissertation:

The volume of work is 124 computer printing pages. It includes 6 chapters, conclusions, 17 Tables, 2 schemes, 7 drawings, 2 maps, 26 diagrams and 4 annexes. The list of cited refernces comprises 151 sources, including 91 in foreign language.

BRIEF CONTENT OF DISSERTATION

Chapter.1. Environment and Radioecological Problems

There is carried out in a Chapter 1 the analytical literature review. There is considered an importance of studying the range of radiological problems under conditions of contemporary technogenesis as well as the radiation as an ecological factor is evaluated. Also there is studied the effect of ionizing radiation on biogeocenoses and shown the objectives of radioecology as an independent branch of science, and simultaneously, the links between it as a multidiscipline branch and other scientific disciplines.

An emphasis in a given work is placed on contamination of considerable part of ecosystem caused by the man impact as well as on pollution of the environment by agrochemicals. Also, there is considered a role of radioactive sources in environmental pollution, reviewed the natural and radioactive isotopes, the forms of radionuclides in the ground, routes of penetration of radioactive substances into the organism, and described the influence of the accident at the Chernobyl nuclear plant on radioecology in Georgia.

Chapter 2. Targets and Methods of Research

Second chapter is devoted to the targets and methods of research. There is described in this chapter the soils, rivers, vegetation cover and climate in Kutaisi area.

It is emphasized that quite a wide variability of natural conditions is typical of Kutaisi area, which is situated in zone of damp subtropical climate. The most common soils in this area are the following ones: alluvial, subtropical podsol, yellow soil, humus-carbonated and gray soils; from the rivers there are described Rioni, Tskhaltsitela, Chishura and Dzevrula. There is also reviewed a green cover in Kutaisi area: Mukhrani forest, Ajameti prorected area (Former Ajameti natural reserve), Sataplia natural reserve as well as protective zone located between this natural reserve and city, and artificial cork oak (Kolkhian) forest. It is emphasized that the green cover in Kutaisi area pertains to relict broad-leaved forests.

In addition to targets of research, there are considered in this chapter the methods, which have been used during 6 field research expeditions carried out in Kutaisi and its adjacent landscapes in 2020-2011-2012. With a view to radioecological contamination the research was carried out by using the methods and instruments accepted in radioecology: Comparison of absolute values of radionuclides obtained upon analysis of field works, and processing of digitally recorded data with mathematical-statistical method and by using the computer equipment; Determining the content of radionuclides and natural radiation background of the environment by using the geoinformation method; For the study of radionuclide migration in ground waters there have been used the mathematical model approach;

The content of radionuclides was determined in the equipment from Company CANBERRA existing in laboratory of the LEPL Agrarian Radiology and Ecology Institute by using the programs written by the same company in the alpha and gama spectrometric analyzers by using the „Genie-2000" software.

Chapter 3. Evaluation of Natural Radiation Background in Kutaisi Area

There is presented in this chapter the evaluation of natural radiation background of the environment in the study area, which was measured by using the scintillation dosimeter СРП-68-01, №3213 (see Table 1).

Table 1.

Indicators of Natural BackgroundRadiation in Kutaisi Zone

№	Research Area	Backgrou nd Radioatio nmcr/hr	Backgr ound Radioat ionngr/ hr	Annual Irradiation Dose (mzv/jr)	Real Active Dose (mzv/jr)
1	2	3	4	5	6
1	The Chishura riv.	10	100	0,87	0,17
2	The Tskaltsitela	14	140	1.23	0,25
3	Mukhnari forest	11	110	0,96	0.19
4	Gumati Village	12	120	1,05	0.21
5	Banoja Village	13	130	1,14	0,23
6	Kvitiri Village	9	90	0.78	0,16
7	Former Plant of Avantgarde	11.5	115	1.01	0.20
8	Former Plant of Lithophone (Tsereteli str.)	10	100	0,87	0,17
10	Kutaisi Entrance (From the side of Banoja)	10	100	0,87	0,17
11	Nikea Landfill (Nikea str.)	10	100	0,87	0,17
12	Parliament of Georgia	12	120	1,05	0.21
13	Agmashenebeli Ave.	8	80	0,70	0,14
14	Nikea str.	9	90	0.78	0,16
15	ATSU University	10	100	0,87	0,17
16	Chechelashvili str.	8	80	0,70	0,14
17	David Agmashenebeli Airport	10	100	0,87	0,17
18	The Oghaskura riv.	11.5	115	1,01	0.20
19	Chavchavadze ave.	12	120	1,05	0.21
20	Rustaveli ave.	10	100	0,87	0,17
21	Akhalgazrdoba ave.	13	130	1,14	0,23
22	Kutaisi Entrance (frim the east)	12	120	1,05	0.21
23	Houshold Plant "Fresh-Georgia" (Avtomshenebeli ave.)	9	90	0.78	0,16

