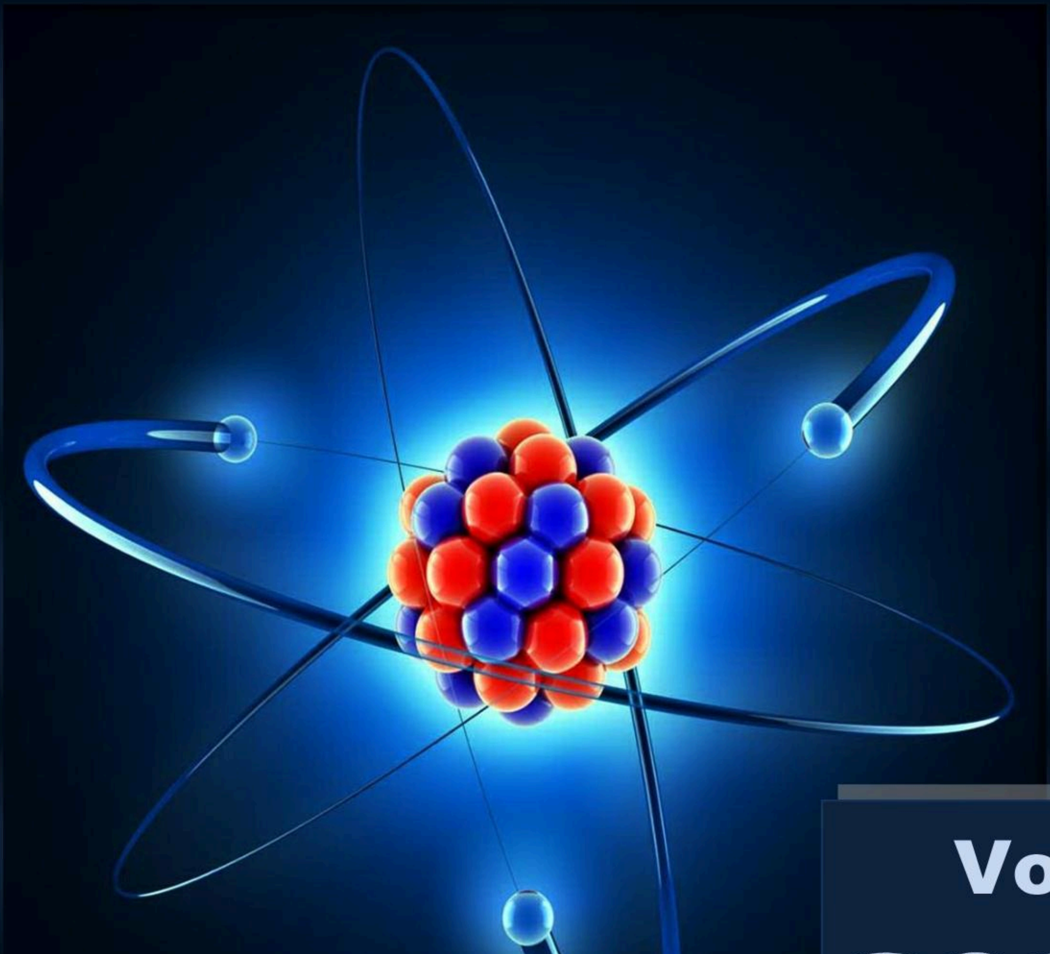
Radiobiology and Radiation Safety



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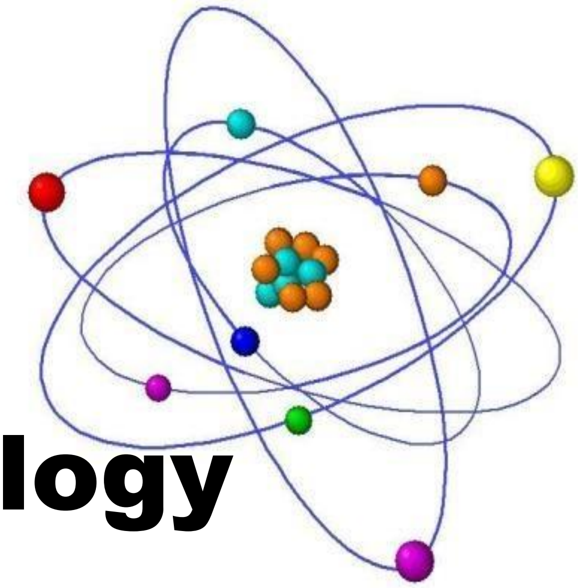

Radiobiology

and

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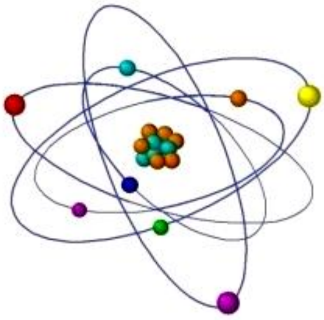
Ivane Tarkhnishvili

(Tarkhan-Mouravi - 1846-1908)

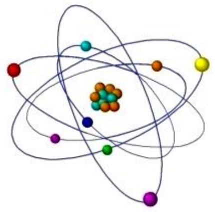
- 175 Years since His Birth



Ivane Tarkhnishvili (Tarkhan-Mouravi, June 1846 – September 1908) was a Georgian scientist from the Tarkhan-Mouravi noble family. He authored various scientific articles, one of which was the first article in Radiobiology. I.Tarkhnishvili's most significant contribution was the discovery of the influence of X-rays on the central nervous system, animal behavior, the heart and circulation, and embryonic development. Indeed, these works have given rise to a new field in science as Radiobiology.

After irradiating frogs and insects with X-rays in early 1896, several weeks after Röntgen's discovery, Tarkhanov concluded that these newly discovered rays not only photograph, but also they "affect the living function". These experiments signaled the birth of radiobiology. Ivane Tarkhnishvili found a marked attenuation of excitability and a total suppression of acidic reflexes. These experiments confirmed that the impairment of reflexes after X-ray exposure depended on neither analgesia nor sensitive skin but on the moderating effect of the central nervous system (CNS) itself. Studying the effects of X-rays on metabolism in the myocardium and the circulation of the heart, he concluded that all of the effects of X-rays were due to their moderating or retarding the activity of the CNS (1896). A few years later, Tarkhnishvili presented an extensive paper on the role of X-rays in biology and medicine (1903). Apart from the fact that Ivane Tarkhnishvili's first radiobiological researches were conducted mainly in the field of biomedical investigations, his further numerous works can be concluded that he laid the foundation for such important radiobiological directions as radioecology, phytoradiobiology, radiological neurobiology, radiobiology of the cardiovascular system, radiobiological informatics and others. Thus, his pioneer works had indeed forecast a new field of science as radiobiology.

DEVELOPMENT OF THE COMPLEX CYTO- AND MOLECULAR GENETIC MARKERS FOR PREDICTING OF COMPLICATION OF RADIOTHERAPY



Ormotsadze G.L., Zedginidze A.G.
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ABSTRACT

Prediction, prevention and treatment of early and especially late adverse effects of radiation therapy is an urgent task in modern biology and medicine. The aim of the present study was to evaluate the informativeness and clinical efficacy of cyto- and molecular-genetic characteristics of genome instability in terms of diagnosis and prognosis of radiogenic complications. 30 oncologic patients with larynx cancer (stage 2 end 3) undergoing the radiotherapy were investigated. The irradiation was carried out on a linear accelerator: 2Gy/fraction, total dose 70 Gy, Leucocytes, dicentric chromosomes, level of micronuclei in buccal (MnB) and erythrocytes and level of DNA-Cometbefore irradiation, after receiving half and total dose were investigated. Exploratory and confirmatory data analyses methods (K-mean Clustering, ANOVA, Xi^2,) were used. To identify the optimal predictors of the risk of complications, a Binary Logistic Regression analysis and Receiver operating characteristic (ROC) curve analysis was performed. After receiving a half-dose of irradiation a statistically significant *changes of all characteristics is observed in patients ($F \geq 9.21$; $p<0.001$). Clustering patients by the amplitude of radio-induced deviations from the background level (level before irradiation) of characteristics revealed groups of low and high risk of complications.It was confirmed that there is a causal relationship between the stage of the disease and the risk of complications, although its statistical significance is close to the threshold value ($\chi 2 = 8.22$, $p = 0.051$), which indicates that the stage of the disease is not the only factor that determines the risk of complications.Analysis of the cyto and molecular-genetic profile of the complication risk revealed a statistically significant relationship between it and the frequency of dicentric chromosomes, level of micronuclei in erythrocytes and buccal cells ($F \geq 5$; $p \leq 0.05$). The levels of leukocytes and DNA comets depend on both the stage and the level of risk ($F \geq 5$; $p \leq 0.05$). To determine the optimal predictors of the risk of complications, a binary logistic regression analysis was performed. It was found that the strongest predictors are the background level of DNA comets (regression coefficient = 0.89 ± 0.41; $p = 0.029$) and the micronuclei level in buccal cells (regression coefficient = 21.92 ± 8.86; $p = 0.013$). Using the Receiver Operating Characteristic analysis, revealed the high clinical efficacy of the criterion (AUC = 0.93), and the optimal Cutoff_level (0,5), providing Sensitivity = 0.866 and Specifity = 0.875.*

Our results suggest that levelof*the of DNA comets together with level of MnB*before treatment can be used to predict the risk of developing *complication* after*radiotherapy*.

Key words: radiotherapy, complications, micronuclei, DNA-comets

INTRODUCTION

Cancer is the second leading cause of morbidity and mortality worldwide, and is responsible for about 10 million deaths per year. Globally, about 1 in 6 deaths is due to cancer.Even though there are no specific drugsdesigned for it, radiotherapy (RT) is the main treatmentfor cancer and over 60% of cancer cases require radiation therapy. Modern cancer therapy has successfully cured many cancers and converted a terminal illness to chronic disease.However, like any therapeutic intervention, it is also characterized by complications that can be conditionally divided into early and late complications[1,2].The most common are short term side effects – results from destruction of some stem cells in the compartment of rapidly dividing epithelial tissues (skin, gut, oral mucosa, bone marrow, sclera and hair follicle). These side effects tend to be short-term and mild, most side effects go away after treatment. But some continue, come back, or develop later. These are called long-term or late effects. One possible late effect is the development of a second cancer. This is a new type of cancer that develops because of the original cancer treatment. The risk of this late effect is low. And the risk is often smaller than the benefit of treating the first cancer (https://*www.cancer.org*/*treatment*).

In the last two decades late non-cancer radiogenic effects are considered as a subject of a special attention, which is explained by the level of health risks associated with them, and the growth rate of the population at this risk. These effects, previously called deterministic effects, are now referred as tissue reactions because it is increasingly recognized that some of these effects are not determined solely at the time of irradiation but can be modified after radiation exposure.

In 2011 the International Commission on Radiological Protection approved a Statement on Tissue Reactions, suggesting that there are some tissue reaction effects, with very late manifestation. For the lens of the eye and for circulatory system, the threshold in absorbed dose is now considered to be 0.5 Gy. Most commonlate tissue effects observed in response to radiationtreatment are pericardial disease (acute pericarditis, delayed pericarditis, pericardial effusion, and constrictive pericarditis), radiation-induced atherosclerosis, myocardial and endocardial disease (pancarditis, cardiomyopathy), valvular disease and conduction disturbances [3-6]. If the early effects are temporary and disappear after a few weeks, the late effects tend to be irreversible and progressive in severity.Cardiotoxicity related to thoracic and mediastinal radiation therapy of cancer survivors remains the most common cause of morbidity and mortality [4-5]. Childhood cancer survivors represent a unique, particularly high-risk group, for example, if the radiotherapy for breast cancer was associated with an absolute risk increase of 76.4 (95%CI 36.8-130.5) cases of coronary heart disease and 125.5 (95%CI 98.8-157.9) cases of cardiac death per 100 000 person-years [5], then in survived childhood cancers patients the relative risk of severe cardiac disease at the age of 40 is 1.9 at a cardiac radiation dose of 1–5 Gy and 19.5–75.2 at a dose > 15 Gy [6-7].

Until recently, the classical model for explaining early and late radiogenic complications was the target cell hypothesis, according to which the severity of the complications mainly reflected tissue depletion resulting from direct destruction of putative target cells, leading to subsequent functional deficits[8].

Current understanding of the possible mechanisms of long-term complications, caused by radiation, include senescence to endothelial cells due to DNA damage and oxidative stress, Increased levels of IL-1, IL-6, IL-8, and TNF-α as well as reactive oxygen species [9-11], pro-inflammatory cell recruitment, thrombin, platelet activation [12], metabolic and immunologic alteration [13],the formation of persistent nonresolved inflammation [14]. The product of the above pathways is accelerated atherosclerosis, fibrin deposition, intimal thickening, lipid accumulation, inflammation, and thrombosis. The spectrum of coronary artery disease (CAD), cardiomyopathy, pericardial disease, valvular disease, and conduction abnormalities are collectively described as radiation-induced heart disease [15].

Modern approaches to solving this problem are based on the creation of models for the early stratification of the risk of complications, which will allow the identification of patients at high risk, the development of modified methods of radiation therapy and preventive treatment for them [7,15].

In this respect, the genomic instability is considered as a one of the most promising models, which allows to describe on a single hypothetical basis, both early and late radio-induced effects [16].Research is focused on the search for genes and gene products that determine the response to DNA damage, DNA repair, apoptosis and, most importantly, systemic effects due to the excitation of inflammatory "danger" signals and activation of the innate immune/autoimmune response, find ways of predicting thosepatients likely to suffer with long-term side effects, and develop new approaches for their amelioration [17-20].

The main limitation of genome-wide associative studies (GWAS) is due to the methodological difficulties in establishing a causal relationship between the genotype and phenotype of the patient and the risk of developing long-term complications in multigenic and multifactorial studies, and their relatively high cost [21].

Our approach, which aims to develop inexpensive, simple, clinical practice-oriented criteria for assessment of radiogenic health risk, and which includes experimental, clinical, and population-based studies, focuses on the development of complex risk predictors based on the integral characteristics of a number of functional systems of the body [22-28].

The aim of the present study was to evaluate the informativeness and clinical efficacy ofcyto-and molecular-genetic characteristics of genome instability in terms of diagnosis and prognosis of radiogenic complications.

MATERIALS AND METHODS

Source of Patients and data colection: 30 oncologic patients – 10 women and 20 men (mean age) with larynx cancer, undergoing the radiotherapy taking into account the stage of the disease were investigated. All patients were treated with a fractional radiotherapy. The irradiation was carried out on a linear accelerator with the following level: 2Gy/fraction, total dose (70 Gy). Hematologic and genetic (leucocytes, chromosomal aberration, between them dicentric chromosomes, micronuclei level in buccal mucosa cells and erythrocytes, DNAstrand break damage investigated by comet assay)analyses were carried out in dynamic - before irradiation, during half receiving dose and after finishing the course.

Statistical Methods. Exploratory and confirmatory data analyses methods (K-mean Clustering, ANOVA, Xi^2), were used to reveal the statistical significance of the difference between the mean values of the parameters.

To identify the optimal predictors of the risk of complications, a Binary Logistic Regression analysis was performed:

$$P(+) = \frac{EXP(Z)}{1+EXP(Z)} (1)$$

where P (+) is the probability that a particular patient with specific characteristics falls into the category of severe patients. Only linear combinations of individual parameters were considered at this stage:

$$Z = b_0 + b_1 X_1 + b_2 X_2 + . . . + b_n X_n \quad (2)$$

Where $\{\boldsymbol{X_i}\}_{\boldsymbol{i=1}}^{\boldsymbol{n}}$- values of n indicators of rescaled and re-centered in relation to physiological norm

$$X_i = \frac{X_i' - \overline{X'}}{STD(X')} (3)$$

To assessment of clinical effectiveness of the complex risk predictors, receiver operating characteristic (ROC) curve analysis was performed.For primary data processing, analysis and graphical visualization MATLAB R 2020 and STATISTICA-12 mathematical software packages were used.

RESULTS AND DISCUTION

After receiving half-dose of radiation, statistically significant changes (F> 9; p <0.001) of all characteristics was observed in comparison with thear background values. A fundamentally different regularity of genetic disorders was detected after receiving total dose; statistically significant increase (F> 9; p <0.001) of dicentric chromosomes, DNA comets, and and level of micronucleiency in buccal cells is observed, although the number of leukocyte count is unchanged (F> 9; p <0.001), and the frequency of micronuclei in erythrocytes is significantly reduced (F> 9). ; p <0.001). (Fig.1, Tab.1)

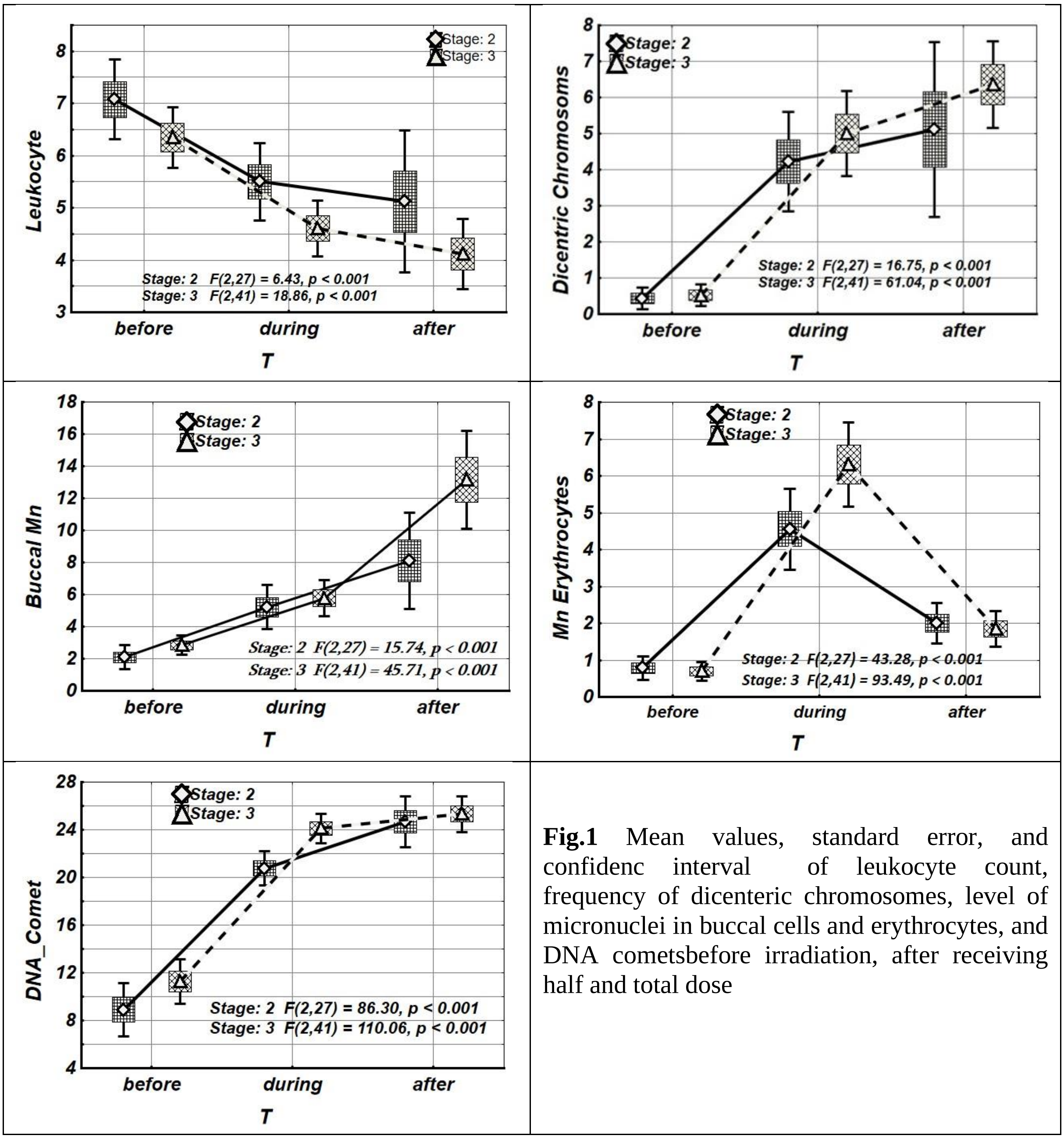

Fig.1 Mean values, standard error, and confidenc interval of leukocyte count, frequency of dicenteric chromosomes, level of micronuclei in buccal cells and erythrocytes, and DNA cometsbefore irradiation, after receiving half and total dose

The postradiation dynamics of the study characteristics presented in Fig.1 Tab.1 as a whole coincide with the existing representations about the processesin proliferating cell populations [28] developed after total irradiation, although the effects of local fractional irradiation are also clear. This is reflected in the nonlinear dose-dependence of quantitative and structural (genetic) changes in proliferating cell populations, as well as in the specificity of dose-dependent changes in different proliferating cell populations, which probably depends on the one hand on te amount of the absorbeddose andtheir radiosensitivity, and on the other hand on the length of their life cycle and the specifics ofeliminationof damaged oraged cells. With regard to the effects associated with the stage of cancer, this clearly indicates a close relationship of the severity of radiological changes with various modifying factors during radiation therapy. The presented regularities clearly indicate the methodological difficulties of prognosys the severity ofradiological complications under fractionated,local irradiation, which are

Tab.1 Dependence of postradiation dynamics of research characteristics on the stage of the disease

N	***Statistics***	***F; p***	***F; p***	***F; p***	***F; p***
	Stage Group	***Stage2***	***Stage2***	***Stage 3***	***Stage 3***
	Period	***Before÷During***	***During ÷After***	***Before÷During***	***During ÷After***
1.	Leucocytes	F=9.21; p<0.001	F=0.14; p=0,71	F=13.57; p<0,001	F=0.99; p=0,32
2.	Dicentrics	F=21.59; p<0.001	F=4.10; p=0.06	F=10.99; p=0.001	F=28.90;p<0,001
3.	Mn_Buccal	F=23.49; p<0.001	F=0,1; p=0,8	F= 17.80; p<0,001	F=28.90; p<0,001
4.	Mn-Erythro	F=76.41; p<0.001	F= 23.60; p<0,001	F=37.18;p<0,001	F=1,20; p=0,30
5.	DNA-Comet	F=84.07; p<0,001	F=12.28; p=0,003	F=125.50; p<0,001	F=1.89; p=0.18

related to the systemicity of effects, and require a complex approach to their solution.