1	2	3	4	5	7
24	Mrttalurgical Plant (Shevchenko str.)	11	110	0,96	0.19
25	Cement Plant Ltd. "Tobe" (Avtomshenebeli ave.)	9	90	0.78	0,16
26	Automechanic Plant (Avtomshenebeli ave.)	10	100	0,87	0,17
27	Lemonade Plant Ltd."Noka" (Tabukashvili str.)	12	120	1,05	0.21
28	Former Electromechanic Plant (Gugunava str.)	9	90	0.78	0,16
9	Botanical Garden	9	90	0.78	0,16
30	Kutaisi Central Square	10	100	0,87	0,17
31	Bagrati Cathedral	9	90	0.78	0,16
32	Godogani Village	13	130	1,14	0,23
33	Vartsikhe Village	13	130	1,14	0,23

As seen from Table 1, the natural radiation background in the City of Kutaisi and its adjacent landscapes varies from 8 to 14 mcR/per hour and it is considerably lower than permissible level (20-30 mcR/per). Also, there are given in this Table the annual radiation doses (mSv/per year) with a view to radiation sanitary and hygiene, which the local population has been exposed to and which varies from 0,70 mSv/per year to 1,23 mSv/per year.

Based on these data, the map of natural radiation background in Kutaisi area is drawn up (see the Map № 1).

Chapter 4. Determining the Content of Radionuclides in Different Rings of Ecological Chain in Kutaisi Area

There is presented in this chapter the content of radionuclides determined in different rings of ecological chain in Kutaisi area during research works. This chapter consists of three sub-chapters; in the first sub-chapter there is considered the study of grounds in the City of Kutaisi and its adjacent landscapes.

The content of radionuclides (according to data of 2010-2012) in the grounds of the City of Kutaisi (Bq/kg) is given in Table 2.

Table 2.

Consistency of Radionuclides in the Soil of Kutaisi Zone bec/kg

№	Screening place	Depth cm.	Radionuclides with activities bec/kg								
			^{40}K	^{137}Cs	^{208}Tl	^{212}Pb	^{214}Pb	^{214}Bi	^{224}Ra	^{226}Ra	
1	2	3	4	5	6	7	8	9	10	11	12
1	Mukhnari forest	0-5	187	53	14	38		14	380		
8	Sataplia Reservation Entrance	0-5	376	92	5.3				398		
		5-20	493	104	13				322		
9	km away from Sataplia Reservation	0-5	682	56	10					13	
		5-20	41	25					125		
10	2km away from Sataplia Reservation	0-5	374	37	6.1	5.5			62.5		
		5-20	611	28					81	16	
11	3km away from Sataplia Reservation	0-5	1702						326	18	
		5-20	2020		6.2				241	14	
2	The Tskaltsitela riv. (at New Bridge)	0-5	440	17		37			425		
		5-20	524	47					279	18	
3	Chognari Alley	0-5	351	82	21				350	15	
14	Parliament Building	0-5	548	57		30				17	
7	Kutaisi entrance (from Banoja side)	0-5	388	4.8	208	36		14		16	
		5-20	534	3.3	40	38	8.8			14	^{228}Ac-22 ^{219}Rn-14
		20-40	594			27				17	
		40-60	623		11	33				17	^{228}Ac-27
		60-90	289		13	44				17	^{228}Ac-25
5	Gumati Entrance	0-5	237	103		45				18	
12	Kvitiri Village	0-5	401	27	22	29	5			13	^{59}Fe-1.8
13	Former Autoconstructing Plant	0-5	567	32	23	37	10			10	^{54}Mn-0,7
18	Mukhnari forest near the	0-5	556	4	42	45	32	18			^{228}Ac-28 ^{211}Bi-98

	Tskaltsitela riv.										
6	Gumati near the Rioni riv.	0-5	595	13	26	30				16	^{54}Mn-0,9 ^{219}Rn-21
4	Near the Chishura riv.	0-5	295	28	25	28		15		17	^{211}Bi-76
		5-20	393	70	26	36		15			^{211}Bi-76
		20-40	473		7.8	19	13			28	
		40-60	336			23	17			42	
15	Former Avantgarde Plant	0-5	423	54	23	27					
16	Near Landfill	0-5	455		26	28	5,7			16	^{7}Be-6,6 ^{203}Hg-1,3
17	Former Lithophone Plant	0-5	110	23		6.3					
		5-20	53	13.5			3,5			3,1	

As seen from Table 2, the maximum content of ^{40}K (2020 during research works was fixed at a distance of 3 km southwestward from Sataplia natural reserve at depth 20-40 sm in the layer of the soil, but the minimum content (53 Bq/kg) – near to the former Kutaisi Lithopone Plant at depth 5-20 sm in the layer of the soil. The overall average content of ^{40}K varies at most from 500 to 600 Bq/kg that is by 1,4-1,6 times higher (according to data of Moscow State University, the permissible level of the average volumetric activity is 370 Bq/kg).

Diagram 1. ^{40}K migration in the soil of Kutaisi Zone (Bec/kg)

As is seen from Diagram 1, the content of ^{40}K radionuclide in the Banoja village area at depth 0,5 sm is lower than at depth 5.20 sm. At the same time,

the migration of ^{40}K in the soil from up to down is occurred naturally. In particular, the movable forms of the isotope of ^{40}K move from up to down, but in the parent material its content is lower.

The content of Ra^{226}-isotope in samples reaches the maximum quantity (42 Bq/kg) at depth 40-6- sm in the ground layer near the Chishura River, but the minimum quantity – in the ground adjacent to the former Kutaisi Lithopone Plant (3,1 Bq/kg). Its average content varies from 15 to 18 Bq/kg that is within normal ranges, since the permissible volumetric activity in the soils with ^{226}Ra is 38 Bq/kg (V.F. Kozlov. Radiation Safety Reference Guide, Moscow, 1991).

The content of ^{224}Ra isotope reaches the maximum quantity (425 Bq/kg) at depth in the ground layer near the Tskaltsitela River, but the minimum quantity (62,5 Bq/kg) at 0,5 depth of the ground layer at a distance 2 km southwestward from the Sataplia natural reserve.

The maximum content of ^{212}Pb (45 Bq/kg) was fixed on the highway (from the East and South at the entrance to the city of Kutaisi) at depth 0.5 sm in the ground layer, but the minimum content (5,5 Bq/kg) near to the Sataplia natural reserve at a distance of 2 km (southwestward) at depth 0,5 sm in the ground layer. Generally, the depositing of ^{212}Pb is caused by vehicle exhaust emissions.

The content of ^{214}Pb-taken from samples varies from 3,5 Bq/kg (at depth 5,20 sm in the ground near to the former Kutaisi Lithopone Plant) to 32 Bq/kg (at depth 0,5 sm in the ground near the Tskaltsitela River, in Mukhnari forest park). It is a product of decomposition of ^{226}Ra. Therefore, ^{214}Pb will be always fixed when the ^{226}Ra exists.

The maximum content of ^{208}Tl (42 Bq/kg) reaches at depth 0.5 sm in the layer of ground existed in Mukhrani forest park near the Tskaltsitela River, but the minimum content (5,3 Bq/kg) – at depth 0,5 sm in the ground at the entrance to the Sataplia natural reserve. It represents a product of decomposition of ^{224}Ra and ^{12}Pb. Therefore, its existence in case with radionuclides is perfectly natural.

The maximum content of ^{137}Cs radionuclide was fixed at depth 0,5 sm (104 Bq/kg) in the ground at the entrance to the Sataplia natural reserve, but the minimum content (3,3 Bq/kg) at depth 5.20 sm at the entrance to the City of Kutaisi from the side of Banoja village. The average content of ^{137}Cs varies

from 50 to 57 Bq/kg.

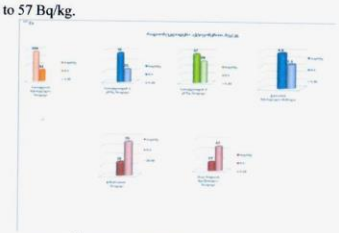


Diagram 2. ^{137}Cs migration in the soil of Kutaisi Zone (Bec/kg)

As is seen from Diagram 2, the content of artificial radionuclide ^{137}Cs in the area of Banoja village at depth 0,5 sm is higher than at 5,20 sm that indicates that the upper layer of Banoja ground is rich with humus and it has a heavy mechanical composition that is conditioned by binding of ^{137}Cs in the upper layers.

It is clearly seen from the same Diagram that we have a different picture in the grounds near the Chishura and Tskaltsitela rivers. This circumstance demonstrates the less content of humus in the upper layers of these grounds as well as the light mechanical composition (skeletal soils). Therefore, the radionuclide ^{137}Cs moves from up to down.

As is seen from the column "Others" of Table 2, in the samples of soils at the several points there have been fixed some contents of ^{228}Ac, ^{211}Bi, ^{219}Rn and ^{54}Mn isotopes. It is noticeable that at depth 0.5 sm in the grounds at the landfill there was fixed ^{7}Be (6,6 Bq/kg) and ^{203}Hg (1,3 Bq/kg) that is caused by domestic waste.

As a result of the study of soils the determined volumetric activities of radionuclides (at depth 0,5 sm and 5,20 sm) have been drawn on the radioecological map (see the Map №2).

In the second sub-chapter of the Chapter 4, there is shown the determination of the content of radionuclides in the samples of waters and deposits of the rivers in the City of Kutaisi and its adjacent landscapes, for

which purpose these samples have been taken from the rivers of Rioni, Chishura, Tskaltsitela and Ogaskura (see Table 3).

Chart3.