Clustering of half-dose irradiated patients for values of their characteristic (K-mean clustering) revealed two groups of patients: 1) high level of leukocytes, low micronucleilevel in buccal cells and erythrocytes, low level of DNA-comet (low risk of complication), 2) low level of leukocytes, high level of micronuclei and DNA-comet (high risk of complication), (Fig.2). Given that chromosomal aberrations (dicentrics) and leukocytes are classic markers of the severity of acute radiation pathology, with a high degree of credibility we can assume that the identified groups of patients can be considered as high and low risk groups in terms of development of radiological complications. (It should be noted that in about 15% of patients in the high-risk group developed a side effect during or immediately aftertherapy).

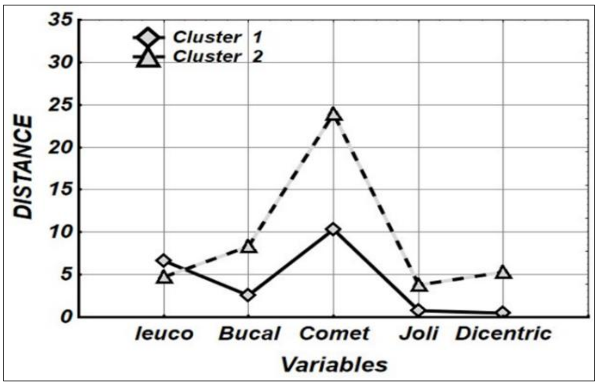

Fig. 2. Cluster means of normalized characteristics in patients of low (solid line) end high risk of complication (dashed line)

Expected and observed frequencies of high and low risk patients were analyzed to determine the possible causal relationship between disease stage and complication risk in the study cohort.It was confirmed that there is a causal relationship between the stage of the disease and the risk of complications, although its statistical significance is close to the threshold value ($\chi2 = 8.22$, $p = 0.051$), which indicates that the stage of the disease is not the only factor that determines the risk of complications (Fig. 3). Analyze of the cyto- and molecular-genetic profile of complication risk factors have revealed that groups of patients with high and low risk of complications after receiving half-dose of irradiation are statistically significantly different in the frequency of dicentric chromosomes, micronuclei level in erythrocytesand buccal cells**(F≥ 5; p≤ 0,05)**.

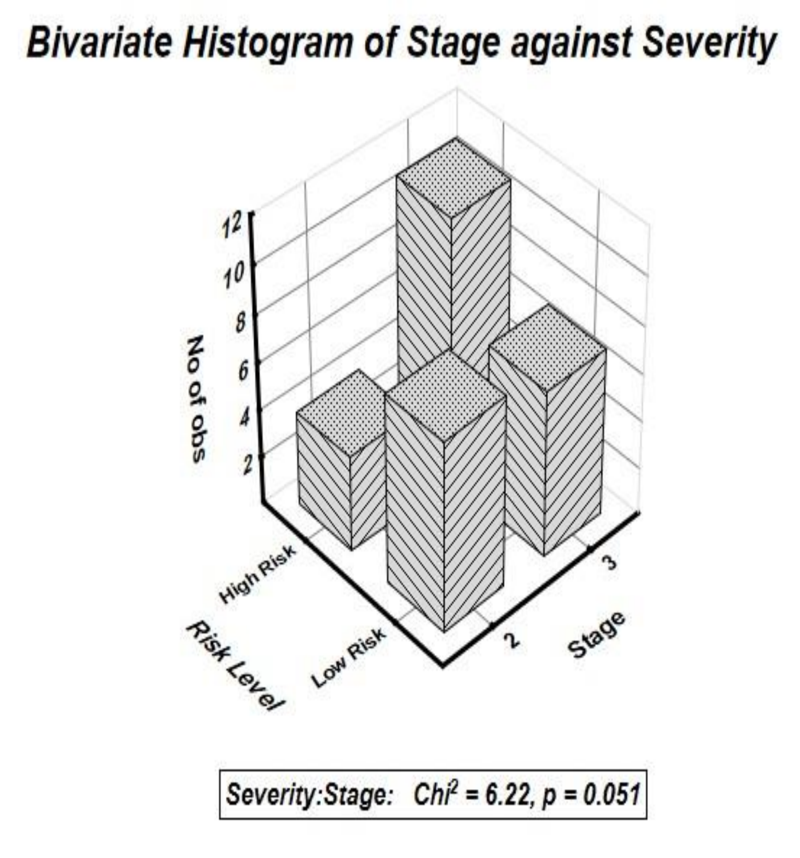

Fig.3. Patients distributions according to the stage of the disease and the risk of complications.

The influence of cancer stage on the values of these characteristics is not revealed ($F \leq 2$; $p \geq 0,3$). Leukocyte and DNA comet levels depend on both stage and risk level ($F \geq 5$; $p \leq 0,05$), (Fig.4, Tab.2).
The results clearly indicate the multifactorial nature of complication risk, the mechanisms of which we find impossible to analyze in the present article, although it is clear that the complexity of complication risk predictors is necessary.In view of the abovemultivariable logistic regression analysis was performed to develop a complex cyto end molecular-genetic predictor of risk of complication. At this stage of thestudy we were looking for a multivariate discriminant function in the form of a linear combination of the background frequencies of DNA comets of micro-nucleated buccal cells:

$$\mathbf{logit(y) \sim A_0 + A1 \times Mn + A_2 \times DNA\_Comet,}$$

Was shown, theth Linear function with regression coefficients$A_0=21.92\pm8.86$ ($p=0.013$),$_1=1.68\pm0.70$ ($p=0.017$), $A_2=0.89\pm0.41$ ($p=0.029$)significantly predicts high-risk patients groups(Tab.3**).**
The clinical performance of the complex prognostic criterion and the optimal cut-of value were assessed using the receiver operating characteristic (ROC) curve, which includes all possible decision thresholds from the result of the diagnostic test.As knownROC curves are a useful tool in the assessment of the performance of a diagnostic test over the range of possible values of a predictorvariable.

N	***Stage Group***	***Stage2***	***Stage 3***	***High Risk***	***Low Risk***
	Risk group	***High Risk÷Low Risk***	***High Risk÷Low Risk***	***Stage2÷ Stage3***	***Stage2÷Stage3***
1.	**Leucocytes**	F=8,2; p=0,025	F=1,2; p=0,26	F=0.65;p=0,26	F=6,3; p=0,02
1.	**Dicentrics**	F=5,3; p=0,04	F=53; p=0,002	F=0,64; p=0,82	F=1,46; p=0,44
2.	**Mn_Buccal**	F=16,8; p=0,008	F=17,8; p=0,002	F=0,17; p=0,80	F=0,10;p=0,85
3.	**MnErythro-**	F=9,0; p=0,02	F=5,0; p=0,03	F=7,3; p=0,015	F=1,50; p=0,23
4.	**DNA-Comets**	F=7,0; p=0,033	F=31,0; p=0,001	F=11,0; p=0,01	F=29,0; p=0,001

Tab. 2. Statistical significance of the influence of disease stage and complication risk on the level of leukocytes, the quantity of dicentric chromosomes, DNA comets, micronuclei in buccal cells and erythrocytesafter receiving half-dose of irradiation

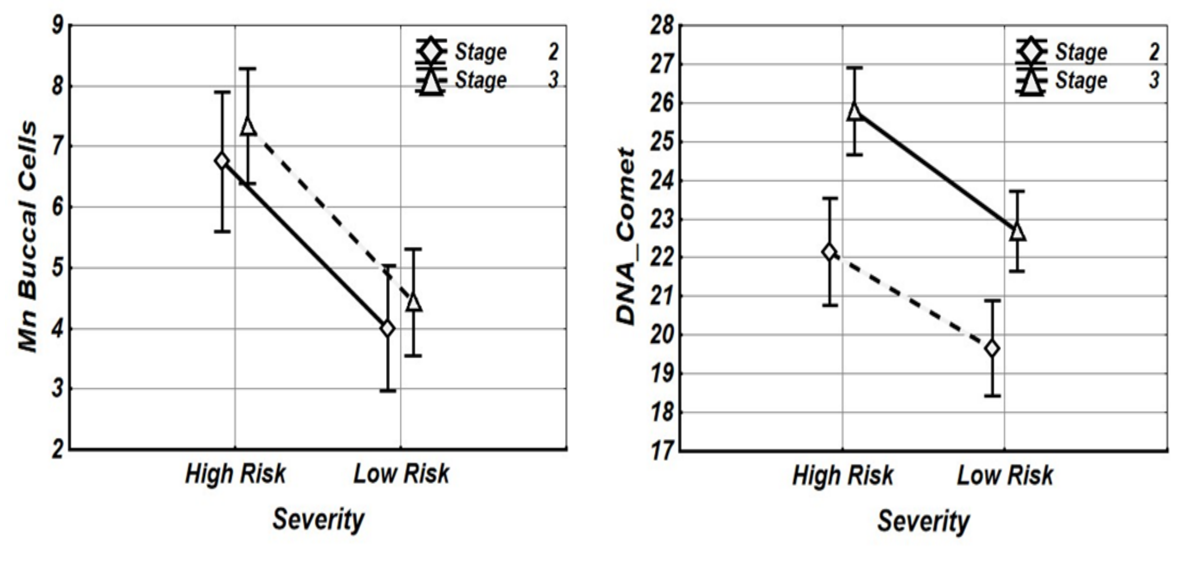

Fig.4. The background levels of micronucle in buccal cells and DNA comets in different risk and stage patient groups.

Logistic Regression, Binomial Distribution				
N	**Indicator**	**Estimate**	**SE**	**pValue**
1.	Intercept	-21.92	8.86	0.013
2.	Micronuclei	1.68	0.70	0.017
3.	DNA-Comet	0.89	0.41	0.029

Tab.3 Regression coefficients, Standard Error and p-value of multivariable linear discriminant function, for predicting the high-risk patients groups

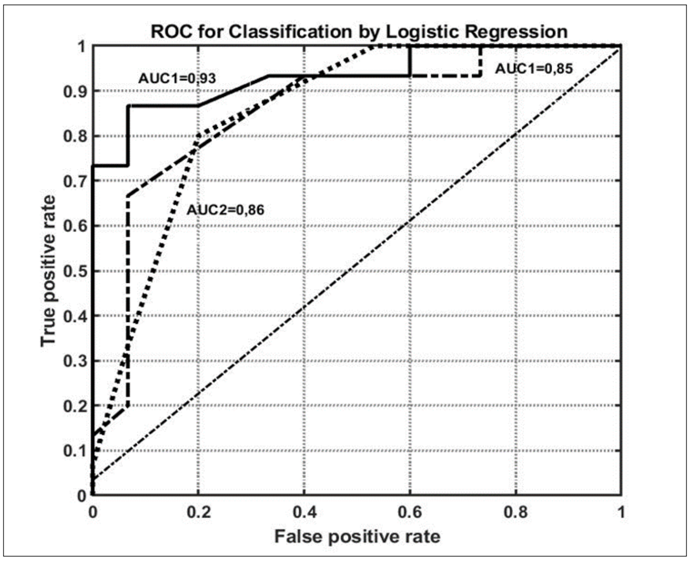

Fig.5: receiver operating characteristic curve (ROC) of MnB level (dotted line), DNA-Comet (dashdotted line) and its linear function(solid line) in predicting cases with highrisk, and the area under ROC curve (AUC) of the studied parameters in predicting cases with high complication risk

The area under the ROC curve of complex complication risk predictors (AUC = 0.93) indicates its high clinical efficacy compared to the individual characteristics of MnB (AUC = 0.86) and DNA-Comet (AUC = 0.85) (Fig.5).

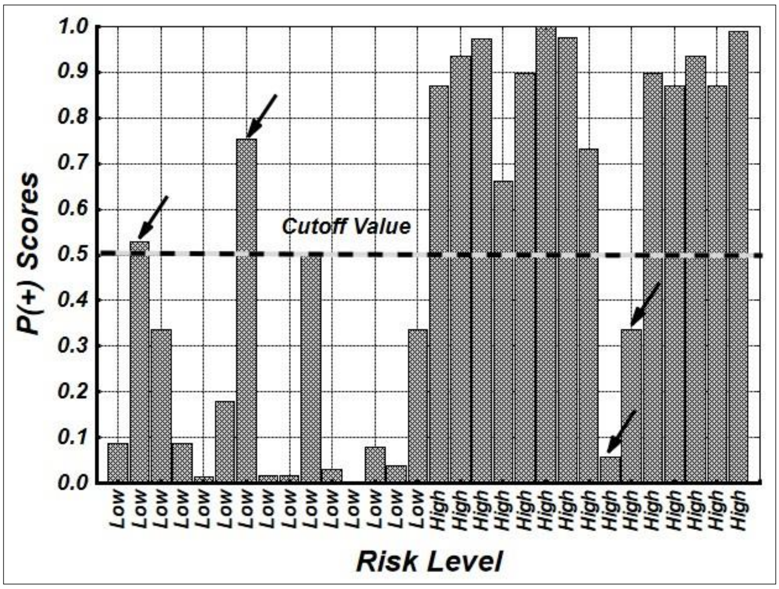

Fig. 6. Values of Logit function (P(+)) in low and high risk group patients and Cutoff value (dotted line). Arrows indicate incorrectly identified cases.

Figure 3 presents the values of complex discriminant function (P(+)) in low (0) and high (1) risk patients. Cut-of value P(+)=0,5 (dotted line) ensures the sensitivity of the criterion = 0.866 (86,6% of high risk patients are correctly identified) and specificity = 0.875(87,5% of low risk patients are correctly identified.

Limitation

We do not consider appropriate to generalize the adopted complex criteria to the whole population of larynx cancer patients, due to the limited sample size of a study cohort. However, the perspectives of the discussed approach are clear.

Conclusion

The results showed a high informative value of the complex criterion for assessing the risk of radiogenic complications of radiotherapy, developed on the basis of the DNA-comets and MnB levels before treatment, the clinical efficacy of the criterion was also confirmed in a limited cohort of cancer patients, but, how effective it will be for predicting Late tissue effects of radiotherapy is a matter for further investigation.

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ENVIRONMENTAL GAMMA RADIATION DISTRIBUTION IN WESTERN GEORGIA

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ABSTRACT

*Some results of investigation of environmental gamma radiation (**Γ**) distribution in western Georgia are presented.Measurement of Γ was made on ~ 20 cm above the ground surface at 228 different points by using portable gamma survey meter. The terrain height (H) varied from 1 to 1928 m above sea level. A map of the distribution of the values of Γin the study area is presented. The statistical characteristics of the values of Γ and the peculiarities of their distribution on the territory of western Georgia have been studied. In particular, the following results were obtained. Mean value of Γ is 87nSv/h, range of change: 40-194 nSv/h.The repeatability of the values **gamma radiation** has a unimodal form with the right asymmetry with a max of 20.6% at the value Γ = 87 nSv/h.There is an increase in the values of Γ with the terrain height.Wherein coefficient of linear correlation of individual values of Γ with the H is 0.26.Connection of the height-averaged values of Γ on the H has the form of a power function: $\Gamma = 53.608 \cdot H^{0.0927}$.*

Keywords: Environmental Gamma-Radiation, Natural Radioactivity.

INTRODUCTION

Studies of the natural radioactive in Georgiahave been going on for a long time. A survey of these works, in particular, can be found in [1-2]. Let's note some of them.So, the determination of the content of radioactive elements in the waters of Georgia is conducted since 1912 (mainly the radioactive elements of the uranium series: uranium, radium and radon). At the end of the Thirties of past century these works of the Institute of Geophysics were continued, and was including a study of rock radioactivity [2].

Preliminary studies of radon in the human habitat in different regions in Georgia (habitable and public rooms, Tbilisi subway, etc.) were carried out in 2001-2002 [3-5]. Later there was realized in Georgia the large-scale monitoring of radon in the soil, drinking water and air of apartment houses; were built the maps of the distributions of radon in the indicated media; the connections of the content of radon with the metastasis of lung cancer were revealed; also recommendations were given regarding the protection of population from the dangerous levels of the content of radon. The chemical composition of drinking water simultaneously was studied, were conducted the measurements of the gamma-radiation of soil and walls of the rooms of the houses, content of light ions, meteorological parameters, etc. [6-11]. Traditionally were examined the general problems of radiology [12-14].

In the last years was continued the study of the influence of the ionizing radiations (radon, gamma-radiation, cosmic rays) on the formation secondary aerosols in the atmosphere according to scheme gas→ particle. It is obtained that all types of the indicated ionizing radiations are the catalyst of the formation of sub-micron aerosols from the gases [15-17]. Inparticular, in contaminated air an increase in radon leads to an increase in the content of secondary aerosols and the decrease of the concentration of light ions (i.e., to worsening inthe quality of air). In the final - this is negative influences on the health of people [16-17].

This work is a continuation of previous research.Some results of investigation of environmental gamma radiation distribution in western Georgia are presented below.

Study Area, Materials and Methods

Study area – western Georgia. Measurement of values of **gamma radiation** was made on ~ 20 cm above the ground surface at 228 different points by using portable gamma survey meter.The data on the values of gamma radiation for 51 points were taken from [18], measurements at the remaining 177 points were carried out by the author of this work in 2007-2008.The terrain height varied from 1 to 1928 m above sea level.

In the proposed work the analysis of data is carried out with the use of the standard statistical analysis methods of random events [18-19].

The following designations will be used below: Mean – average values; Min – minimal values; Max - maximal values; Range – Max-Min; Median - median value; Mode – modal value; St Dev - standard deviation; σ_m- standard error; C_V = 100·St Dev/Mean – coefficient of variation, %; Skew – coefficient of skewness;K_{urt} - coefficient of kurtosis; Count – number of measured points; 95% and 99%(+/-) – 95% and 99% confidence intervals of average; R^2 – coefficient of determination; R – coefficient of linear correlation;α - the level of significance; Γ- value of **gamma radiation,** nSv/h; H - terrain heightabove sea level, meter.

RESULTS

Results in Fig. 1-4 and in the Table are presented. In Fig.1. General picture of distribution of dose of**environmental** gamma radiation in western Georgia is presented.