Water Screening Guidance for Radionuclides in the Rivers of Kutaisi Zone (bec/L)

№	Screening place	Radionuclides with activities, bec/L						
		^{40}K	^{137}Cs	^{208}Tl	^{212}Pb	^{214}Pb	^{214}Bi	^{224}Ra
1	Spring near the Chishura riv.	64						
3	Chishura Residue	652	3,45	6.3	29			295
4	Chishura riv.	63,5						
5	Rioni riv. Lithaphone Plant	52						
6	Rioni riv. – Kutaisi entrance	58					4.6	
7	Rioni riv. – Landfill residue	455		26	28	5.7		16
8	Rioni riv. – Gumati Residue	572		28	39	30	18	19
9	NNarrow stream at 2km away from Sataplia	77		6.2				34
10	Tskaltsitela riv. at New bridge	53					3.1	
11	Tskaltsitela riv. residue	569	7.4	10	36	16		17
12	former Lithophone Plant settling reservoirs near Dry Bridge	84		6.7			2.3	24
13	Oghaskura riv.	116		4.7				
14	Running Water (Kvitiri Village)	40						

As is seen from Table 3, the isotope of potassium (^{40}K) was found in largest quantities in the rivers of Kutaisi area. In particular, the maximum content of ^{40}K (652 Bq/l) in the rivers of Kutaisi area was fixed in deposits of Chishura River. The volume activity of ^{40}K on the territory of Kvitiri village in the samples of potable water was 48 Bq/l that is two times higher than permissible level.

The isotope ^{224}Ra reaches maximum content (295 Bq/l)in deposits of

Chishura River.

The following contents of isotopes have been discovered in the studied samples: ^{212}Pb and ^{214}Pb, ^{208}Tl, ^{214}Bi, ^{137}Cs.

In the third sub-chapter of Chapter 4, there are given the results of radioecological investigations in plants existing in the City of Kutaisi and its adjacent landscapes. In particular, the investigation was carried out in the most common in Kutaisi area plants, such as oak and plane trees; as well as in laurel, zelkova, tkemali and in such coniferous plant as cypress. The determined contents of radionuclides in the samples of leaves from mentioned plants are shown in Table 4. Chart 4.

Plant Leaves Screening Guidance for Radionuclides in the Kutaisi Zone (bec/kg)

№	Sample type; screening place	Radionuclides (bec/kg)								
		^{7}Be	^{40}K	^{137}Cs	^{208}Tl	^{212}Pb	^{214}Pb	^{214}Bi	^{224}Ra	^{226}Ra
1	2	3	4	5	6	7	8	9	10	11
1	Oak (Mukhnari forest)		1673	19	27		55	78		
2	Oak (Gumati Entrance)		691				18			
3	Kvitiri - Laurel		730							
4	Oak (Chognari alley)		711	5.4						21
4	Oak (Sataplia Reservoir Entrance)		791							
5	Oak (1km away from Sataplia Reservoir)		1548							61
8	Oak (3km away from Sataplia Reservoir)		1535	5.3						
9	Hay (Avtokarkhana str.)		816					31		
10	zelkova (T.Tabidze str)		654					15		
11	White Plum (T. Tabidze str)		863			18				
12	Cypress (T.Tabidze str.)	22	280							
13	Plane Tree (Akhalgazrdoba ave.)	33	734			26			128	
14	Plane Tree (Avtokharkhana Aitport)		456							
15	Plane Tree (Ninoshvili str.)		470					5.4		
17	Plane Tree (Tamar Mepe str.)		359							
18	Plane Tree (N. Lomouri str.)		585					7.5		
19	Plane Tree (Tsereteli str.)		495							
20	Plane Tree (Nikea str.)		376							
22	Plane Tree (at the building of Georgian Parliament.)		625							
23	Plane Tree (ave. –Park for students and Youth)		359				9.1			69
24	Plane Tree (Rustaveli ave.)		395							

As is seen from the data, according to overall content of ^{40}K, the largest quantity of them is fixed in Mukhrani forest park (1673 Bq/kg). It is necessary to note that when comparing the samples of soils and plants, there was defined the correlation dependence between the content of ^{40}K in the soil and the content of the same radionuclides in the leaves of oak tree. In particular, from the results of field research expeditions, the maximum content of ^{40}K was discovered in the ground (at depth 0,5 sm – 1702 Bq/kg, and at depth 5.20 sm – 2020 Bq/kg) existing at a distance of 3 km from the Sataplia natural reserve. Also, according to results of studying the all samples of plants, the maximum content of ^{40}K was fixed in the oak leaves existing at a distance of 3 km from the Sataplia natural reserve.

When calculating the transfer factor of ^{40}K from soil the soil into the plant, it is evident that it is quite high and equals (at depth 0,5 sm in the ground) 1673/1702=0,98 and (at depth 5,20 sm in the ground) 1673/2020=0,83.