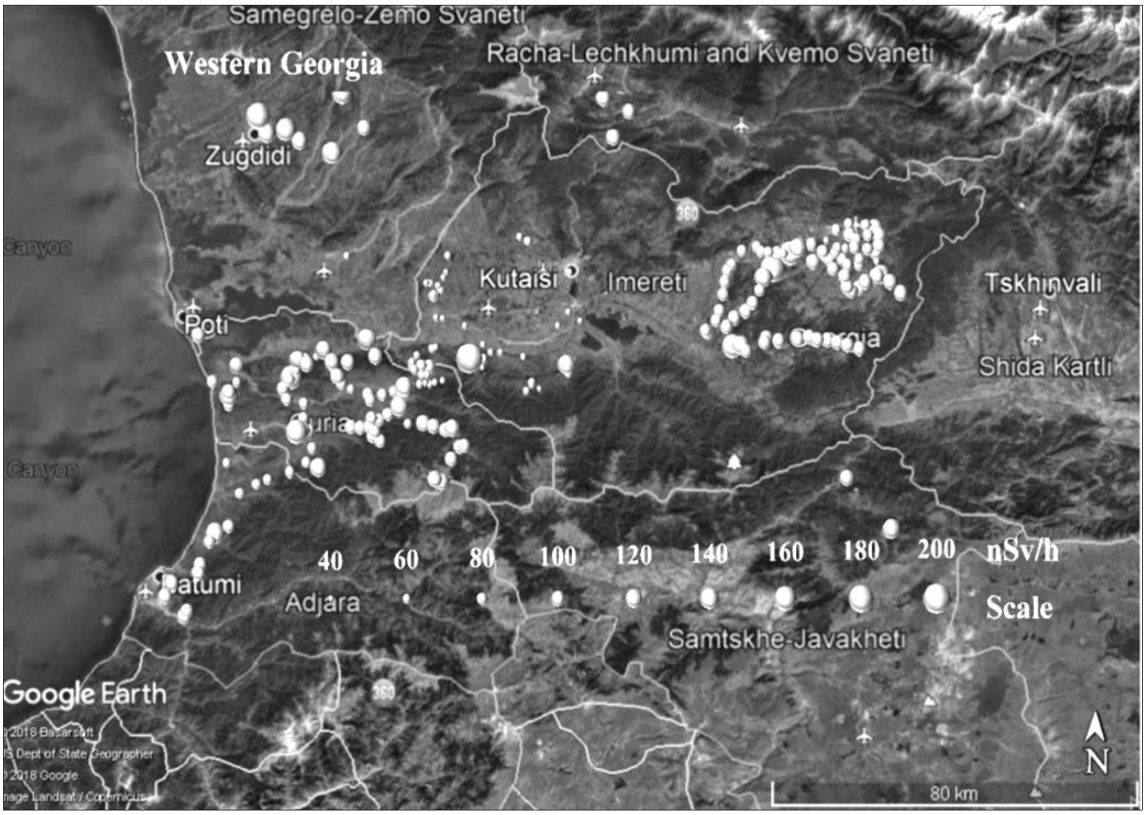

Fig. 1. Distribution of dose of environmental gamma radiation in western Georgia.

The statistical characteristics of valuesof gamma radiation in western Georgia in the Table are presented.

Parameter	nSv/h	Parameter	nSv/h
Mean	87	σ_m	2
Min	40	C_v, (%)	34.1
Max	194	Skew	0.52
Range	154	Kurt	0.50
Median	87	Count	228
Mode	88	95%(+/-)	3.9
St Dev	30	99%(+/-)	5.1

Table. Statistical characteristics of valuesof Γ in Western Georgia.

As follows from this Table mean value of Γ is 87±3.9nSv/h (95% confidence intervals of average) and 87±5.1nSv/h (99% confidence intervals of average), range of change: 40-194 nSv/h.Median, modal and coefficient of skewness values of gamma radiation indicate that the distribution of Γ values is unimodal.Value of coefficient of kurtosis indicates a weak right asymmetryof this distribution.

This is clearly demonstrated in Fig. 2, which shows the repeatability of gamma radiation values. The maximum repeatability is 20.6% at a value of Γ = 87 nSv/h.

In this case value of R between values of Γ and the H is only0.26 ($\alpha < 0.005$), (Fig.3)– negligiblecorrelation [19].

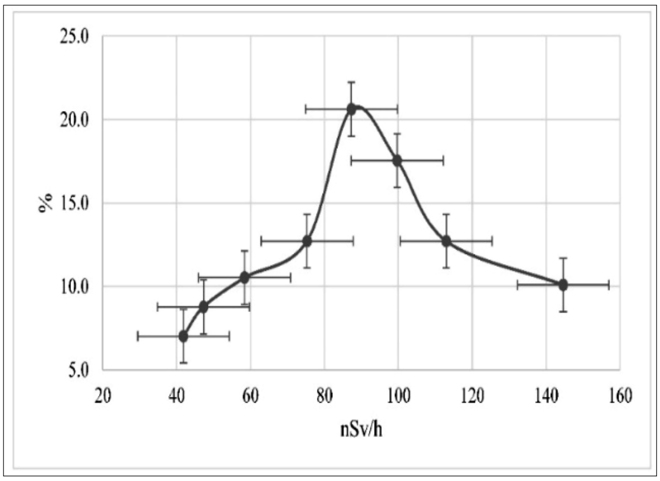

Fig. 2. Repetition of valuesof Γin Western Georgia.

Analysis of the data showed that the values of gamma radiation increase with the height of the terrain.

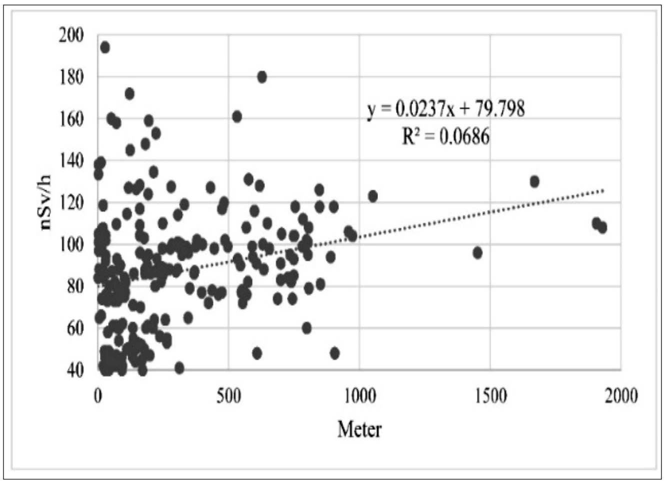

Fig.3. Correlation of individual values of Γ in Western Georgia with theheight of the terrain.

In Fig. 3 linear correlation of individual values of Γ in Western Georgia with the height of the terrain is presented.

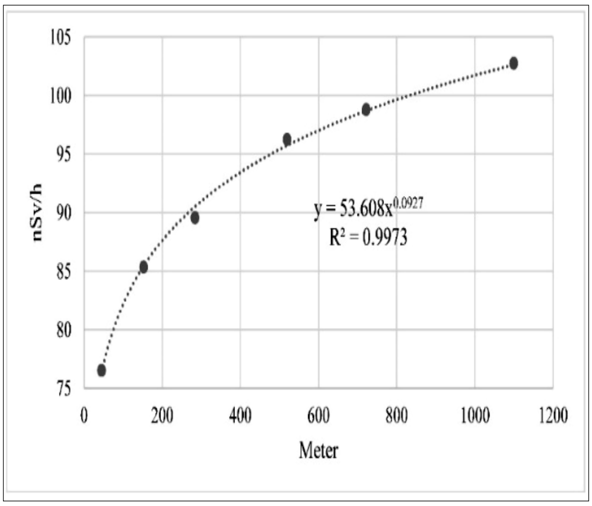

Fig. 4. Dependence of the height-averaged values of Γ in Western Georgia on the height of the terrain.

A much clearer picture is observed when averaging data on gamma radiation for different ranges of terrain heights (Fig. 4).In this case connection of the height-averaged values of Γ on the H has the form of a power function: $\Gamma = 53.608 \cdot H^{0.0927}$, $R^2=0.9973$ ($\alpha< 0.005$), (Fig. 4) - very high correlation [19].

Finally note that the data given in the Table on the wholeare in satisfactorily agreement with similar data given in [20-24].

So, in study [20] the environmental gamma radiation was measured at different 16 points in Bitlis (Turkey). The lowest values of environmental gamma radiation are 41 nSv/h at ground level and 35 nSv/h at the one-meter level on the location XIII, the highest values of environmental gamma radiation are 478 nSv/h at the ground level and 453 nSv/h at the one-meter level on the location XVI.

On paper [21] preliminary results measuring the gamma dose rate distribution in north eastern Burkina Faso where the concentration of uranium in the soil is elevated are presented.The dose rate at one meter above the ground varies between 50 nSv/h and 300 nSv/h. The mean value in the study area is about 128 nSv/h.

In work [22[according to the years of research, maps of pre-Chernobyl background radiation and radon volumetric activityin buildings within the territory of Belarus were constructed. In particular, values of gamma radiation were change in the range 10–120 nSv/h.

According to [23], the total natural dose rate of gamma radiation from soils on the territory of oil fields and beyond the sanitary protection zone (SPZ) in 2005 was 30-430 nSv/h.

In [24], it was found that the intensity of gamma radiation at individual points of the Ajichai fault was - within the fault: 60-150 nSv/h, outside the fault: 40-100 nSv/h.

CONCLUSION

In the future, we plan to continue retrospective analysis of the available data on natural radioactivity in the environment, as well as conduct more detailed studies in this direction for different regions of Georgia.

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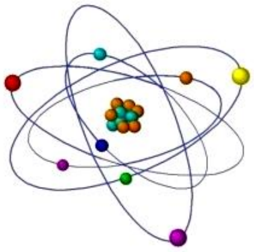
DISTRIBUTION OF RADIOCESIUM AMONG THE ORGANS OF WEEDS PLANTS



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ABSTRACT

Regularities of radionuclide accumulation and distribution in individual organs of the plant from radiocesium contaminated soil according to different vegetation periods by a widespread weed throughout Georgia -Chenopodium album L. is discussed in the paper. General localization of the radioisotope in the organs of the experimental plant was shown by radioautography method. Radioactivity characteristics of both soil and study plant organs has been determined by spectrometric analysis. It is concluded that the presented Chenopodium album L. can be used as a marker test system to study the penetration and distribution of radionuclides from the soil in the bodies of wild-growing weeds, which in turn creates a precondition for implementation of effective cleaning of contaminated areas by radionuclide and phytoremediation measures.

Key words: radionuclides**,** weeds plants, radiocesium accumulation

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INTRODUCTION

As a result of the active development of nuclear energy programs there is a risk of significant amounts of radioactive decay products to be reached and locally contaminated into the Earth's surface [1,2,3]. After getting in different landscapes, radioactive isotopes are actively involved in the biological cycle of substances cycle. As numerous studies conducted in recent decades have shown, radioactive products of decay accumulate from the environment into flora and fauna, which leads to increase their quantitative rate in the biological cycle of substances cycle [4-7].

Plant foodsis a shortest way to enter decomposition products in the human body;however, no less dangerous are animals which are feeding by the plants contaminated with radionuclides. In both cases, the plant is the source of radionuclides in the human body.Long-lived radioactive nuclides are more essential from the radionuclides that pollute ecosystems [8-9]. The dimensions and degree of contamination by short-lived isotopes is limited by the duration of their existence and the relatively small area of their distribution in nature at a time when contamination by long-lived radioactive isotopes is long-lasting and can spread over a significant area under matching conditions [10]. One of the most dangerous contaminants of phytocenosis in this aspect is ^{137}Cs, which has a long half-life (more than 30 years) and the ability to incorporate significant amounts into the biological cycle of substances through the plant [11]. Due to the properties of the soil and the physic-chemical characteristics of the radionuclides themselves, radionuclides penetrate in the plant and accumulate in varying quantities; The intensity of accumulation is determined by the biological characteristics of a particular plant. It should be noted that plants can transfer relatively high doses of radioactive substances without significantly impairing their growth and development processes. In the plants, without their injury can accumulate such a large amount of radioactive isotopes that they become unusable and dangerous to humans.

A number of scientific publications have established the pattern that different radionuclides penetrate into a plant are unequally distributed and therefore the damage level of plant different parts can be substantially different. Therefore, the study of the regularities of accumulation of radionuclides absorbed by the plant, according to the individual organs of the plant, is a topical scientific-practical task.

MATERIALS AND METHODS

Widespread weed in the whole territory of Georgia- Chenopodium album L. was selected as the research object. In order to obtain a homogeneous test material, the seedlings were cultured under standard conditions and then transferred to radioactive soil. Soil contaminated with radiocesium was used as the radioactive substrate. Plants grown on contaminated soil intended for radiometry were subjected to drying and shredding on an electro-homogenizer until a powdery mass was obtained. The con-tent of radionuclides was determined by gamma spectrometry (Gamma-Beta Spectrometer "ATOMTEX МКС-AT-1315" and Gamma-Spectrometer "CANBERRA" with liquid nitrogen freeze germanium detector). For conduction radioautography under compression conditions, the dried intact plant was placed on X-ray tape. After being pressurized, the plate was exposed in the standard way and the image was transferred to negative mode by computer scanning. The accumulation coefficient in different organs of the plant was calculated in relation to the content of ^{137}Cs in the soil and in plant tissues.

RESULTS AND DISCUSSION

The penetration of radionuclides from the soil into the plant is the first step in their transition from abiotic components of ecosystems to biotic components in the food chain. Once they are getting into the plant from the soil, the radioactive substances, due to their chemical properties, are distributed to the plant organs. To study the localization parameters of the model weed plant Chenopodium album L. in the organs, we conducted a study by radioautographic method (pic 1). As can be seen from the picture, all parts of the plant grown on radiocesium contaminated soil showed local darkening of the photographic material, indicating the general localization of the radioisotope in the plant parts.

The young organs of the plant are known to contain significantly more potassium than the long-lived organs: it is more abundant in the organs and tissues where the processes of metabolism and cell division take place intensively [14].Due to the above, active transport of radiocesium is carried out through potassium channels and it is natural that similar processes are observed with respect to the movement and localization of this radionuclide [15]. It is natural that this parameter should vary according to the vegetation of the plant. To study the dynamics of radiocesium content in growth and development processes, we analyzed the above ground parts of the plant during the 8 months of vegetation. From Figure 2 can be seen that radiocesium is accumulated most actively in plant tissues during the early stages of vegetation (310Bq/kg).

It is at this time in the development of the plant is observed active growth and accumulation of vegetative mass. In the following period (June-September) the intensity falls relatively (302-298Bq/kg), and at the end of the vegetation period it reaches the minimum value (279Bq/kg). Overall, the results obtained are consistent with a general understanding of the mechanism of radiocesium penetration by potassium channels in the plant tissues. Active growth - Maximum number of ^{137}Cs in the proliferative activity zone, further stabilization of the growth reaction and finally, cessation of growth processes and enhancement of radioisotope basipetal conduction [16]. For a detailed study of the final volume of radio cesium penetrated into the plant organs, we conducted a radioactivity study of individual parts of the plant. As can be seen from Figure 3, the highest radioactivity was observed in the lateral roots, the lowest rate was observed in the main trunk tissues. The picture of radiocesium accumulation according to *Chenopodium album L* organsis as follows: lateral roots> main root> leaves> secondary trunks> main trunk.

Fig. 1 Radioautography of the seedling of *Chenopodium album L* cultured on radiocesium contaminated soil (*negative image)*

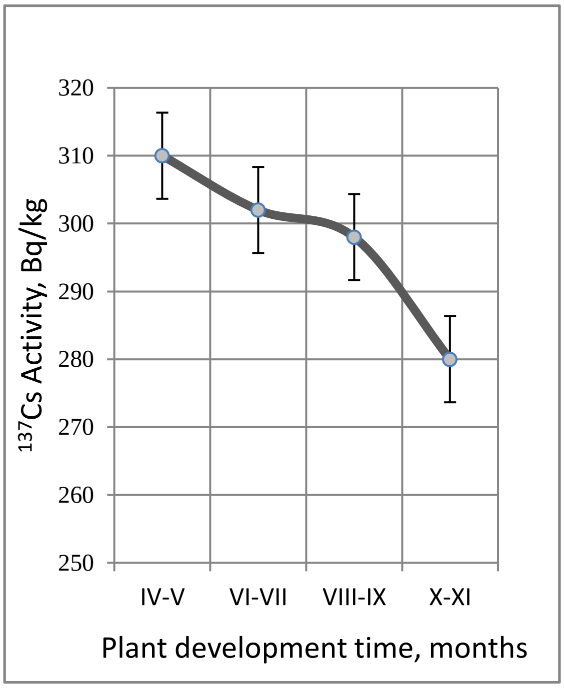

Fig.2 Dynamics of radiocesium content in the above ground parts of the plant in their vegetation process

One of the main determining factors of the overall distribution of radionuclides in plants is the characteristic of quantity and condition of radionuclides in the soil. In order to calculate the coefficient of accumulation of radionuclides in the organs of the test plant, in addition to the indices of radioactivity of the tissues, it is necessary to determine the characteristic of the radioactivity of the soil. Spectrometric analysis showed that the soil used in the experiments contained 12,230 kBq/kg ^{137}Cs.Another important radiation parameter is the form of radionuclide in the soil and its availability to the plant. The radiocesium gets into the bonded state fairly quickly when it gets into the soil. Over time, ^{137}Cs are absorbed by soil minerals, where they take up potassium in crystalline structures and become inaccessible for plants. It’s accepted this phenomenon to be called "radionuclide aging". It’s believed that showed period lasts 1-4 years, although in the paper [17] this period is estimated at 5-10 years.

Thus, the soil used in our study, which was characterized by a 20-year period of radionuclide contamination, was difficult to assimilate in terms of radionuclide penetration into the plant. The rates of radionuclide accumulation coefficients in different organs of Chenopodium album L are shown in Figure 4. From the data, at the end of the vegetation, the main content of radioisotope is accumulated in the root system (61%), and in the above ground parts - only 39%. Active accumulation of radioisotope from underground parts is characterized by lateral roots (33%), and from above ground parts- leaves (21%).

It is noteworthy that the parameters analyzed in the paper (accumulation coefficients, distributionaccording to the organs, specific tissue activity) are mainly related to the form of the presence of radionuclides in the soil. In this regard, in the weed plant Chenopodium album L, which we used as amarker, was detected the active transport and accumulation of radionuclides from soils that have beensubjected to radionuclide fixation with soil elements for many years. On the other hand, the accumulation of radionuclides in the soil, which is characteristic of weeds, can be used to effectively clean radionuclide-contaminated areas and carry out phytoremediation measures.

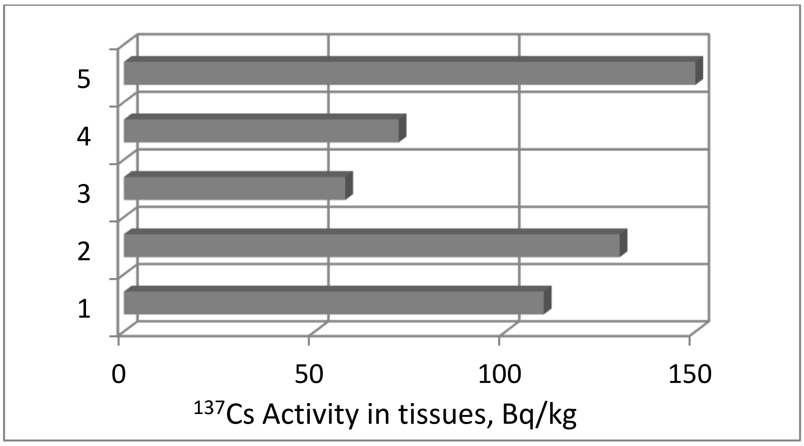

Fig.3 Distribution of radionuclides in plant organs

1-main root; 2-lateral roots; 3-main trunk; 4-secondary trunk; 5-leaves

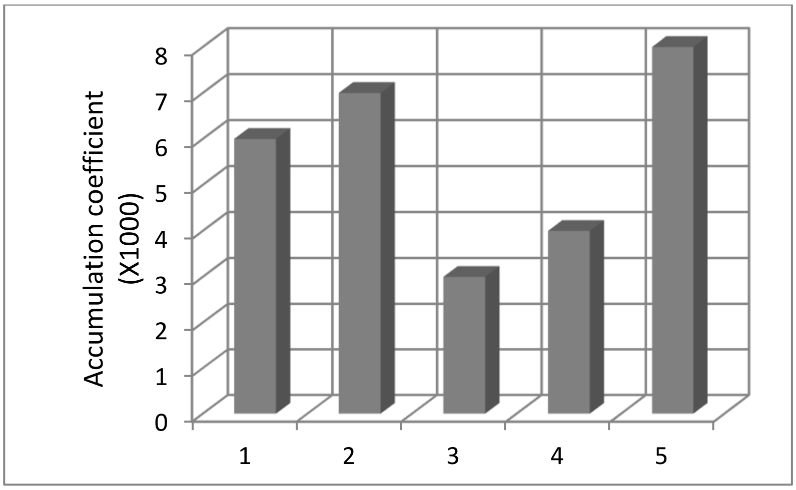

Fig.4 Radiocesium accumulation coefficients in the tissues of contaminated soil grown *Chenopodium album L*

1-main root; 2-lateral roots; 3-main trunk; 4-secondary trunk; 5-leaves

CONCLUSIONS

The obtained experimental results allow to conclude that the common species of Chenopodium album L. presented in the paper can be used as a marker test system to study the penetration and distribution of radionuclides from the soil in the bodies of wild-growing weeds. Maximum and minimum levels of radionuclides were observedaccording to the developmental stages of weeds.Since the assimilation of radionuclides by the root system may play a key role in the transmission oflong-time important information for determining the levels of radiation contamination of wild andnon-lived radionuclides into the food chain, the data obtainedcoagricultural phytocenosis.

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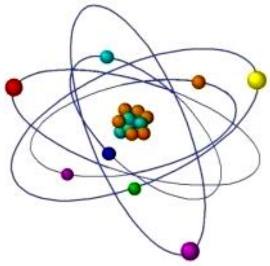
THE ROLE OF THE LEAD ^{210}Pb IN THE MANIFESTATIONS OF THE EFFECTS OF RADON EXPOSURE ON LIVING ORGANISMS: A CONCEPTUAL ANALYSIS



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ABSTRACT

The article discusses the auto-synergistic effects arising from the decay of radon in a living organism and the role of radonogenic radioactive lead ^{210}Pb in these effects. Assessments of the influence of this isotope on the long-term consequences of above effects and their relationship with various modes of radon therapy are investigated.

Key Words: radon, lead ^{21}Pb, combined effects, dose-effect model, long-term effects

It is generally accepted that the obvious pathological effect of radon exposure on the body is lung cancer resulting from a radiation burn of alveolar tissues by alpha radiation generated by the decay of radon and its daughter elements in the chest cavity [1-3]. This effect is created directly during the respiration process, although its realization takes some time due to the accumulation of radiation damages. That’s why it can be considered as a long-term effect of radiation exposure.

At the same time, the existence of this primary effect is in no way an obstacle to the development of other pathological processes that have the character of more long-term consequences of radon exposure with much more complex mechanisms and require much longer time intervals for their implementation. These mechanisms include the combined impact of radon decay products. Let's consider these processes in more detail.

As you know, radon is a radioactive gas, formed during the natural decay of radium, an element of the uranium-238 series, which accumulates in rocks, soil and water. Radon is easily released from the soil into the air, where its concentration drops rapidly and is generally not dangerous. The average level of background radiation induced by radon in the atmospheric air fluctuates in the range of 5–15 Bq / m^3, however, in enclosed spaces, the concentration of radon is higher, with the highest values of its concentration being observed in mines, caves and water treatment facilities. In buildings and structures, the level of radioactivity associated with radon can range from 10 Bq/m^3 to more than 10 kBq/m^3 [4].

It is also known that, historically, miners in underground works had an increased incidence of lung disease, which ended lethally. This phenomenon, or rather, its consequences, were known long before the discovery of radon itself, and was called the "disease of miners", being exactly the same scythe that Rock reaped the lives of underground workers, but its causes and mechanisms were revealed much later [5].

Studies of the physiological effects of "rays and emanation", begun in 1901 by A. Becquerel and P. Curie and then was continued by E. Rutherford and F. Soddy, were associated with the discovered in 1900 by F.E.Dorn and A.Debierne radioactive gas radon, and in 1904 P. Curie together with A. Laborde carried out the first studies of the radioactivity of waters and gases of mineral springs.

As a result of further research, it was found that radon is the second cause of lung cancer after smoking [1]. The mechanism that causes lung cancer, as indicated above, is considered to be a radiation burn of thetissues of the alveoli by alpha particles generated during the decay of both radon itself and its daughter elements and the damage to chromosomes caused by them. This phenomenon occurs for the most part just in the conditions of underground workings with a pronounced saturation of air with radon and its progenies [1]. According to various estimates, radon causes from 3 to 14% of all lung cancer cases, depending on the average level of radon concentration in the soil and the prevalence of smoking in the country [1].

In addition, studies in Europe, North America and China have confirmed that radon, even in low concentrations, for example in residential areas, is also dangerous for health and is a significant factor in the incidence of lung cancer worldwide [6].

It was later found that an increase in the average value of long-term volumetric activity of radon for every 100 Bq / m3 increases the risk of lung cancer by 16% [7].

It was assumed that the dose-effect relationship is linear, and the risk of lung cancer increases in proportion to the increase of the radiation dose caused by inhalation of radon [8]. It has also been found that smokers are 25 times more likely to develop lung cancer from exposure to radon than non-smokers [8]. The risk of developing other types of cancer was not found.

The healing properties of radon were known long before the discovery of radioactivity. It was noticed that after bathing in some springs and staying in caves, people gained strength and diseases receded. The waters of Baden-Baden were known to the ancient Romans. They have built large bathing structures for their soldiers on these springs, and in 214 AD. - Imperial baths - Baths of Caracalla. Centuries later, in 1861, R. Bunsen made the first chemical analysis of the waters of the famous resort, and in 1904 the physicist H.F.Geitel and a resident of Baden-Baden, the pharmacist O.Ressler, discovered the radioactivity of Baden's waters. In the same year, the radioactivity of numerous thermal healing springs of another German resort - Bad Kreuznach, built in 1817, was revealed, and in 1912, after the discovery of radon adits, the resort opened the world's first inhalation radon center.

In 1904, the first reports appeared in the press about the radioactivity of the waters of Bad Gastein in Austria, known for their healing properties since ancient times. The world's first radon resort was built in 1911 in the Czech town of Jachymov, where Pierre and Maria Curie conducted their experiments with uranium ore, and it is rightfully called the cradle of the atomic age.

Balneological procedures with radon water are a traditional method of spa treatment and are successfully used in case of number of diseases. The high efficiency of using radon waters for health purposes has been proven by numerous experimental and clinical studies and is widely presented in the literature [9].

The specificity of radon water treatment is ionizing radiation accompanying the decay of radon and its daughter products. During radon balneotherapy, radon and its short-lived decay products, including alpha-radioactive - ^{218}Po and ^{214}Po, are deposited on the skin of patients, forming an active plaque, which is a source of α-radiation, which makes up 90% of all radiation energy emitted during the decay of radon [10-11].

Taking a bath is accompanied by the entry of radon into the body, primarily into the skin, where a kind of radon depot is formed, from where, through the microcirculation system, it enters the blood or diffuses into the internal organs, and then leaves the body at different speed, being released through the lungs (60%) or skin (40%) [11].

According to modern concepts, radon baths are α-irradiation of the skin. At the same time, it is believed that inhalation of radon during medical procedures, unless it occurs in conditions of a high concentration of radon in the air, as, for example, in mines, does not have a significant effect on the body due to its low concentration and thanks to protective devices (shields above the bathroom, aspirators and forced ventilation.

The alpha radiation of radon and daughter products interacting with a substance leads to its ionization, which causes complex physicochemical and biological changes in cellular metabolism, stimulates oxidative processes. Radiolysis products (radio toxins) cause disruption of glycolysis and oxidative phosphorylation Processes, which underlies changes in cell function.

Under the influence of the active plaque of radon and its daughter products formed on the skin, afferent impulses in the skin increase, reaching the central parts of the nervous system, which in turn causes a stream of efferent impulses that contribute to a change in the level of functioning of organs and systems. A change in the skin analyzer leads to a restructuring of the activity of the cerebral cortex and the peripheral nervous system. Radon baths affect the nervous system at all levels.

Radon has analgesic and anti-inflammatory effects on the body, helping to eliminate chronic inflammatory processes in various organs. In low concentrations, radon increases the function of the thyroid gland and ovaries, and in high concentrations inhibits it. The complex positive effect of radon baths on the human body becomes clear within the framework of the general biological hypothesis of radiation hormesis [12]. This hypothesis is based on the assumption that low doses of ionizing radiation (equal to or slightly higher than natural background levels) are beneficial in stimulating the activation of repair mechanisms.

In addition, due to the impossibility of penetration of α-particles emitted by radon through the outer layer of human skin (the stratum corneum of the epidermis, which does not contain living cells), the only possible effective way of radon exposure to the human body is its decay inside the body or in the immediate vicinity of mucous covers.

That is why, as a result of further research, lung cancer was recognized as the most studied manifestation of the pathological effect of radon on a living organism, which is in good agreement with the historical data presented above. However, it is unlikely that a radiation burn of the lungs and the pathology caused by it are the only way of exposure to radon on the body, especially since nowadays the ability of radon to penetrate from the chest cavity through the lungs into the bloodstream and spread throughout the body is well known [13].It is also known that part of the radon enteringthe body can be excreted from the body through the same systems [13].

These processes imply that a certain part of radon will decay inside the body and exert one way or another effect on biological processes in it. At the same time, today only model calculations are attempted to determine how much radon enters the body and how much is ejected back into the external environment [14-15], but it is difficult to assess how reliable are the models underlying these calculations.

For this reason, if it is necessary to estimate the radiation dose absorbed by specific organs under the influence of radon, the concentrations of radon and its daughter elements in the environment must be recalculated using certain model concepts, the study of the adequacy of which is a separate and, at best, non-trivial problem to be solved. In such cases, further effects are influenced by the ratio of the lifetimes (half-lives) of progenes and the times of their migration in the body until they are converted into long-lived isotopes, in particular, lead 210Pb, which is the longest-lived radioisotope in this decay chain.

Many works today are devoted to assessments of the penetration of daughter products of radon decay into the body [16-17]. Among other things, this is due to the fact that the products of its decay, which are metals, form microscopic nodules that can penetrate both the pulmonary barrier and through the skin, and this ability is largely related to the distribution of these nodules in their geometric dimensions. Investigations of the size distributions of such nodules in specific underground workings and the construction of lung cancer risk models on this basis are also devoted to many works [18-19]. On the other hand, it should be taken into account that radon progenyes (isotopes of lead and polonium, see Table 1) are very active chemical substances that easily enter into connection with biological structures.

It should be expected that the efficiency of their interaction with living matter will be the higher, thelongerthe time of their contact within the body. Since, as mentioned above, lead ^{210}Pb belongs to the lead interms of the duration of existence in the body of all the daughter radioactive elements of radon, it can beassumed that this isotope of lead will bring the maximum chemical effect into the biological consequences of the decay of radon in the body.

It also directly follows from the above table and the decay scheme that any effects of radon exposure on a living organism will necessarily be complex, associated with the indispensable participation of lead 210Pb in them, including one in which this effect can be synergistic, i.e. enhancing the pathogenic properties of radiation.

In addition, today the toxicological properties of lead in the body, including the processes of its transport, accumulation and excretion, are well studied. According to these studies, lead is a toxicant that accumulates on a range of body systems and is especially harmful for young children. In the body, lead is absorbed into the brain, liver, kidneys and bones. Over time, lead builds up in teeth and bones [20-21].Exposure to humans is generally measured by blood lead measurements [22]. Lead in the blood binds to hemoglobin, replacing iron in it and is transferred between organs, including in the form of a secondary stream. In particular, the lead accumulated in the bones enters the bloodstream during pregnancy and becomes a source of exposure to the developing fetus. It has also been established that there is no threshold concentration of lead below which it would not pose a health hazard [23].

Radon decay schema

For this reason, the long-term deposition of radioactive lead in the body, which occurs mainly in the bone tissue, in the future can lead to damage the bone marrow by the decay products of radon and lead itself, together with its chronic low-energy gamma radiation (44 keV) and cause pathological changes in the blood, including being a possible cause of leukemia.

Thus, this behavior of lead puts under the question mark the expediency and safety of any radon treatment procedures, if they create conditions for the decay of radon inside the body and, along with a large half-life of its decay (more than 22 years), respectively, to the long-term deposition of this isotope of lead in it.Let us now consider some informational properties of the indicated lead isotope in the process of radon decay.In contrast to penetrating radiation, the dose of which absorbed by a biological object can be measured instrumentally,that sequentially decaysinto a number of daughter elements, practically does not allow such measurements in the body.

Table 1. Decay of radon and its progenies.

Element	Decay type	Energy, MEV	Half life	Efficiency
^{222}Rn	α	5.49	3.8235 days	
^{218}Po	α	6.00	3.11 minutes	99.98%
^{214}Pb	β γ	0.67, 0.73 0.35, 0.30, 0.24	26.8 minutes	
^{214}Bi	β γ	1.54, 1.51, 3.27 0.61, 1.76, 1.12	19.9 minutes	99.98%
^{214}Po	α	7.69	164.3 microseconds	
^{210}Pb	β γ	0.06, 0.02 0.044	22.3 years	99%
^{210}Bi	β γ	1.16 0.27, 0.30	5.012 days	99.9999%
^{210}Po	α	5.30	138.376 days	
^{206}Pb	--		stable	

However, from the well-known in nuclear physics [24] and given in Table. 1 of the scheme of radon decay directly implies that the number of 210Pb lead atoms formed in the body under the influence of radon is exactly equal to the number of radon atoms decayed in the same place (of course, taking into account the corrections for the latter biological withdrawal from the body).

On the other hand, the decay energy of each radon atom to lead ^{210}Pb, which is a physical constant, makes it possible to determine the radiation dose absorbed in this process in the form of the product [25]

$$E = N_{210Pb} \text{ x } P_{222Ra/210Pb} \quad (1),$$

where E is the absorbed dose, N_{210Pb} is the number of 210Pb lead atoms deposited as a result of radon decay, and $P_{222Ra/210Pb}$ is the decay energy of one radon atom to lead ^{210}Pb, i.e. lead accumulated in specific organs is an indicator and measure of the radiation dose absorbed by these organs.Expression (1), along with the experimentally determined amount of radiation damage, makes it possible to construct a dose-effect model that is characteristic and accepted in radiation biology. The construction of such a model requires at least two specific estimates - an estimate of the absorbed dose, which can be the amount of lead deposited as a result of exposure to radon, and an estimate of the changes caused by this dose. In this case, quantitative indicators of radiation damage, which usually means chromosomal aberrations, can participate as the effect of radon exposure [26-27].

The construction of a dose-effect model makes it possible, in principle, to establish a one-to-one relationship between the absorbed dose and the number of radiation defects caused by this dose, which makes it possible to perform forward and reverse linear prediction procedures.

On the other hand, it is known that the generation of chromosomal aberrations can occur not only under the influence of radiation, but also under the chemical influence of the same lead ^{210}Pb [28-29], which together can create both a purely additive and nonlinearly additive, in other words, a synergistic response, and there are certain indications of the existence of such an effect [1].

In this case, the degree of synergism will be determined precisely by the lifetime and biological activity of the chemical decay products, and the process itself should be qualified as **auto-synergistic**, or generated by the simultaneous effect of radiation and chemical factors of radon decay.

Therefore, the magnitude of the complex effect of radon and its decay products will be depended from two factors:radiation factor (1) and chemical factor

$$E_{chem} = N_{210Pb} \qquad (2)$$

i.e. that (2) indicates the multiplex, dual role of lead in these estimates.It should be noted that such kind of nature of the processes associated with the effect of radon on a organism can be indirectly points to the well-known fact of the nonlinear relationship between the effect of radon and smoking [1] (due to the ingestion of heavy metals, including lead) on the development of pathological processes.Thus, it must be recognized that in the processes of radon exposure on the body, the radioactive lead ^{210}Pb, which is formed during the decay of radon, is also an obligatory actor, and all the effects of radon exposure are directly related to the participation of this metal in them. In addition, it becomes clear that in the described process it will be difficult to separate the effects of a radiation and chemical nature, which should be taken into account when constructing a dose-effect model.Besides, one should also take into account the different efficiency of the individual parts of the specified process.Therefore, the complete process should be written as

$$H = \left(N_{210Pb} x\, P_{222Ra/210Pb}\right)^{\alpha} + (N_{210Pb})^{\beta} + K_{Sinerg,210Pb/222Ra}(3),$$

where $\left(N_{210Pb} x P_{222Ra/210Pb}\right)^{\alpha} = N_{rad}$ is the radiation component of the total number of defects, $(N_{210Pb})^{\beta} = N_{chem}$is the chemical component of the total number of defects, and$K_{210Pb/222Ra} = N_{sinerg.}$ is the synergistic component of the total number of defects.
Thus, the problem of constructing a dose-effect model for radon, taking into account the processes associated with the generation and effect of lead 210Pb on living objects, is comes down to establishing a numericalrelationship between expressions (2) and (3)at different levels of radon exposure (absorbed dose).

To clarify the unknown indicators of efficiency α and β, as well as the indicator of the degree of synergy $K_{Sinerg,210Pb/222Ra}$, it is proposed to conduct experimental studies on small laboratory animals, exposing them to radon and lead, including artificially introduced, at various ratios of these components and studying the biological effects of such an impact, as well as the mechanisms of accumulation, transport and removal of radioactive lead from the body in order to construct correct estimates of boththe absorbed dose of radiation and the degree of synergy of the above-described phenomenon, as well as the ability to display predicted results on other biological objects, including humans.

Thus, it must be recognized that in the processes of radon exposure in the body, the radioactive lead ^{210}Pb, which is formed during the decay of radon, is also an obligatory actor, and all the effects of radon exposure are directly related to the participation of this metal in it.

In addition, it becomes clear that in the described process it will be difficult to separate the effects of a radiation and chemical nature, which should be taken into account when constructing a dose-effect model.

Considering everything above mentioned, it becomes clear that without taking into account the multifaceted role of lead ^{210}Pb generated by the decay of radon, it is not possible to construct correct estimates of the effect of radon on the body, including its medium-term and long-term consequences. Our subsequent studies are aimed at solving this problem.

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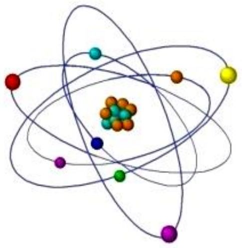
DEVELOPMENT OF THE HYDROPHYTIC STRUCTURE OF THE BIOPLATEAU TYPEFOR THE PURPOSE OF PHYTOREMEDIATION



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ABSTRACT

A floating structure of a bioplateau has been developed for the purification of water bodies from the toxic substances, the biotic component of which is terrestrial plants. Chemically inert floating materials were used as a substrate for the construction of the bioplateau: perlite, expanded clay, granular foam, vermiculite, cork. Substrate testing has shown that granular expanded polystyrene is the most optimal for the usage. The study of different options for seed germination in the design of the bioplateau has shown that its placement on the top of the substrate is the best option. The usage of perlite in combination with granular foam had created an additional capillary effect, due to which the seeds germinated at a faster rate. To optimize the hydrophytic structure a grid was used, which made it possible to increase the overall density of the bioplateau. An algorithm for creating a "rolled" plant that is suitable for transportation and placement in the surface water bodies that require purification from toxic substances has been developed.

Key words: water purification, phytoremediation, bio plateau, radionuclides, terrestrial plant

INTRODUCTION

Anthropogenic activities and emergencies have led to significant pollution of the environment, in particular water bodies, which is gaining global scale and causing undesirable consequences for humans and ecosystems [5, 11]. According to the forecasts of the Ukrainian experts, further intensive industrialization will lead to irreversible environmental changes and a catastrophic reduction of relatively clean freshwater resources in Ukraine as a source of drinking water [4, 16].