As is seen from Table 5, the following isotopes have been discovered in the studying samples of plants: ^{212}Pb and ^{214}Pb, ^{208}Tl, ^{214}Bi, ^{224}Ra, ^{226}Ra, ^{7}Be, ^{137}Cs.

It is noticeable that pollution of of soils, plants and waters by radionuclides in Kutaisi area mostly does not exceed the permissible levels and by taking the correct radioecological measures it is possible to keep them at the present level and gradually to improve it in the future.

Chapter 5. Radioecological Evaluation of the Former Home Station Sites of the Former Soviet Army in the City of Kutaisi

There is reviewed in this Chapter the advisability of the study of conduscting of research in the former home station of the former Soviet army site located in Kutaisi area, and there are given the determined content of radionuclides in the grounds and leaves of the plants on this territory.

Table 5.

Soil (0.5 cm deep) Screening Guidance for Radionuclides in the Military Dislocation in Kutaisi Zone (bec/kg)

	Screening place	Radionuclides (bec/kg)											
		^{7}Be	^{40}K	^{137}Cs	^{208}Tl	^{212}Pb	^{212}Bi	^{214}Pb	^{214}Bi	^{224}Ra	^{226}Ra	^{228}Ac	^{235}U
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Landing Assault Brigade 31		361	96	17	26	26			286		66	
2	Artillery Regiment (Nikea str.)		429	29	15	24	24	11	16	264	16	61	
3	Cadre divisions Of Russian Defence "Blue Division"		359	102	20	32	31			344		79	
4	Food Warehouse (Ninoshvili str.)		415	38	19	30	30	10	14	331	14	76	
5	Russian Internal Troops (Cadet Training Centre)		334	35	15	23	23	8	11	253	11	58	
6	Communications Unit (Chechelashvili str.)		450	24	12	18	18	5	7	199	6.8	46	
7	Construction Battalion (near Press House)		419	12	15	23	24	11	16	256	16	59	8.9
8	Military Enterprise House (N Lomouri str.)		393		25	40	40	10	14	434	14		9.1
9	Army Headquarters 31		394		9.7	29	29	9	13	314	13	40	
10	The military repair works department (Chavchavadze str "Kechi")		587	42	15	24	24	8	11	260	11	59	
11	Housing - Maintenance department (Baku str.)		489	55	12	31	31	7	10	258	10	49	8
12	Communications base (Tamar Mephe str.)		687	52	16	24	24	15	21	266	21	61	
13	Ammunition Depot (Terjola district ;Godogani Village "Kokhi")		129	21	21	32	32	9	13	353	13	81	

14	Aviation bombs warehouse (Baghdati district; Vartsikhe Village)		727	14	11	17	17			185		42	5.1
15	Autokarkhana Airport		421	132	16	25	24			266		61	
16	Army Headquarters 31 (T.Tabidze str. (Akhali Mitsa))		455	46	17	26	26	11	16	285	16	65	

Table № 6.

Plant Screening Guidance for Radionuclides in the Military Dislocation in Kutaisi Zone (bec/kg)

№	Plant. Screening Place	^{7}Be	^{40}K	^{212}Pb	^{214}Bi	^{224}Ra
1	Dzelkova- Army Headquarters 31		654		15	
2	White Plum - Army Headquarters 31		863	18		
3	Plane Tree - Army Headquarters 31	22	280			
4	Plane Tree - Cadre divisions Of Russian Defence	33	734	26		128
5	Plane Tree – Autokarkhana Airport		456			
6	Plane Tree - Food Warehouse		470		5.4	
7	Plane Tree - Landing Assault Brigade 31		466			
8	Plane Tree – Constructing Batallion		395			
9	Plane Tree - Military Enterprise House		585		7.5	
10	Plane Tree - Aviation bombs warehouse		480			
11	Plane Tree - Artillery Regiment		376			
12	Plane Tree - Communications Battalion		472			
13	Plane Tree - The military repair works department		493			
14	Plane Tree - Ammunition Depot		555			

Particular attention in Table 6 needs to be directed toward ^{137}Cs isotope. Its content was fixed almost everywhere in a particularly large quantity (except two points). And, in a particularly most large quantity (102 Bq/kg) it was discovered on the territory of the former Division of Russian Ministry of Defense and on the territory of airport in Automobile Plant district (132 Bq/kg).

As is seen from Table, there has been discovered on the territory of Kutaisi the ^{235}U, which is called "the weapon-grade uranium". Among all

field research expeditions conducted on the territory of the city, existence of ^{235}U only in the former home station of Former Soviet army points to the pollution of these territories by military waste.

It is necessary to note that also the isotope of beryllium -7 was discovered in two points.

The content of radionuclides (at depth 0,5 sm) in the grounds of the former home station of former Soviet army in the city of Kutaisi is shown on the Map №2.

Chapter 6. The Mathematical Modeling of Radionuclide Migration in the Ground Waters

This Chapter is devoted to the setting the problem of radionuclides migration and description of mathematical model. For solution of problem there is used the finite elements method. There is considered in a Chapter the setting and solution of model problem.

The provision of population with potable water very often is carried out by means of ground waters, in particular as it takes place in Kutaisi. Thus and so, the analysis of ground waters flows as well as of radionuclides migration in them represents a significant aspect of regional planning.

There is considered in this Chapter the convective-dispersive transport in stationary planned filtration flow if there are the linear sources (river) and point flowing (water intake) as well as the point sources of pollutions (the dump).

One of the most efficient methods of the solution of transport problems of radioactive substances is the mathematical modeling approach, which as opposed to other approaches, is distinguished by its universality and flexibility.

In case of the existence of the intensity sources or leakage, the differential equation of stationary planned filtration takes the following form:

$$\frac{\partial}{\partial x}\left(T_x\frac{\partial H}{\partial x}\right)+\frac{\partial}{\partial y}\left(T_y\frac{\partial H}{\partial y}\right)+Q=0 \qquad (1)$$

where $H(x,y)$ - is a piezometric head; Q - - intensity of water sources (the water pumping corresponds to negative value); $T_x=k_x m, T_y=k_y m$ - the water-supply capacity ratios of layer along the axes x and y; m - capacity of layer (height).

The boundary conditions are written down as

$$H=H^* \qquad (2)$$

(the boundary condition of the first kind – there is assigned the pressure at the boundary) and (or)

$$T_x\frac{\partial H}{\partial x}\cdot l_x+T_y\frac{\partial H}{\partial y}\cdot l_y+q^*=0 \qquad (3)$$

(the boundary condition of the second kind – there is assigned the flow at the boundary), here $\vec{l}(l_x,l_y)$ - is a unit vector of outer normal line to the boundary line

Solution of the boundary value problem (1),(2),(3) ensures distribution of piezometric head $H(x,y)$ within the domain under study. The filtration field of velocities $\vec{V}(V_x,V_y)$ is determining by the following dependences:

$$V_x=-k_x\frac{\partial H}{\partial x}, V_y=-k_y\frac{\partial H}{\partial y} \qquad (4)$$

The differential equation of the convective-dispersive transport:

$$n\frac{\partial c}{\partial t}+V_x\frac{\partial c}{\partial x}+V_y\frac{\partial c}{\partial y}=\frac{\partial}{\partial x}\left(D_x\frac{\partial c}{\partial x}\right)+\frac{\partial}{\partial y}\left(D_y\frac{\partial c}{\partial y}\right) \qquad (5)$$

where the - D_x, D_y - are the dispersion factors in the direction of axes x and y; $c(t,x,y)$ - is a non-stationary concentration field of impurity.

The boundary and starting conditions take the following form:

$$c(t,x^*,y^*)=c^*$$
$$c(0,x,y)=c^0 \qquad (6)$$

(the boundary condition of the first kind – there is assigned the impurity concentration in the subterranean water).

For the solution of problem of ground waters movement and radionuclides migration by using the finite elements method, the numerical algorithm and FORTRAN computer program for personal computer have been developed.

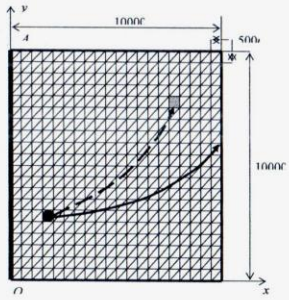
Setting and Solution of Model Problem

The filtration is considered in a plane area, which represents a square box the sides of which equal 10 km (Pic. 1). The river flows along the square side and ensures piezometric head with value of 200 m. The head on the opposite side is 150 m, the outputs on the other sides of square equal to zero. The filtration factors are k_x = 40 m/per day and k_y = 20 m/per day.

There are located in studying area the pinpoint pollution sources

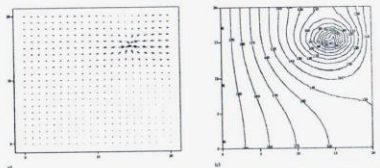
(shaded square box). In accordance with the filtration velocities field of the trajectory of ground water particles passing through the pollution source, the pollutants can penetrate into the water intake (dot line) and cannot penetrate into the water intake (unbroken line). In the first case the taken water is polluted, but in another case – it is not polluted.

The problem space was evenly decomposed into 800 triangular elements and the linear interpolation polynomials were used. The obtained linear algebraic equation system has been solved by using the Gaussian elimination method. The computation process was notable for higher response speed and stability.



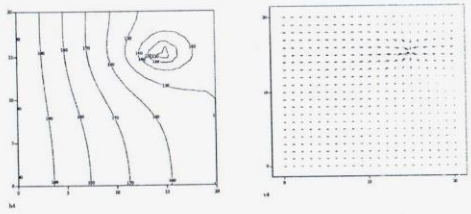
Pic.1. To the setting of model problem

With the water intake volume $Q = 10000m^3 / day$ the pictures of pressure levels and filtration velocities are shown on the Pic. 2. In this case the trajectory of particles passing through the source of pollutions is penetrated into the water intake area.