Taking into account the results of monitoring studies in recent years, surface waters of Ukraine are classified as water quality class 3-5, and the most environmentally hazardous toxicants are radionuclides and heavy metals. Toxic and carcinogenic effect on living organisms of these elements are primarily associated with high solubility, migration, cumulative ability of their compounds and participation in biological processes [2, 9, 14].

Traditionally, chemical and physicochemical methods are used for wastewater treatment, which have a limited scope, certain advantages and disadvantages and mostly do not allow achieving the normative values of residual concentrations of pollutants entering and accumulating in surface aquatic ecosystems [3,12,18]. Therefore, to improve the ecological status of water bodies, it is necessary to create effective, environmentally safe and cost-effective, compared to existing methods, systems for restoring the quality of large volumes of aquatic environments, which is developing new or improving existing methods of extracting these ecotoxicants from water bodies.

Nowadays much attention is paid to the use of phytoremediation technologies to improve thecondition of water bodies. In world practice, various phytoremediation systems are used, in particularhydrophytic structures using higher aquatic plantsand aquatic biota [1,10,13,15,17,19].

Traditionally, the functioning of the bioplateau is based on the transiting of contaminated water through a system of biofilters located on the soil surface. This treatment scheme makes existing types of plateaus limited in terms of mobility and capacity, and the use of higher aquatic plants as biological components complicates the operation of the plateau. However, it is known that not only higher aquatic plants are characterized by high levels of accumulation of ecotoxicants, but also higher terrestrial plants in aquatic (hydroponic) culture have a high sorption capacity for radionuclides and toxic metals [6-8]. Therefore, despite the achievements in the usage of bioplateau, the need for scientific justification for the development of phytoremediation technology, which consists of studying the absorption capacity of terrestrial plants and creating an effective hydrophytic structure such as bioplateau, is an extremely important task.

During the development of the floating bioplateau with the use of terrestrial plants that have the maximum ability to accumulate radionuclides, the following tasks were set and solved:

- searching for species of terrestrial plants that are able to grow in conditions of high humidity;
- testing of different types of substrates that provide high buoyancy and close connection with the root system of plants;
- testing of substrates and plants for the formation of the floating bioplateaus;
- searching of the optimal means of seed germination (upper location according to the substrate, mixing with the substrate);
- optimization ofthe hydrophytic structure.

MATERIALS AND METHODS

As biosorption material the usage of intact higher terrestrial plants and their isolated parts (mainly leaf-stem) is evaluabled. Plant material is an element of the biofilter, which is a system that uses the sorption properties of the root system of intact plants.

The second stage in the construction of a floating bioplateau was the searching for a substrate for the development and growth of the plants. The chemically inert floating materials, such as perlite, expanded clay, granular foam, vermiculite, cork are used. These substrates must meet the following requirements: non-toxicity to plants; minimum porosity - to minimize the ingrowth of roots into the granules of the substrate and ensure the buoyancy of the bioplateau structure.

The third stage in the construction of a floating bioplateau was the combination of different options of seed and substrate. To obtain the required hydrophytic system, a combination of seed variants of promising higher terrestrial plants and substrate was studied. The method of placing seeds on the top of the substrate, below and the method of mixing the substrate with plant seeds was used.

To construct a bioplateau by the method of placing seeds below the substrate, the bottom of the cuvette measuring 21 × 12.5 × 2.5 was covered with seeds, cm3: peas (40), corn (40), barley (25), oats (25); poured granular foam (1.5 cm); added 100 ml of settled water from the water supply; placed in a thermostat at t = 24 ºC.

Next, a bioplateau was created by mixing the seeds with the substrate: pre-soaked for 8 hours corn (40 cm^3) and peas (40 cm^3) were used. Foam was poured into 21×12.5×2.5 cuvettes and mixed with seeds. 100 ml of settled water from the water supply was added and placed in a thermostat at t = 24 ºC. The construction of the bioplateau by the method of placing the seeds on top of the substrate was performed in the following order: a cuvette of size 21×12.5×2.5 was used; the bottom was covered with a layer of granular foam (500 cm^3); the surface of the granular foam was moistened; 100 ml ofsettled water from the water supply was added; with a layer of perlite (70 cm^3) was covered; perlite was moisturized; on the surface was placed the seeds (cm^3): hemp (25), mustard (25), rye (25),oats

(25), amaranth (3), flax (15), millet (15), barley (25), rape (10), corn (40), thyme (5), oatmeal (5); the seeds were covered with a layer of perlite (50 cm^3); then it was placed in a thermostat at t = 24ºC. To optimize the hydrophytic structure of the bioplateau, a supporting mesh and perlite was used, poured on top of granular foam (70 cm^3).

The design of the bioplateau for the using in the field. A cuvette measuring 30×40 cm was used; a grid was placed on the bottom of a cuvette; the bottom was covered with a layer of granular foam 1.5 cm thick; a layer of perlite was poured on top of the foam; 200 ml of water was poured into the cuvette; during further germination another 600 ml of water was added; a spray to moisten the surface of the substrate was used; a mixture of seeds: corn (200 cm^3) - barley (100 cm^3) - meadow thyme (10 cm^3) was used; a thin layer of perlite was sprinkled on the seeds; the cuvette was placed in a plastic bag to create a wet chamber.

RESULTS AND DISCUSSION

At the first stage of the study, pea, corn and barley seeds were placed at the bottom of the substrate - foam. After 3 days of seed germination - peas almost did not germinate, corn and barley showed good results - the seeds began to germinate. After 7 days of incubation, the barley germinated well - the length of the shoots reached about 10 cm; in the version of the bioplate with corn - about 3-5 cm. Peas have sprouted up to 3 cm, there is a bacterial infection of plants. Thus, the construction of a bioplate by seed germination from below does not meet the requirements for hydrophytic structure: the substrate of the bioplate is not necessarily bound by the root system of plants, the buoyancy of the structure is not ensured.

The pea and corn seeds were used to study the variant of seed germination mixed with the substrate. The polyfoam acted as a substrate. It was found that corn mixed with the substrate for 7 days sprouted about 3 cm, peas are not a promising plant, because it has a high level of bacterial infection. Thus, the construction of the bioplateau by mixing seeds with the substrate also does not meet the requirements for the bioplateau: the substrate of the structure is not necessarily bound by the root system of plants, the buoyancy of the bioplateau is not provided.

Another option for designing of the bioplateau was the germination of seeds on top of the substrate. The studies have shown that in all variants of the combination of foam with plants, there was an effect of binding the substrate to the root system and there was a high level of buoyancy of the bioplateau. A weak effect of substrate binding to the root system was observed by combining vermiculite with plants. The variants of the combination of the cork with plants showed a weak effect of binding of the substrate to the root system, as a result of which the buoyancy of the bioplateau is not ensured. Combining expanded clay with plants also gave a weak effect of binding of the substrate and the root system, due to the low buoyancy of the bioplateau.

In the course of experimental studies, it was found that the placement of seeds for germination on top of the substrate is the best option for its germination, which in its turn allowed obtaining a dense structure of the bioplateau for the further research.

The next task was to optimize the hydrophytic structure. To minimize the edge effect (looseness at the edges of the bioplateau), it was decided to use a fine-grained mesh, which allowed to increase the overall density of the bioplateau. For this purpose, when constructing the bioplateau, firstly, a grid was placed on the bottom of the cuvette, then polyfoam and plant seeds (Fig. 1).To ensure more complete contact of germinating seeds with the substrate, perlite was used, becauseit in the combination with the foam creates an additional capillary effect, which provides faster seedgermination. The components of thebioplateau were placed in the followingsequence: mesh - foam - perlite - seeds.

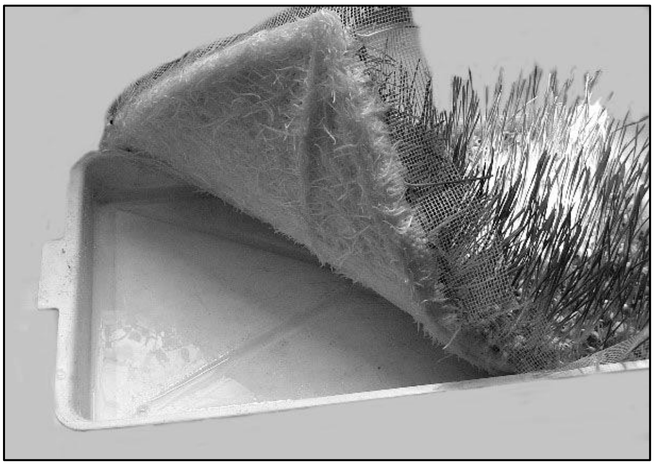


Fig.1. Bioplateau with the using of fine-grained mesh

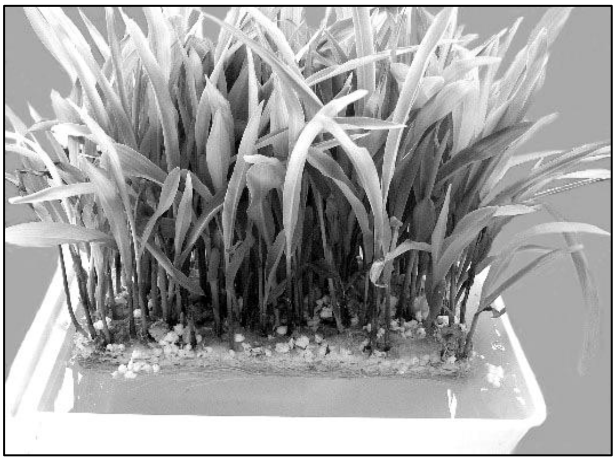
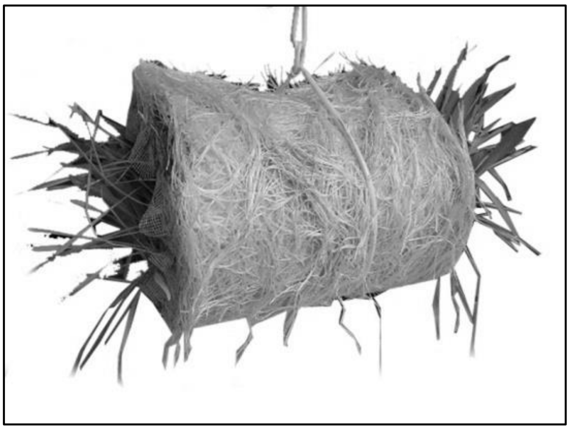


Fig.2. Checking of the floatation of the bioplateau

The next stage of the work was the study of the buoyancy of the constructed bioplateau in the laboratory

Thus, the constructed hydrophytic structure differed from the previous versions by the maximum density and homogeneity of the system, which ensured a high level of buoyancy and ease of transporting the bioplateau to water bodies.

The usage of the bioplateau in the field.Since it is planned to use a bioplateau to clean xenobiotic-contaminated water bodies, one of the tasks was to test the possibility of transporting the proposed type of bioplateau for placement on the mirror of the reservoir.



First of all, an important task was to minimize mechanical damage to bioplateau plants during transportation, so it was decided to focus on the practice of transporting lawn grass in the form of a roll. It was planned to find out the possibility of twisting the plateau into a roll for the purpose of transporting the hydrophytic structure to the required water bodies. In fig. 3 a bioplateau of the rolled type is presented.

Fig.3.The bioplate that waspreparedforthe transportation

Fig.4. The location of the bioplate on the river

The germination of plants to create a rolled bioplateau using a mesh gave a very good result: the bioplateau is quite dense, the root system binds the substrate well, which allows them to be easily twisted into rolls, makes them transportable – in other words, it is possible to deliver and place the bioplateau on the surface of reservoirs (Fig.4).

The laboratory-built floating bioplateau, designed to purify water bodies, has been successfully transformed and tested in an open surface body of water.

CONCLUSION

Thus, a new method of constructing a floating structure of a bioplateau for purification of reservoirs from toxic substances, the biotic component of which is terrestrial plants, has been developed.

Tests of several types of floating substrates have shown that granular expanded polystyrene is the most optimal for use. It is established that the placement of seeds on the top of the substrate is the best option for its germination.

The use of perlite in combination with foam created an additional capillary effect, so that the seeds germinated faster. The required density of the bioplateau, in particular the sealing of the edges of the bioplateau, was provided by a mesh with a small mesh.

The parameters of the bioplateates obtained in the experiments make it possible to transport them in the form of a roll for placement on the surface of reservoirs that require purification from toxic substances.

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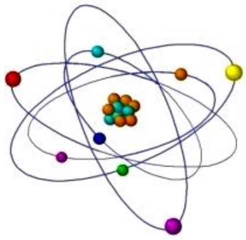
THE ACTION OF BIOLOGICALLY ACTIVE ADDITIVES ON THE FORMATION OF DISTANT RADIOBIOLOGICAL EFFECTS



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ABSTRACT

The paper discusses the risks caused by the use of biologically active additives in radiotherapy and diagnostics in terms of radiation safety. Their inclusion in the treatment methodology is an acute biomedical problem due to the unforeseen negative effects of their interaction with other pharmacological drugs. It has been concluded that insufficient study of the risks of using BAAs with different radiological methods can pose a serious threat to the patient's health and life.

Key words: Biologically Active Additives, gamma- irradiation, distant radiobiological effects

INTRODUCTION

The development of innovative medical technologies related to various types of radiation requires constant updating of our knowledge in the field of radiation safety. In addition to this, it is becoming especially necessary to carry out studies based on the fundamental radiobiological patterns established in specialized centers [1-4]. However, due to numerous reorganizations, the number of such centers in Georgia has significantly decreased. At the same time, scientific centers and commercial structures are functioning, where the solution of radiobiological tasks is led by specialists in neighboring fields. It is clear that in some cases, this circumstance can lead to the formation of a false direction and distortion of the laws of scientific discipline, so the realization of the data in such publications poses significant risks both in the processing of biomedical technologies and in predicting the risks of their use [5]. Recently this has been associated with a significant increase in biologically active additives (BAA) in the pharmaceutical market. It is known that unlike medicines, BAAs are used in healthy people and rarely for medicinal purposes [6-7]; In the latter case, their use is associated with certain risks, namely: 1) low level of study of their effects on the body; 2) dangers of overdose; 3) unforeseen adverse effects of interaction with other pharmacological drugs involved in the treatment methodology. Given the above, the study of limiting factors for the use of BAAs, especially in the presence of radiological clinical methodology, is an acute biomedical problem.

MATERIALS AND METHODS

For the study of distant effects, we propose a model based on in vitro irradiation of plant stem cells and the study of chromosomal aberrations in them. This choice was due to the fact that most of the buds on the market are based on plant material. Typically, they contain plant-specific secondary metabolites - phenolic compounds, terpenoids, alkaloids, glycosides, as well as antioxidants - tocopherol, ascorbic acid, carotenoids, polyphenols. All of these substances are involved in the detoxification of oxygen forms mainly in the membrane and cytoplasm. For tissue culture, we used the Murashige-Skoog cultural medium, in which the phytohormonal composition was gradually changed before and after irradiation. In vitro tissues were irradiated at 1-10 Gy dose intervals on a"gamma-capsule-2" irradiation device with a radioisotope of ^{137}Cs at a dose rate of 1.1 Gy/ min.

White mice of standard, homogeneous populations were used to study the effect of biologically gamma-radiation dose of 4.5 Gy was used. The criterion in the analysis of distant radiobiological ffects was the average life expectancy. Analyzes were performed on control and experimental groups of animals. Each group included 30 animals. The control group was represented by non-irradiated mice that were in similar conditions as the experimental animals. One part of the experimental animals was fed saturated food with antioxidant mixture of multivitamins for 10 days before irradiation, while the other part was subjected to the usual food ration. Irradiation was performed at a dose of 4.5 Gy.

RESULTS AND DISCUSSION

Decreased functional, structural, and metabolic activity characteristics of cells and tissues are known to be one of the primary indicators of the condition of living objects when exposed to radiation. In this regard, the relationship between functional state processes and the level of radioresistance is an important criterion that determines the entire subsequent period of post-radiation recovery of the organism; however, substantiating the interrelationships of these systems through experiments has some methodological difficulties. Therefore, in order to influence the multifunctional regulatory system, we used in vitro cultural callus tissue, in particular, phytohormonal compounds, through which it is possible to have a complex effect on the functional and metabolic activity of the study tissues.

Model experiments on plant stem cells of D.stramonium have shown that the phytohormonal compounds we use, which are used for modeling substances of secondary metabolism, along with radiation, increase the probability of aberrations in cells. As can be seen from the first graph presented, the impact of growth-regulating substances (cytokinins - stimulate proliferative activity in tissues) during pre-radiation exposure on the tissue increases the likelihood of cytogenetic disturbances, while exposure to the same substances during the post-radiation period significantlyreduces radiation damage.

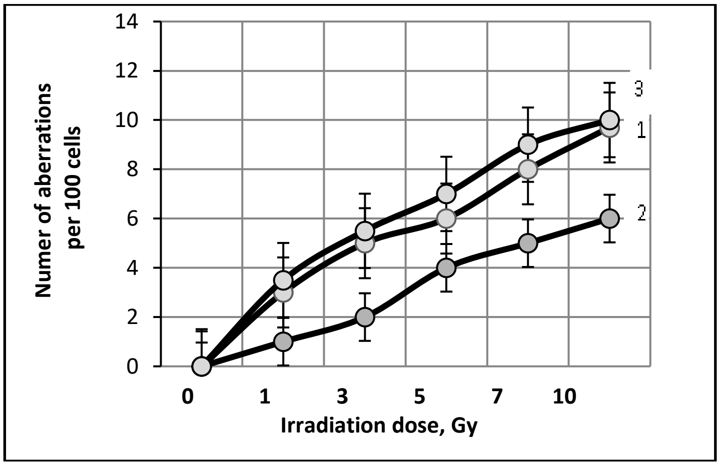

Fig.1. Influence of natural phytohormonal compounds on the number of chromosomal aberrations in irradiated stem cells (*in vitro*)

1. Chromosomal aberrations (complete phytohormonal medium); 2. Phytohormonal post-radiation action (using cytokines only); 3. Phytohormonal pre-radiation action (using cytokines only).

Model experiments have shown that the phytohormonal compounds used, which have the ability ofdamage in cells when exposed to radiation (Fig. 1). As can be seen from the picture, the main factormodeling the action of compounds of secondary metabolism, increase the likelihood of geneticis pre-radiation action, which determines the functional and metabolic state of tissues during radiationexposure. To confirm this view, we conducted a study on laboratory white mice.

Along the mice control group, a group fed with a mixture of multivitamins and antioxidants soaked in standard food for one week before irradiation was used. The data presented in Figure 2 show the regularity of the tendency to decrease the average life expectancy of the test animals when exposed to a pre-radiation regime of a mixture of multivitamins and antioxidants (Fig. 2-2), compared to the standard feeding option irradiated with the same dose (Fig. 2-3). Considering the results obtained in the general context of radiation safety problems, we can conclude that the issue of determining and standardizing the use of biologically active additives during radiation exposure to the organism has not been sufficiently studied.This is evidenced by data from recent clinical trials. In particular, it has been shown that taking dietary supplements during mammary glans's chemo- and radiotherapy increases the risk of relapse and death [8]. This includes food supplements that contain antioxidants and vitamins. It is believed that one of the ways of exposure to chemicals and radiation on pathological cells is oxidative stress, and antioxidants block this process, thus reducing the effectiveness of treatment. For this reason, it has been several years' doctors have been advising patients not to take antioxidants during therapy, although so far there has been no convincing scientific evidence to support this recommendation. Georgia is not an exception in this regard too, where there are no normative protocols for the use of biologically active supplements containing natural antioxidants. Despite a number of publications that have shown the dangers of misinterpreting the effects of some natural compounds during radiation exposure, the risks posed by this phenomenon still remain unnoticed. In this regard, the results of a study by American scientists who analyzed data on the lifestyle and prognosis of recovery of 1134 patients undergoing radiotherapy and chemotherapy. The researchers found that patients who received any antioxidants, including carotenoids, coenzyme Q10 and vitamins A, C, and E, at the beginning of chemotherapy and during chemotherapy, had a 41% higher risk of redeveloping breast cancer and 40% higher risk of death before the next observation, compared to the patients who excluded any supplements [8].

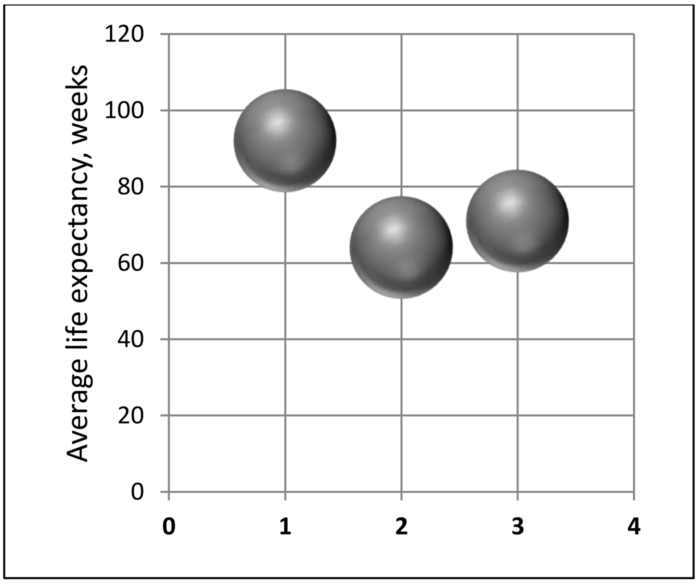

Fig.2. Impact of radiation exposure on the life span of white mice

1-control (non-irradiated); 2 - irradiation at a dose of 4.5-5 Gy under the influence of pre-radiation BAAs; 3 - irradiation at a dose of 4.5-5 Gy (the diameter of the figures in the diagram shows a 95% confidence interval).

CONCLUSION

Comparing the results obtained by us with the data of other studies, it becomes clear that insufficient study of the risks of using biologically active additives in combination with various radiological methods poses a serious threat to the health and life of patients. There is no doubt about the fact thatthe initial stage of treatment poses a serious threat in the form of distant post-radiation effects.

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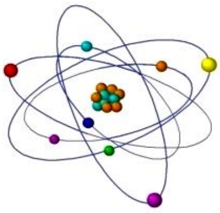
INTRODUCTION OF MODERN METHODS OF RADIATION GENETICS INTO THE MEDICINE IN GEORGIA



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ABSTRACT

The article provides an overview of the development of radiation genetics in the Georgian medicine. It considers stages of introduction of genetic methods in the examination of persons exposed to different doses of ionizing radiation under different conditions. The results of chromosomal biodosimetry, introduced since 2000, have been summarized in persons who had received high and low doses as a result of accidents due to contact with abandoned, orphan radiation sources, as well as during professional contacts and in the process of radiation therapy. In addition to the results of chromosomal research, both in total irradiation in accidents as well as during radiotherapy, the importance of using methods for determination of *micronuclei* level *in lymphocytes, buccal and erythroid cells, as well as, using the comet method, DNA damage for the purpose to assess the clinical state of irradiated subjects is being analyzed.*

Key words: chromosomal biodosimetry, micronuclei, DNA damage medical management

The estimation of biologic effects of Ionizing Radiation (IR) started immediately after their discovery.The first scientific articles were written at the end of the 19th century, and then it was concluded that this type of radiation is harmful to biological organisms, including humans. Meanwhile, humanity cannot avoid the use of ionizing radiation, because for the delivery of energy, the transfer of energy and other possibilities, especially in medical diagnostics and treatment, this is the best method. The use of ionizing radiation is constantly increasing, but, in addition to positive results, its destructive effect on the human body has been proven[2].At the end of the 19th century a famous Georgian scientist, Tarkhnishvili, discovered the effect of theinfluence of X-rays on the central nervous system, animal behavior, the heart and circulation, and embryonic development Indeed, these works have given rise to a new field in science as Radiobiology. Ionizing radiation is one of the most powerful physical mutagens among harmful environmental factors. Mutagen is an agent that affects the genetic apparatus and changes the DNA of a cell. It is assumed that DNA damage in the nucleus of single individual cell can initiate carcinogenesis[9]. Among the various types of lesions induced double-stranded DNA breaks are considered to the most relevant of the deleterious effects of IR.All systems of living organisms respond to the impact of mutagens. Radiation can cause and heal the most complicated diseases.The key moment in the development of tumor cells is a mutation. Being a strong mutagen, ionizing radiation primarily causes changes in the genetic apparatus and induces genome instability. Genetic instability plays a central role in carcinogenesis. During tumor development, diploid cells show mutations in genes responsible for maintaining genome integrity (Caretaker genes) and in genes that directly control cell proliferation (Gatekeeper genes). That’s why cytogenetic indexes are excellent biomarkers for detection the effect of irradiation [1,6].Changes in organisms caused by total body irradiation in accidents and radiation catastrophes have been well studied.

General and local irradiation, even in the identical doses, causes significantly different effects. Although the general radiobiological principles underlying external beam and radionuclide therapy are the same,there are significant differences in the biophysical and radiobiological effects of irradiation [3].

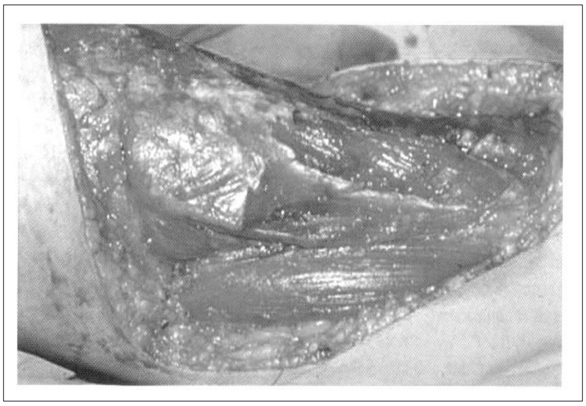

Fig.1. Radioactive sourcesin 1997 in 11 military servicemen developed skin reaction of different stageswas suspected.

Today the impact of ionizing radiation of various doses is intensively studied. Most works are focused on low doses; this effect on organism does not immediately cause clinical changes and appears only after long time and more often by development of cancer associateddiseases.

The main contingent for investigation of low doses radiation impact are professionals, being influenced due to their occupation and inhabitants of regions with increased radiation background.Although, the general radiobiologic principles underlying external beam and radionuclide therapy are the same, there are significant differences in biophysical and radiobiological effects. Dosimetry is a base of radiation safety. The main methods of this are physical dosimetry methods, but this methodsprovide only extrapolation information about the dose absorbed by the human organism and its biological effects. In contrast, biodosimetry methods give us opportunity to register the real biological damage to organism caused by ionizing radiation. Biodosimetry plays an important role in the triage and medical management of radiological casualties. Biological dosimetry using the levelof chromosome damage, is very important, because unlike physical dose measurement, it takes into account interindividual variation in susceptibility.In Georgiathe necessity of biodosimetry studies arose after several accidents, which happened in Georgia at the end of 90th, especially after the incident in the Lilo training center after irradiation 11 military servicemen.During withdrawal of Soviet troops from Georgia, because of bilateral violation of the environmental safety regulations for radioactivity-containing ammunition transfer, Georgia became the range for investigation of low dose radioactive impact on living organisms.Radiation impacts directly could have influenced the health state of the population, the density of which is quiet high around the regions of some military lands.The personnel of Georgian military bases and the population from the adjacent territories could have been affected by radioactive sources of different intensity. During the 10 years 18 individuals got serious radiation trauma, and quite big contingent was exposed to chronic impact of low doses irradiation.After withdrawal of Soviet military troops from Georgia many radioactive sources were left without appropriate supervision.

Fig.2. Poorly healing skin wounds

In cytogenetic laboratoryof Georgian Institute of Hematology and Transfusiology were detected specific disorders –dicentrics and ring chromosomes. In 2000 y. employees of these laboratory with support of IAEA, were sent to the IPSN of French Atomic Centre. In the laboratoryof multi-parametric dosimetry the owncalibration curves for dicentric chromosomes' yield were drawn.

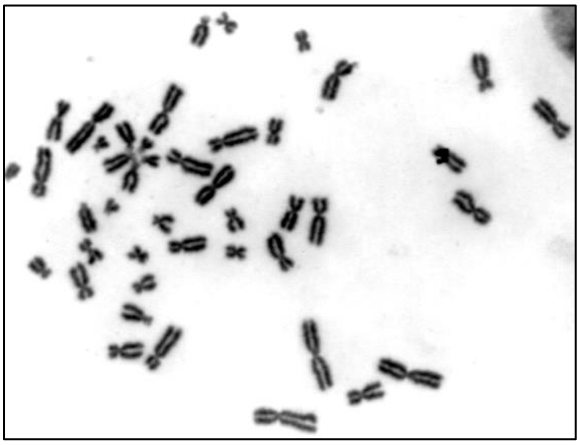

Fig. 3.Dicentric chromosome and acentric fragments

During following years were investigated more than 300 persons. The aim of the work was to determine the received dose for carrying out medical and preventive actions timely. The work was supported by ISTC (International Science and Technology Centre) in frame work of Project G-564) and Georgian State Radiation Program.Biodosimetry was carried out with conventional dicentric chromosomal assay. Parallel application of two cytogenetic methods – quantity calculation of dicentrics and definition of level of micronuclei promoted more exact definition of the absorbed dose (2,4). Before detection of absorbed individual dose upon quantity of unstable chromosome aberration on upon micronuclei yield were established the background data. The first doseswere established in11 military serviceman fromLilodata.

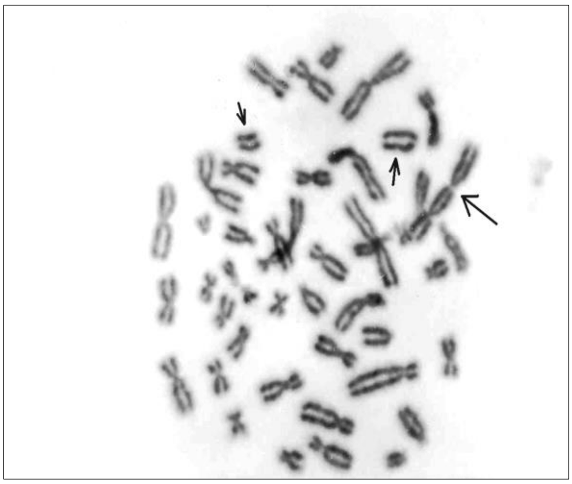

Fig. 4. Metaphase with chromosomes association, composed by 5 chromosomes

Investigations were carried out in dynamics. In all of them were revealed unstable chromosome aberrations-dicentrics, centric rings and fragments (slides) and 1 and more micronuclei in binuclear lymphocytes. The doses 0.5 - 1.6 Gy were detected [11].

Patie showed a decrease in humoral immunity, oligo- or azoospermia. Severe hematological abnormalities were not observed. Later developedlymphocytosis. The next accident happened in mountain region – village Lia. Cytogenetic analyses were carried out on three men, who had serious radiation trauma in result of contact with uncovered, highly active ($1.3 \cdot 10^{15}$Bq) thermo generator (^{90}Sr).As it was determined by IAEA special commission, X-rays dose on 1m distance was 1Gy, and in close contact – 240 Gy. In each person > 500 metaphases were analyzed. The following doses were determined. The absorbed doses. 2.8 Gy, 3.3 Gy and 1.2 Gy respectively were determined. Besides general dose, the dose was established with the method of Dolphin to establish the exact dose on the irradiation region. They were 3.0Gy, 4.3 Gy and 1,9 Gy respectively. All three had severe radiation trauma and they died at different times.

Determination of the received dose also was carried out in professional group-64people(liquidators, radiologists and radiation therapists) and in the individuals who leave or work on the territory, where radiation source was found (132 persons),Besides dicentrics and micronuclei the number of acrocentric chromosomal associations per cell (association index) was scored. Statistical confirmation of significance of acrocentric chromosome associations' phenomenon under low dose radiation impact was obtained. (12) The number of associations increased to 1 Gy and then decreased gradually. As a rule, associations were composed from 4 and more crocentric chromosomes.

For determination of acrocentrics' nucleolar organizing regions' (NOR) transcriptional activity the part of preparations were $AgNO_3$-stained by Bloom and Goodpasturemethod (7).

The extension of satellite filaments of acrocentric chromosomes was noticeable, what was the result of their deheterochromatinisation. It is considered that frequency of associations depends from satellite condensation extent and chromosomes with elongated filaments have tendency towards associations' formation.$AgNO_3$ stainingof nucleolar origanizing regions (NOR) revealed positive reaction, what confirms the amplification of transcriptional activity of these regions.

The assumption was madethat this phenomenon could be considered as a first response (indicative activity or stage) of cell on radiation impact of low intensity.

In order to carry out preventive measures, when examining persons exposed to radiation even in the cases, when on suspicion of low doses irradiation revealed number of dicentrics does not allow dose establishing, ascertaining increased number of acrocentric chromosomes' associationmakes ground for suspectIn 2002-2004 in two regions of Georgia – (Daba Vaziani and Dedoplis Tskaro) by was established that 19 individuals had received radiation doses exceeding 0.2 Gy and in 30 persons were revealed dicentrics, which quantity exceeded the background data, but didn't give us an opportunity to establish the received dose as it could be less than 02, Gy.

After 14 years re-examination was made to the inhabitants from risk group of both regions.- 37persons. (The work was supported by the IAEA Projects 17099/RO and 18791/RO).This examined group included individuals who had received an estimated dose 0.2–0.7 Gy or had increased number of chromosomal aberrations, though insufficient to determine a dose. Out of 19 people subjected to dose estimation in 2004, eight (estimated doses 0.3, −0.5 Gy) died from various cancers.

We could reexamine nine persons who were subjected to dose estimation and also 28 inhabitants from the risk group. .In one man, whose previous established dose was 0.3 Gy, we/ found 3 dicentrics (0.01 per cell) in a 300 analyzed metaphases and stable chromosome aberrations (marker chromosomes). According to our calibration curve, the possible dose of exposure should be <0.2 Gy but more than our control.

We were interested in one patient with previously established dose of 0.7 Gy. This patient suffered from the first degree of disability. Clinical examination of this patient has revealed slight enlargement of lymph nodes, gastritis, colitis, and lymphocytosis. Two dicentric chromosomes without acentric fragments were detected in 200 metaphases. No stable aberrations were observed.In individuals who have been examined this year, no significant cytogenetic, clinical, or hematological disorders have been observed. We have also investigated DNA damage by comet assay. We did not observe any significant difference in the DNA damage produced in the exposed residents compared to the unexposed individuals (8%–12%). Since the comet assay detects the DNA break breaks, it is possible that the breaks formed due to initial irradiation might have been eliminated from the system. All investigated individuals were examined by physician-oncologist, and peripheral blood tests were conducted. In some of them, anemia and lymphocytosis were detected. Other disorders in hemogram were not identified. Comparing the chronic irradiation of 10–12 years ago (0.2–0.7 Gy) and clinical outcome, differential response was seen in patients who received similar amounts of radiation wholebody irradiation with identical doses is causing very heterogeneous response in different individuals. This might depend on different factors, such as immunological stage, age, and sex. There are several data that organism response on IR can depend also on genetic polymorphism. [6, 8, 15].

Many scientists have studied the effect of total body irradiation, but only in recent decades work has begun on the problem of the effect of local irradiation on the whole human body.

The next stage of our research was to study the state of cancer patients during radiotherapy.The goal of radiation therapy (RT) is to deliver a therapeutic dose to target tissues, while minimizing the risk of complications for normal tissues. Nowadays, technological advances in radiation delivery and the introduction of particle therapies have strongly limited the amount of dose distributed to normal tissues and eenhanced the tumor killing capacity.During radiation therapy, there is a risk associated with irradiation of normal healthy tissue and the development of radiation-induced complications. (5). To assess the biological effect, it is essential to use a reliable test systems, which will also include individual radiosensitivity of the organism. (13). The effect of local irradiation was studied in 30 cancer patients with tumors of the same anatomical localization undergoing the radiotherapy taking into account the stage of the disease.These studies were carried out by employees of the laboratory of radiation safety problems of .I,.Beritashvili Center of Experimental Biomedicine.All patients were treated with a fractional radiotherapy. The irradiation was carried out on a linear accelerator with the following level: 2Gy/fraction, total dose (65.25-70 Gy). Age of the patients was varied between 55-72 years. The stage of the disease, age and gender of the patient were registerered in all cases. Hematologic and genetic analyses were carried out in dynamic. The study of chromosomal abnormalities, the DNA damages by the comet assay, and the micronuclei in lymphocytes, erythroid and buccal cells revealed a statistically significant correlation between the initial cytogenetic indices in cancer patients and their dynamic changes during and after the radiation exposure.Considering the heterogeneity in the response of patients as well as individuals to IR, caution should be exercised and appropriate treatment regimen should be planned for effective therapeutic outcome (14).

During radiation therapy should be taken into consideration patient’s individual sensitivity to irradiation and different radiosensitivity of various tissues. Extrinsic factors, including dose, age, additional treatment, and comorbidities can also modify individual response. Au WW. Mutagen sensitivity assays in population studies.Mutat Res.2003 Nov;544 (2-3):273-7.

However, excluding these extrinsic factors, about the 80% of individual response to RT remains unexplained, raising the possibility of underlying genetic differences as a cause for these variations (9).

The heterogeneity of the level of damage correlating with the efficiency of the flow after radiotherapy confirms the informativity of investigated biomarkers during local irradiation.The received data revealed the appropriateness of registering genetic parameters for predicting of post-radiation complications.The development of the use of modern methods of radiation genetics in the clinical management of persons irradiated in different situations necessitates the further development of this area.

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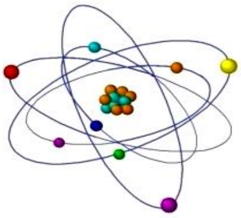
IMPACT OF HEAVY METALS ON THE PLANT'S POST-RADIATION RECOVERY PROCESS



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ABSTRACT

Present research discusses experimental results of simultaneous action of heavy metals' different concentrations and radiation on the intensity of post-radiation recovery in Lemna minor L. The effect caused by the heavy metals was modeling via adding cadmium and zinc ions into the plant's medium during its cultivation. It was shown that at specific concentrations zinc ions have capability to increase intenstiy of plant's post-radiation recovery under irradiation with relatively low doses. It should be noted that similar phenomenon was not detected while using cadmium ions. At all cadmium ion concentrations, used in the experiment, increase in the negative effects of gamma radiation was observed. Moreover, increasing the zinc ion concentrations resulted in nullifying of all the positive effects, as well as with the use of cadmium the negative effect caused by radiation exposure was increased.

Key words: gamma-radiation, heavy metals, post-radiation recovery, *Lemna minor L.*

INTRODUCTION

The influence of various physicochemical factors on the environment on phytocenoses is complex. In many cases, different types of damaging factors act much differently during simultaneous action than the same factors separately. This phenomenon acquires special interest when the damaging factors of different nature act on the living organism. In this regard damaging factors such as ionizing radiation and heavy metals are especially interesting.

Ionizing radiation is produced by radioactive decay, of which gamma radiation is one of types. Gamma radiation (high energy photons) has two main mechanism of action: 1) direct damage of molecules, inducing DNA molecule destruction, lipid peroxidation and/or enzyme denaturation, and 2) radiolysis of cellular water, generating reactive oxygen species (ROS) that can indirectly induce cellular damage [1]. As it is known, the total effect of the radiobiological reaction on the organism is formed by the damage caused by gamma radiation on the one hand and the potential of post-radiation recovery on the other hand [2]. Thus, great importance is attached to the study of the modifying factors of these effects.

It should be noted that a number of organic and inorganic substances undergo modification in the post-radiation recovery process and the complete metabolic process of the cell is involved in. Of particular interest in this regard are the phenomena: 1.Factors acting on the recovery process, which is naturally, involved in intracellular metabolism and 2. Factors those are completely foreign to the organism. Specific examples are cadmium and zinc.

To begin with, Zn is an essential micronutrient involved in a wide variety of physiological processes in a living organism. Here are several roles of zinc:

It is structural component of a large amount of proteins and participates in catalysis [3]; It participates in protection of an organism; Membrane-bound Zn has structural, regulatory and antioxidant functions; the latter also serves as a pool of readily available Zn [4]; Zn is an essential component to maintain proper structure of cytoskeleton; Zn plays an important role in cell signaling [5]. Zn-binding proteins constitute almost half regulatory transcription factors in the human genome [6]. Zn is an important factor for the cellgrowth as well [7].