Pic.2. The line of the level of piezometric head and the field of velocities of the filtration movement in case of existence of water intake with volume $Q = 10000m^3 / day$

There is existed the critical value of water intake, when the subterranean water passing through the source of pollutions is not penetrating into the water intake area yet. There are shown on the Pic. 3 the pictures of levels of pressure and filtration velocities with critical value of water intake $Q_w = 3250m^3 / day$.



Pic.3. The line of the level of piezometric head and the field of velocities of the filtration movement with critical value of water intake $Q_w = 3250m^3 / day$

Conclusions and Recommendations

1. Based on the field and cameral studies, there is determined in the samples of soils, rivers and plants from the City of Kutaisi and its adjacent landscapes the content of the following radionuclides:. ^{40}K, ^{224}Ra, ^{226}Ra, ^{212}Pb, ^{214}Pb, ^{211}Bi, ^{214}Bi, ^{208}Ta, ^{235}U, ^{228}Ac, ^{219}Rn, ^{7}Be, ^{203}Hg, ^{59}Fe, ^{54}Mn, ^{137}Cs.
2. As a result or research,, the content of ^{137}Cs in the grounds adjacent to the rivers of Chishura and Tskaltsitela is coniderably higher at depth to 0-5 sm than at depths to 5-20 sm that points to the less conetent of hunus in the upper layers of these grounds, as well as to light mechanical composition (so-called ekeletal soils) that points to the less content of humus and to light mechanical composition that caused the movement of ^{137}Cs radionuclides from up to down. But in the grounds adjacent to Sataplia natural reserve (from south-west side) at depths to 0-5 sm, the content of ^{137}Cs is higher than t depths to 5-20 sm that points to the fact that upper layer of the ground on this territory has a heavy mechanical composition and is rich with humus that has conditioned the binding of ^{137}Cs.
3. The high volumetric activities of ^{137}Cs (about 104 Bq/kg) was fixed on the studfying territory that represents the trace of "spotty" contamination caused by the accident at Chernobyl nuclear plant bringing here due to meteorological conditions, but the high content of ^{137}Cs (about 132 Bq/kg) in almost all sites of the former home station of the former Soviet army in the City of Kutaisi points to the fact that to the influence of the Chernobyl nuclear accident, there is added the influence of military waste of the armed forces that require to carry out additional studies and investigations;
4. Only in the grounds on the territory of the former home station of the former Soviet army, there was fixed the content of ^{235}U, which is called "the weapon-grade uranium" that conditions the necessity of monitoring of these sites
5. Only on the territory of Kutaisi landfill there were found 1,3 Bq/kg of ^{203}Hg that is caused by industrial or domestic waste.
6. As a result or research the maximum contents of bullet isotopes ^{212}Pb and ^{214}Pb have been fixed on the highways (at the entrances to the City of Kutaisi. Depositing of the these isotopes is caused by vehicles exhaust emissions
7. On the territory adjacent to Sataplia natural reserve, there was determined the correlation between the soil and the content of ^{40}K in the plants;
8. During the research works in the plants a certain amount of ^{7}Be was discovered that is also may be caused by vehicles exhaust emissions.
9. As aresult of mathematical modeling of radionuclides migration process in the ground waters, there have been developed the mathematical model, the numerical algorithm of model implementation and FORTRAN program for personal computer; there is given the setting model problem and conducted the computing experiments for
10. The mathematical model developed for the case of contamination of ground waters by radionuclides (during providing the population with potable water) allows quantitative evaluation of pollution in the water intake area. The computing experiment has shown that on the possibility of water intake pollution influence not only positional relationship of the source of pollution and water intake, and the direction of filtration flow in absentia of water intake, but the volume of taken water as well.
11. It was established that the natural radiation background on the studied territory varies from 8 to 14 mcR/per hour that is lower then permissible level (20-30 mcR/per) and does not endanger the population. There were no detected the out of control radioactive sources and radioactive contamination in the studies areas;
12. Based on the carried out research, for the first time ever in Georgia the maps of natural radiation background and radiological maps of the grounds (at depths to 0-5 sm and 5-20 sm) in the City of Kutaisi and its adjacent landscapes have been drawn up.
13. The research results can be used in the future by scientists and researchers. It should be useful to Emergency situations department of the Ministry of Internal Affairs, as well as to Defense and Health Ministries.
14. Based on the obtained results the carried out research enables to develop the state and regional programs for further studying the territories and developing the activities for their rehabilitation.
15. The rsults or research carried out can be used in the futre for the improvement of radiation safety standards in Georgia.

List of Publications Related to Dissertation:

1. M. Khetsuriani. Ecological Investigation of Bio-Landscapes Adjacent to the city of Kutaisi. LEPL Agrarian Radiology and Ecology Institute. Radiological and Agro-Ecological Investigations. Vol. 7. Tbilisi. 2010, p.76
2. M. Khetsuriani. Environmental Protection Problems in Kutaisi. LEPL Agrarian Radiology and Ecology Institute. Radiological and Agro-Ecological Investigations. Vol. 7. Tbilisi. 2010, p.173
3. M. Khetsuriani. Brief Description of the Environmental Situation in Kutaisi. LEPL Agrarian Radiology and Ecology Institute. Radiological and Agro-Ecological Investigations. Vol. 7. Tbilisi. 2010, p.188.
4. M. Dvali, M. Macharashvili, G. Zardiashvili, Zh. Mindiashvili, F. Chebinova - LEPL Agrarian Radiology and Ecology Institute. M. Khetsuriani – Akaki Tsereteli State University. The Content of Radionuclides in the Soils and Some Agricultural Crops of Nikortsminda Village. LEPL Agrarian Radiology and Ecology Institute. Radiological and Agro-Ecological Investigations. Vol. 7. Tbilisi. 2010, p.74.
5. M. Khetsuriani. Radiological Description of Kutaisi and its Adjacent Territories. ATSU, International Scientific-Practical Conference. Kutaisi, 2011, p. 277.
6. M. Khetsuriani. The Content of Radionuclides in the grounds of Kutaisi Area. LEPL Agrarian Radiology and Ecology Institute. Radiological and Agro-Ecological Investigations. Vol. 8. Tbilisi. 2012. p.66.
7. M. Khetsuriani, V. Khvedelidze. Some Issues Related to Evaluation of Radioecological State the West Georgia's Mountain Areas and Epidemiology of Malignant tumors. The mountain Areas LEPL Agrarian Radiology and Ecology Institute. Radiological and Agro-Ecological Investigations. Vol. 8. Tbilisi. 2012. p.64.
8. E. Bibiluri, T. Bregadze, M. Khetsuriani, M. Mikeladze, Z. Chankseliani, M. Tsitskishvili. Radioecological Monitoring Results in Georgia and Implementation Problems. LEPL Agrarian Radiology and Ecology Institute. Radiological and Agro-Ecological Investigations. Vol. 8. Tbilisi. 2012. p.85.
9. M. Mikeladze, M. Liparteliani,, L. Khositashvili, M. Kandelaki, Ts.

Implementation Problems. Radiological and Agro-Ecological Investigations. Vol. VIII. Tbilisi. 2012. p.85.

9. M. Mikeladze, M. Liparteliani,, L. Khositashvili, M. Kandelaki, Ts. Chitiashvili, Al. Japaridze, M. Khetsuriani. Radioecological Description of Agro-Landscapes Adjacent to Zestapfoni Ferroalloys Plant. Radiological and Agro-Ecological Investigations. Vol. VIII. Tbilisi. 2012. p.47.
10. M. Tsitskishvili, E. Bibiluri, T. Bregadze, I. Goginava, M. Khetsuriani, T. Lagazauri. To the Radioecological Study of Radon in Georgia. Radiological and Agro-Ecological Investigations. Vol. VIII. Tbilisi. 2012. p.76.
11. M. Khetsuriani. Radioecological Investigation of Surface Waters in Kutaisi Area. ATSU, International Scientific-Practical Conference. Kutaisi, 2012, p.
12. K.Tskhakaia, M. Khetsuriani. The mathematical modeling of the migration of pollutants in subterranean waters. International Federation for the Promotion of Mechanism and Machine Science "Problems of mechanics" International scientific journal №4 (45) Tbilisi. 2011. page 97-102.
13. 13. M. Khetsuriani, B. Tvalodze. Vegetable Cover in the City of Kutaisi and in Adjacent Landscapes. ATSU International Scientific-Practical Conference. Kutaisi, 2012, p.
14. M.V. Khetsuriani, Doctoral candidate, E.A. Gamkrelidze, Doctor of Chemical Sciences (PhD), Akaki Tsereteli State University, Kutaisi, Georgia. Radioecological research of Kutaisi area surface, "Box of News". Gyanja. 2012. №50. page 70-75.
15. G.D. Chiradze, Z.Z. Mardaleishvili, M.V. Khetsuriani, N.D. Mandaria. Using of Time Series Analysis for the Porpoise of Data Processing of Radiation Monitoring of Site. Journal "New Technologies" 2012, №1.
16. George Chiradze, Zaza Mardaleishvili, Maka Khetsuriani, Akaki Tsereteli State University, Some Issues of Radiation Pollution of the City Area and Building the 3D Dynamic Model of Passive Transfer of Atmospheric Impurities.Buletten of Akaki Tsereteli State University, 2013, №1.