As for the cadmium, it is a non-essential element for the living organism. It is very toxic when it comes to plants, animals or humans, but there may be some exceptions too [8]. In general, Cd toxicity may reveal in a different ways [9].

The pair of these heavy metals is also interesting in that they are very similar not only in chemical but also in biological and biochemical action [10]. It is known that Cd can substitute Zn in various proteins, which consequently provokes cell damage [11]. Moreover, in higher concentrations Cd causes oxidative stress due to existence of free radicals [12].

In conclusion, this interesting relationship between the two metals mentioned, allows us to more thoroughly investigate the impact of metals with different properties on post-radiation recovery.

MATERIALS AND METHODS

We selected the aquatic plant Lemna minor L. as our research object. The reason for our choice is the convenience of Lemna minor L as a test-system when it comes to the studying heavy metals [13], as it is characterized by revealing an instant reaction to the toxicity caused by those metals.We cultivated the plant in the Steinberg medium [14]. The multiplication of the population proceeded by growing 1 colony of the plant, thus achieving the homogeneity of the obtained cultural population. We studied the action of heavy metals by incorporating standard aqueous solutions of cadmium chloride and zinc sulfate heptahydrateinto the medium.Gamma irradiation of the study plant was performed on a machine called “gamma-capsule” where the radiation source was^{137}Cs. The experiment was recorded by counting the total plant organisms as well as the individual frond numbers of these plants. The method is based on the establishment of instant growth of the population.

The change of the latter value reflects the resistance of the environment, that is to say characterizes the sum of all the limiting factors of the environment that impede the realization (r maximum) of reproductive potential. After the exposure time passed, the total amount of the fronds is calculated on the control and each dose (including mother individuals and fronds separated from mother individuals). Based on the received results a population's instant growth coefficient (r) is calculated:

$$r = (\ln(N_t) – \ln (N_o)) / t$$

where N_o is the total amount of the fronds; N_t-the final quantitativeof the fronds; t-exposure time [13].

RESULTS AND DISCUSSION

Nowadays, when it comes to the post-radiation recovery process that occurs after plant radiation damage, scientists largely note the radiation action on individual metabolic processes. One of the examples of this is the reduction of the characteristic and necessary metals in the mentioned organisms as a result of gamma irradiation in plant systems [15]. Therefore, the heavy metals introduced into the plant after gamma irradiation have a potentially positive effect on the post-radiation recovery process. In support of this, various studies have suggested that the introduction of zinc and calcium into the plant medium has been shown to normalize the amount of reduced sulfhydryl compounds induced by gamma radiation in the plant [16].

Various factors of influence on organisms form a complex system of interaction of these organisms with real environmental situations. Synergistic and antagonistic or additive types of reactions of biological systems to the combined effect of radiation and chemical factors are natural events and most likely occur in the low dose range - typical for environmental conditions. For this reason, the actually observed level of biological effects in natural populations inhabiting radioactively contaminated areas, or even heavy metal contaminated areas, often significantly differs from the predicted separate action of factors based on the results of experimental studies. Under these conditions, both external irradiation in low doses and incorporated heavy metals have a significant effect on the level of variability of quantitative indicators of organisms in populations and the possibility of their adaptation to a specific ecological situation.

During the process of studying this issue, we used two levels of, radiation and heavy metals, effects for their doses and concentrations respectively - conditionally low and high levels: 5 Gy - 20 Gy in the case of gamma radiation, 0.07 mg/mL – 0.7 mg/mL for Cadmium and 0.5 mg/mL – 5.0 mg/mL for Zinc. These exposure levels were due to the fact that these levels resulted in adequate inhibition of the growth rate of the plant model we chose.

The main task of our experiment was to determine the impact that various heavy metals could have on the post-radiation recovery of the irradiated plant.

As can be seen from Figure 1-A, the different concentrations of cadmium introduced into the plant’s medium after irradiation of the plant at a low dose (5 Gy) significantly reduced the post-radiation recovery process. In addition, the same graph shows a decrease in the recovery processes in the separate irradiation option as well. A similar pattern, however more intensively expressed, was observed in the high-dose (20 Gy) irradiation variant (Fig. 1-B).

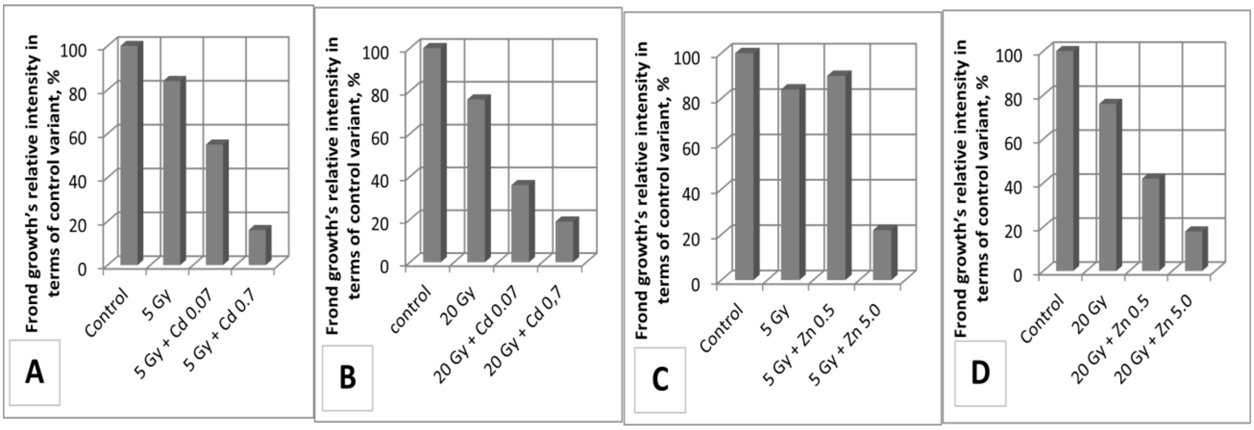

Fig.1 Impact of gamma radiation on the growth of the *lemna minor L* fronds, alongside with heavy metals.

An experiment was conducted with a similar scheme in the case of addition zinc to the experimental plant medium. It can be seen from Fig.1-C that although 5 Gy irradiation resulted in a decrease in frond growth intensity in the plant compared to the control variant, the addition of a low concentration of zinc (0.5 mg/mL) in the same variant resulted in an increase in post-radiation recovery intensity. However, in the same variant, the addition of high concentration of zinc (5.0 mg/mL) changed the potential for post-radiation regeneration to negative.In this regard, it is noteworthy that the experiment conducted by the same method, however, in the case of high doses of radiation with different concentrations of zinc, yielded identical results with respect to cadmium (Fig. 1-D).

As it is known, the response of *Lemna minor L*to inhibitory factors such as the action of heavy metals and radiation can reveal into two levels: individual fronds or population recovery levels [13]. Given this fact and the characteristics of the plant test-system we used, where the growth rate of its individual fronds indicates the level of recovery potential of the plant itself, the population effect rates caused by the same radiation exposure become important. In our case, we used quantitative indicators of plant’s micro-populations of each variant as a criteria for this.As can be seen in Figure 2, which shows the results of population records of the same experimental components (as the growth characteristics of individual fronds), a variant of small concentration of zinc and a small dose of radiation is observed to show 15% growth compared to a separate low dose irradiated plants (Fig. 2-C), while in the remaining experimental elements a similar situation was observed with respect to the frond variants (Fig. 2-A, B, D).

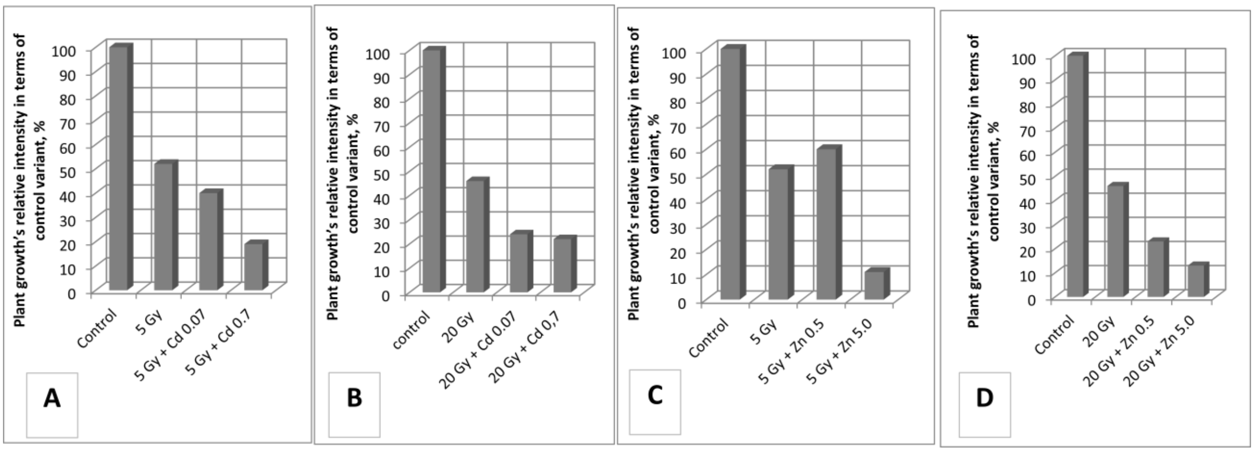

Fig.2. Impact of gamma radiation on the growth-development of separate plantsof *lemna minor L* with the presence of heavy metals.

To more fully describe the effect mentioned, we used the instant growth coefficient concept. This criterion can be used to determine what type of modifying action different concentrations of heavy metals have during the post-radiation recovery period. As can be seen from Fig. 3, both in terms of dose strength and in the presence of different concentrations of heavy metals, a heterogeneous response is observed. For example, at low-dose irradiation (5 Gy) and at low zinc ion concentrations (0.5 mg/mL), we obtained high levels of post-radiation recovery potential.

An increase in the concentration of zinc during radiation exposure of the same dose significantly reduced the level of the above phenomenon. It also sounds quite paradoxical that with an increase in the radiation dose, an adequately high concentration of zinc ions (5.0 mg/mL), if we adapt these figures to the growth dynamics of the plants used in the experiment, facilitates the recovery process at the initial stage of inhibitory action rather than deminishing it. A more contrasting ratio is obtained by the addition of cadmium ions in the plant medium. If the use of 5 Gy irradiation and low cadmium ion concentration (0.07 mg/mL) indicates a high instant growth coefficient, indicating a low inhibitory level corresponding to a low cadmium concentration, then in the case of an increase in cadmium concentration reveals a relatively high toxicity on the plant. This is evidenced by data on the combined action of high doses of radiation and both concentrations of cadmium as well.

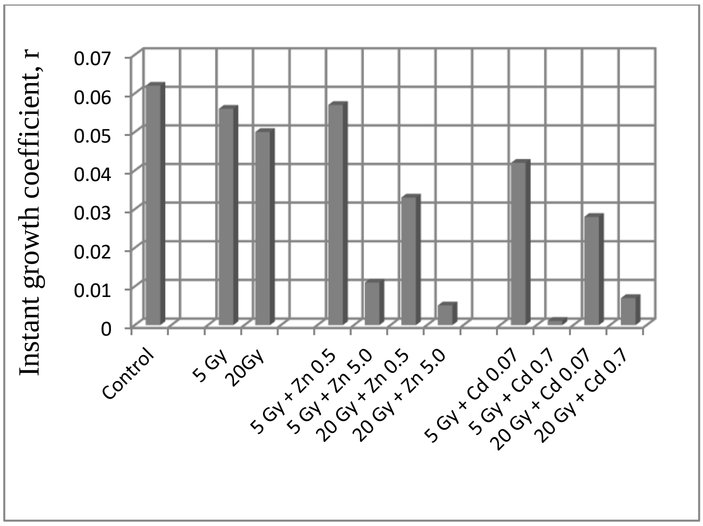

Fig.3 Joint action of heavy metals and radiation on the intensity of *Lemna minor L*'s growth

Overall, based on the results obtained, it can be concluded that the impact of heavy metals has often the opposing action. From this point of view, it can be assumed that the use of low concentrations of zinc ions (0.5 mg/mL) during low-dose irradiation (5 Gy) facilitates the recovery process of a number of radiation-induced proteins, such as alcohol dehydrogenase, carboxypeptidase, aminopeptidase, beta-amyloid, etc., in which zinc is one of the main components. The same outcome was not observed when using cadmium ions in the same proportions. The second effect that may underlie this phenomenon is the increase in the inhibitory impact of heavy metals on the dynamics of the growth intensity of the irradiated plant. Specifically, highly inhibitory concentrations of heavy metals' ions afffect more strongly on actively growing plants, than at the level of weakened growth intensity under conditions of high irradiation doses.

CONCLUSION

Based on the conducted research, we can conclude that the action of physico-chemical factors used in the experiment is often nonlinear, and is highly dependent not only on the level and capacity of the factors, but also on the interaction of processes caused by these factors themselves. These data, in our opinion, are important to monitor ecosystems with different dynamic processes caused by the pollutants, both when assessing their condition and when developing prognostic models.

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STUDY OF COGNITIVE PARAMETERS IN POSTRADIATION PERIOD IN WHITE MICE

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ABSTRACT

The aim of this study is to identify a dose-and time-dependent correlation betweengammairradiation (5 Gy) inducedcognitive parametersand determine role of irradiation in aging process.Using a laboratory whitemouse model, we showed that ionizing radiation exposures causes spatial memory and behavior changes in different age groups of animals.Study revealed Instant reactions of post-radiation recovery and specificity of long term effects after one year of irradiation.Study of cognitive parameters reveled that gamma irradiation decreases spatial learning process and causes radiation aging, what consolidates the contemporary evidence that radiation can accelerate aging and mortality.

Key words: Gamma-irradiation, white mice, cognitive parameters

INTRODUCTION

Ionizing radiation has multiple effects on the brain, behavior and cognitive function. These changes are largely dependent on the radiation dose. Studies revealed that ionizing radiation affects the functions of the central nervous system what results in behavior and memory changes.These changes occur as a result of a direct irradiation of the central nervous system and also indirectly asa response to irradiation of other organ systems [1]. Dysfunctionof the central nervous system is manifested after the period of low doses radiation exposure. Nowadays, there is an increasing number of evident literature that the response of the central nervous system to the radiation is a continuous and interactive process. Particular attention is paid to apoptotic cell (neuronal) death, as well as, cell death and damage induced by secondary injury [2]. Central nervous system is considered as a radiosensitive system, and the degree of its dysfunction can be evaluated by electrophysiological, biochemical and behavioral parameters. Impairments of these parameters can be observed after local and total irradiation of the whole body [3].Recent studies revealed cranial radiation therapy impact on a wide range of brain functions resulting in cognitive and memory deficiency. Radiation-induced changes develop with a dose-volume-dependent severity.Highdoses of ionizing radiation induce reactive gliosis, white matter necrosis, vascular abnormalities, which are irreversible and result in clinical symptoms[4]. Low doses can also induce a wide array of cognitive dysfunctions without any significant morphological changes [5].Detrimental effects develop after months or years of brain irradiation. Acute, early delayed, and late injuries are observed [6]. Cognitive impairment is revealed in various degrees of learning difficulties, behavior changes, and memory deficits [7].The presence of cognitive disorders after exposure of high dose irradiation has a connectionto the hippocampus glial cells and proliferating progenitor cells in the subgranular zone of the dentate gyrus Radiation-induced cognitive dysfunctions is age-dependent,epidemiological studies revealed that the risk for cognitive disfunctions is higher during prenatal and childhood irradiation [13-14].

Populations of neural stem and progenitor cells located in the sub-granular zone of the dentate gyrus are radiosensitive. Radiation inhibits neurogenesis which results in hippocampal-dependent learning and memory impairment. Other mechanisms regulate the inhibition and/or recovery of neurogenesis and include a variety of stress-responsive of signaling mechanisms that impact the level of neuroinflammation [15].

MATERIALS AND METHODS

The experimental protocol was in accordance with the guidelines for care and use of laboratory animals as adopted by the Ethics Committee of the Tbilisi State Medical University (TSMU).

Animal care and maintenance.

Three month and one year old male mice (Mus musculus), were obtained from Vivarium of Tbilisi State Medical University. They were housed in animal cages, with room temperature maintained at 20^0-22^0C, relative humidity of 50-70% and an airflow rate of 15 exchange/h. Also, a time-controlled system provided 08:00-20:00 h light and 20:00-08:00 h dark cycles. All mice were given standard rodent chow diet and water from sanitized bottle fitted with stopper and sipper tubes.

Experimental design

After acclimatization for a week to laboratory conditions, the mice were divided into six different groups. The first controlgroup of three months old mice not irradiated, second group -experimental group of three months old irradiated mice, third control group of 1 year old mice and fourth experimental group – 1 year old irradiated mice, fifth experimental group – of18 months old mice and sixth group18 month old mice after 1 year of irradiation.Mice whole-body irradiation with ^{137}Cs was performed at a dose rate of 1,1Gy/min for the total dose of 5 Gy with a “Gamma-capsula-2”(group 2 and 4);

Spatial learning and formation of memory were estimated in the elevated-type multi-way maze.

The maze consists of 10 platforms (40x10 cm) fixed at height 25 cm. The motivation for movement along the maze under test conditions was to go back in the box-nest fixed at the end of the maze. Experiments were carried out seven days (five trials each day). Animals wereplaced in the start point facing the pathway of the maze.The familiarization session consistedof free exploration of the start and familiar arms for 10 min. On the first day, experimenter helped the animal to find the optimal way leading to box-nest. Number of errors(deviations from optimal trajectory) and total time for crossing the maze were calculated. Analysis of the obtained numerical data allowed us to estimate dynamics of learning process. Free passing in the labyrinth during 10-15 sec and the achievement of automated behavior was considered as a criterion of complete learning process.

All experimental areas werewiped with 20% ethanol after each trial. All behavioral experiments were conducted duringthe light cycleafter two hours of acclimation.

RESULTS AND DISCUSSION

Monitoring of spatial learning process of two animal groups in the elevated maze showed that animals of group I (control group of 3 month old mice;) when placed in the maze for the first time, needed the help of the experimenter only in two trials of the first testing day. Later they independently opened up the new environment and demonstrated research activity. On the 5thday mice of control group completely opened up spatial information. Others made not significant errors and the passage time significantly decreased. On the 6th and 7th days all mice of this group identified shortest way to the target and spent average 0.16 sec. At the end of the experiment, the majority of the animals could pass the maze in 2-3 sec.

Animals of group II (experimental group of 3month old mice) compared to control group showed restriction of movement. On the first day of experiment mice of this experimental group were not able to learn the way leading to the nest, even from the last platform. On second II-IV days mean number of errors decreased and mice reached the target-nest less than 3 minutes. Improvement of learning process and total mean time needed for crossing the maze was determined by middle part of the maze significantly increased the rate of the path recognition. Though, despite the visible improvement of spatial learning process V-VII days mean number of errors gradually increased and on the7thday almost approached the error number results of 1st day.Moreover, mean time of crossing the maze increased to 3.31 on 7th day of experiment. Despite the visible improvement in spatial learning process on II-IV days results obtained from control group animals differed significantly from the control group in both studied parameters (number of errors and time needed for crossing the maze) (Fig 1).

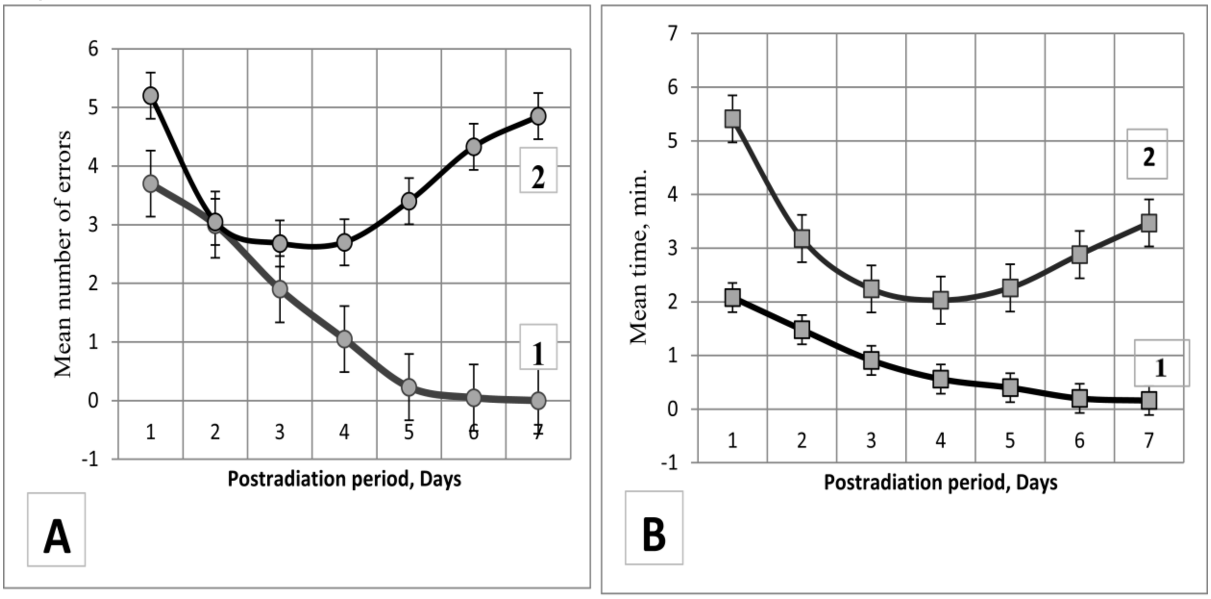

Fig.1 Effect of gamma-radiation on the cognitive parameters of 3 month old white mice (*During one week period*)

A-Mean number of errors in 3 month old mice;

B- Mean number of total time for crossing the maze (min).

The same test was carried out in 1 year old mice: Group III (control group of 1 year old mice), and Group IV (experimental group). in animals of control group number of mean errors and mean time for crossing the maze, accordingly, were equal to 3.85 and 2.04 was equal to 3.85. Later they independently opened up the new environment and number of errors decreased and on the 6thand 7thdays mice found the shortest way leading to target and spent average 0.19 sec.

Animals of group IV (experimental group of 1 year old mice) showed decreased number of errors and on the 5th day of experimentImprovement of learning process and total mean time was determined:mice reached the target-nest in 0.79 sec and number of errors was the same compared to control group.. On second II-IV days mean number of errors decreased and less than 3 minutes. Improvement of learning process and total mean time needed for crossing the maze was determined by middle part of the maze significantly increased the rate of the path recognition. Though, on VI-VII days mean number of errors and time gradually increased on 6th and 7th days of experiment (Fig 2).

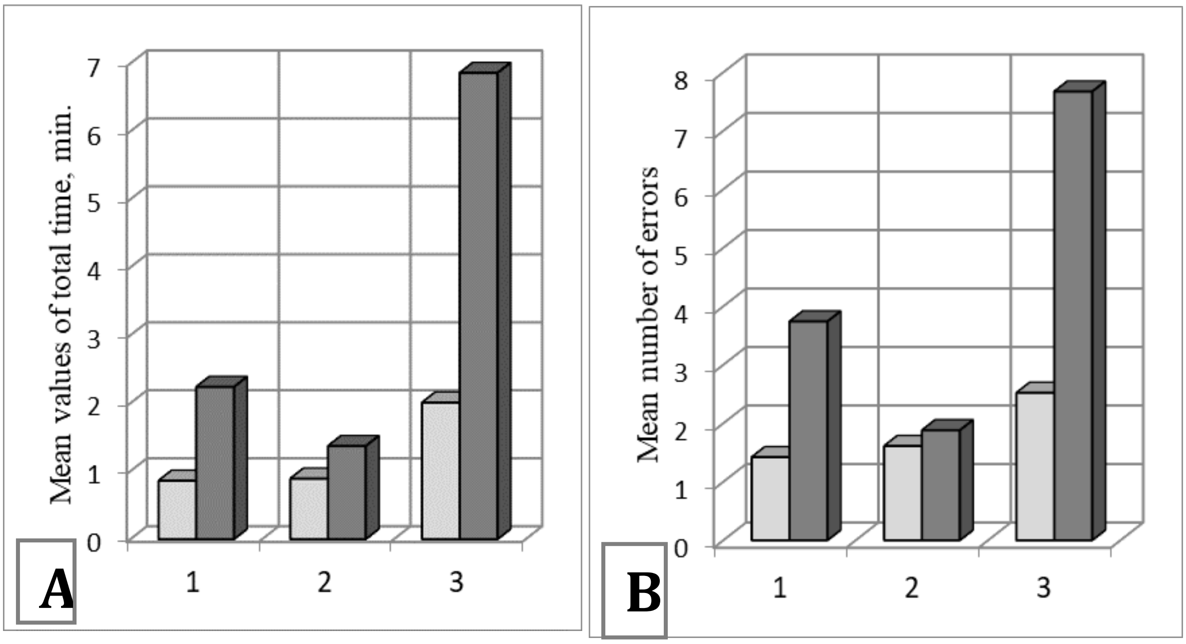

Fig.2. Effect of gamma-radiation on the cognitive parameters of 1 year old white mice (*During one week period*)

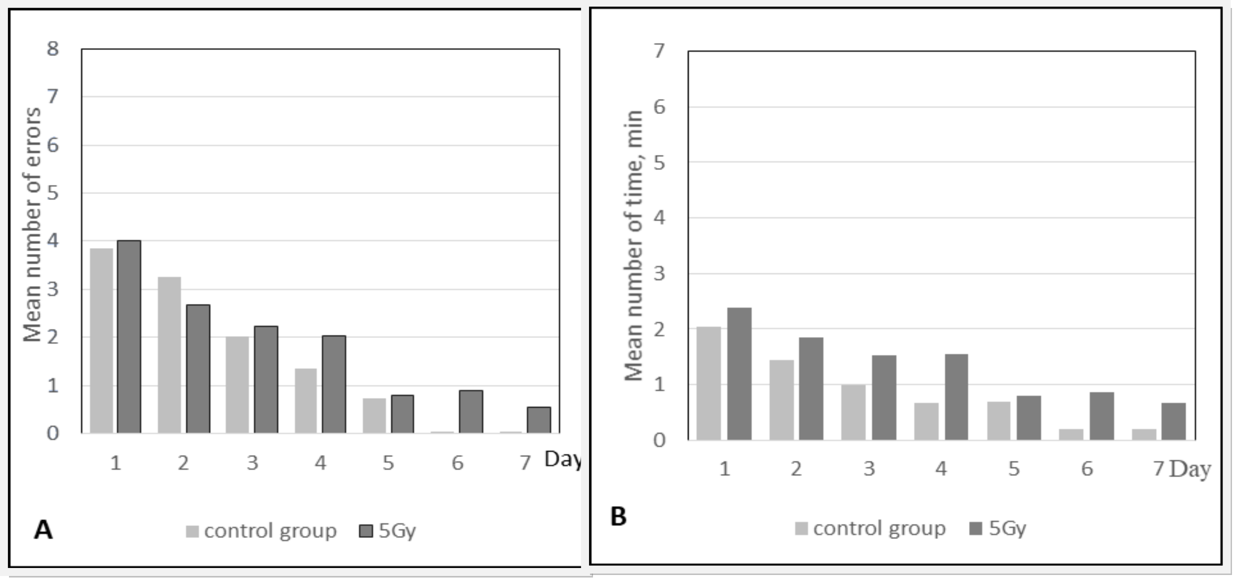

Fig.3 Effect of gamma-radiation on the spatial learning and memory of white mice

A- Effect of gamma-radiation on mean value of errors; **B-** Effect of gamma-radiation on mean number of time; 1-Changes after irradiation in 3 month old mice; 2- Changes after irradiation in 6 month old mice. 3- Changes after 1 year of irradiation.

In Sixth experimental group mean value of total time significantly increased in comparation to control group from 2.01 min to 6.86 min. The same results were obtained when comparing mean time of errors. After one year of irradiation spatial learning process significantly decreased in comparation to 3 and 6 monthold mice (Fig.3).

CONCLUSION

The results support that ionizing irradiation with total dose 5 Gy results in delayed spatial learning process in different age groups. Using a laboratory whitemouse model, we showed that ionizing radiation exposure causes spatial memory and behavior changes in different age groups of animals. Study of cognitive parameters reveled that gamma irradiation can be considered as a factor inducing radiation aging, what consolidates the contemporary evidence that radiation can accelerate aging and mortality.Dynamics of post-radiation effect formation can be divided intoshort and long-term effects. Age related radio resistance plays major role in the early stage of post-radiation recovery. Though, the main mechanism of late radiation effect formation can be related to radiation aging process.

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OVERVIEW OF GARDABANI, RUSTAVI AND MAKHATA MAUNTIAN RADIOLOGICAL SURVEYS

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ABSTRACT

Environmental pollution and its monitoring have been urgent and intensified in recent times. Environmental pollution is a characteristic feature of the last century. Its large scale dates back to the 30s of the century.Industry and road transport pley an imfortent role in environmental poiiution, while agriculchure and siol erosion occupy a relatively small share. The role of radioactive soures in environmental pollutionis great. It is necessary to pevelop and implement investigations and monitoring to protect against radioactive contamination of environmental factors and work facilities.

Key words: environment, radiological reserch, radioaqtive contaminjation, radionuclides.

INTRODUCTION

In terms of environmental impact**,** according to the International Convention, ecologically dangerous productions and facilities include: Nuclear industry, energy (nuclear, hydraulic and Thermal power plants), Ferrous and non-ferrous metallurgy, petro chemistry, chemical Industry, Mining, Cellulose production, transportation of waste, storage-disposal and burial, Construction of roads, railways, highways, airports, dams and reservoirs, deforestation, light industry and more. In pollution no less role is played by transport as well. Pollution in any environment represents new physical, chemical and biologicalagents to them, or their natural average perennial content Overcoming the level override.[1] As a result of pollution occurs soil loss, as a result, the productivity of the ecological system and the biosphere is falling apart. Environment transformation begins at a high stage of public development; Every product of labor represents man and nature The result of joint action.[2] Environmental pollution is the loss of substances and energy Undesirable process caused by human economic action As a result, Such as the extraction and processing of raw materials, whatever Accompanied by waste separation and dispersal in the biosphere. Environmental pollution includes individual ecosystems as well as the entire biosphere Irreversible decay, changing their physical and chemical parameters. Contamination directly or indirectly worsens the conditions of human as a core of society the physical and moral condition of the force produced. Monitoring Explained in the literature as elements of the environment Objectives defined in time and space by an observation system, it complies with a pre-prepared program. In order to evaluate the results, Study of different anthropogenic impacts on the environment A comprehensive tool is its comprehensiveanalysis.Environmental pollution can be of two types: I) natural, of which the cause may be natural disasters. II) Anthropogenic-caused (by)as a result of human activity. They are attributed to various anthropogenic impacts on the biosphere Systems analysis methods. The main feature of the analysis is detailed discussion of the main aspects of the impact. If we divide it into stages, it can be said that the first stage of comprehensive analysis represents the study of the impact of various factors on the environment Issue. If we divide it intostages, it can be said that the first stage of comprehensive analysis represents the study of the impact of various factors on the environment Issue, Which is defined by the detection of such rings Analysis of reactions of biosphere elements for which impact is critical. The role of radioactive sources in environmental pollution is huge: Explosion of atomic bombs, scattered in the environment by nuclear power plants Radionuclides and heavy metals, during Other-radiological accidents Radionuclides emitted into the environment, Human production Activities of radionuclides of natural and artificial origin Distribution in the environment: fertilizer application, ore extraction, etc.[3] The largest share of pollution comes from industry and transport. It is known that the planet consumes 2.4 billion tons of coal, of which As a result, 280 thousand tons of arsenic and 224 thousand tons of uranium are scattered on the earth every day. At this time the world produces 40 thousand tons

Arsenic and 30 thousand tons of uranium. From this it is clear how much Pollution of the environment with these substances prevails. With coal and its recycling and also using it to pollute the environment is real and accountable. In the 80s of the 20th century, In the Georgia Radio ecological and Radiobiological studies have been given special importance. The existence of global radioactive contamination is well known as well as Distributions of its Geo ecological regularities.[5] After Chernobyl accident the radiation background in Georgia increased a lot. Common the radiation background increased 20 times more than the norm. Soil, as a variety of natural resources, is characterized by a number of features. It is a product of long biological transformation of different types of a rock layer. Conditions in which modern soil is formed, has been changed partially or completely. Land is an invaluable treasure of nature; it is the indefinable wealth of the people! Biologically, as a result of Sr_90 and Cs_137 atomic explosions, among the generated radioactive substances, great danger produces those that accumulate in the bones, tissues and organism as well, and forming the main source of damage to the genetic apparatus.[6]

The 1986 Chernobyl nuclear power plant disaster was significantly changed radiation in Condition Georgia, particularly in western Georgia, Which had a significant impact on the Cs-137 and Sr-90 On the ratio.

Increase in pollution levels after Chernobyl nuclear power plant accident mainly is caused by quantifying excess of radioactive cesium. As is well known, one of the main factors in the distribution of radionuclides is Atmospheric Precipitation, wind direction and more.

In Georgia particularly industrialized was and still is city Rustavi zone, as well as Zestaponi zone.(re It is known that these wastes, along with heavymetals, often contain radioactive elements in excessive concentrations.As for Rustavi, this time on the territory of the park located in the center of the city for years

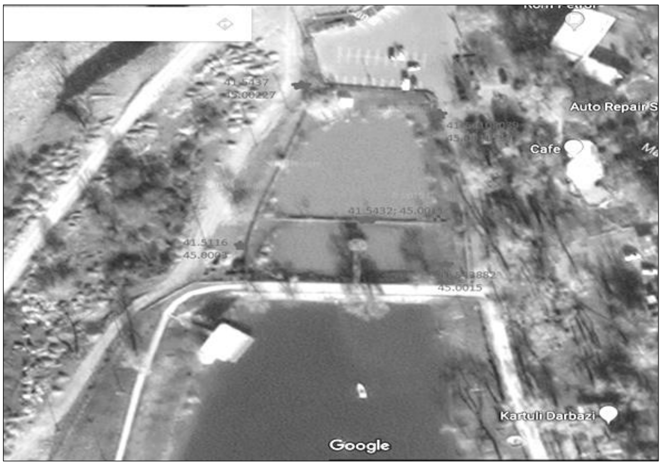
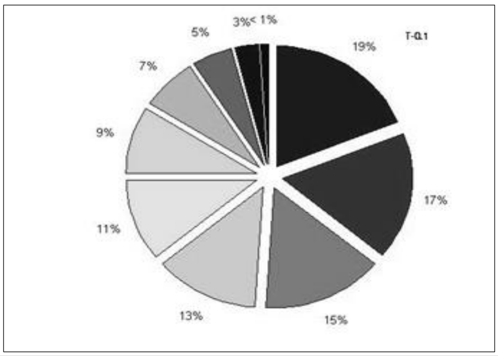


Fig.1.The slag produced in Rustavi Metallurgical Plant was being poured.

It is in this sense that the laboratory conducted by us According to the analysis the inspected part of Rustavi territory for today, Radiation contamination levels (Cs-137 and Sr-90, K-40) radioactive elements are not alarming. However radiation vitreous Reliable representation of the retrospective image requires soil Comparison of changes in pollution levels over time and space. Technogenic contaminant of origin can be deposited on the Earth's surface, Occur due to both airborne and unsystematic dumping of solid waste. As a result of the Chernobyl accident, for example, radiation Pollution norms have been tightened enough. We can say that, the territory of Rustavi, which has been inspected so far, Radiation pollution levels in places based on radioactive elements are not alarming (Cs -137 and Sr-90, K-40). But radiation vitreous Reliable representation of a retrospective image requires level of soil pollution changes over time.[7] In addition the analysis was done by a metallurgical plant Research on recycled slag, In terms of radiation pollution.

In a similar sense. We conducted research in some of Gardabani and In the current area as well, Including on agricultural soils. On the left side of the Mtkvari , there is Gardabani plain as a narrow strip. This plain is connected to the alluvial terraces of the Mtkvari. Based on the above, Peculiar regularity of wind and precipitation distribution in the zone is manifested.[8] A similar pattern was s found in the radiation background as well. 2018-2019 Was conducted Study of natural radiation background, on soils of Gardabani district, where the largest annual dose Accounted for 120 ng / h, 1.06 mz / yr. It is known that the so-called Average of ‘‘normal ’’ regions the data are 0.7 mzv per year. If we compare this figure with the Gardabani zone data, we will see that the Gardabani district is included in the number of regions with increased radiation zone.

Exposure of a polluting agent to the earth can occur both from the air.Chemical contamination in the soil Migration is mainly determined by the slow movement of groundwater, so-called the filtration process. Studies have shown that, in the soil Radionuclides are absorbed by the plant and become its various organs by accumulation. A radiological study conducted in the Gardabani district showed Radionuclide condition of soil, heavy metal content assessed in the soil[4].



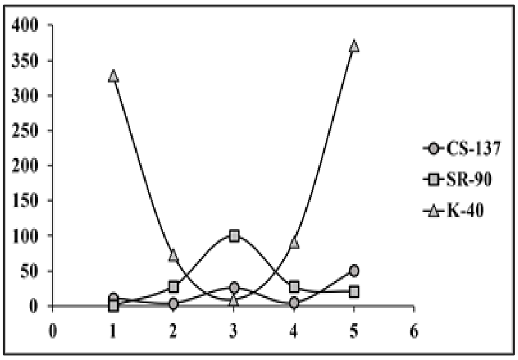


Fig.2 Distribution of Cs -137 and Sr-90, K-40 in soil.

Samples were taken in the villages that were few kilometers away from Gardabani thermal power plant, as the table shows the ^{40}K natural radionuclides in the soils of Gardabani was shown in all samples. Natural radionuclide in soils of ^{40}K Existence is due to the composition of the soil capillariesas well as using phosphorusfertilizers.

Table.1

#	Radionuclide	Activity Bq/kg	T.l	Stat.error %	Uncertainty Bq/kg	Maximum Alloeabie Concentration Br/kg
1	CS-137	11	3,9	25,7	4,35	50
2	SR-90	0	27,4	100	27,4	20
3	K-40	328	72,5	8,6	91,1	370

We also analyzed the heavy metal content of Gardabani For some areas;
As a result of the research we can conclude: the soils of the area adjacent to the Gardabani district thermal power plant are affected by it (heavy metals), which is reflected in the increase of the permissible level of heavy metals inthe soils. And finally in one of the most important districts of Tbilisi, Makhata, We conducted a radiation study of the mountain area. There was over 100 more soil sample. Laboratory analysis was performed in rural areas At the Scientific Research Center for Agriculture and Radiology. Data showed that Pollution levels are Cs-137 and Sr-90, In this case, their increase in intensity is not observed.

CONCLUSION

In the future, we plan to study the following radiologically active areas and to continue the analysis of radionuclide reserch and to contact more detaled studies in this direction for different regions of Georgia.

Table.2.

Place of sampling	Heavy metal content in soils of Gardabani district		
	Zn	**Pb**	**Fe**
41,450905 45,093319	770	360	3492
41,450857 45,093072	260	320	3426
41,450431 45,093351	920	280	3105
41,499659 45,093394	650	220	2988
41,470604 45,083255	910	280	3534
41,469832 45,083255	850	240	3447
41,470308 45,071133	750	220	3360
MPN	300	130	420

Table 3

Sampling coordinates GPS	Deths of radionuclides	**Radionuclides**					
		^{40}K	**^{137}Cs**	**^{208}Ti**	**^{211}Bi**	**^{212}Pb**	**^{214}Pb**
41,450905 45,093319	0-20sm	1414			91		73
41,450857 45,093072	20-40sm	1033		18	119	24,6	68
41,450431 45,093351	0-20sm	1332	11	31	114	30	79
41,450270 45,093404	20-40sm	1258	3				52
41,499659 45,093394	0-20sm	1471	19				80
41,463770 45,084757	20-40sm	1377	13			46	63
41,470604 45,083255	0-20sm	1519	25				56
41,469832 45,083255	20-40sm	919	20				46
41,470435 45,083652	0-20sm	1286	47	41	211	34	117
41,468064 45,083587	20-40sm	1273	17			22	103
41,470308 45,071133	0-20sm	1262	29	23	146	27	60

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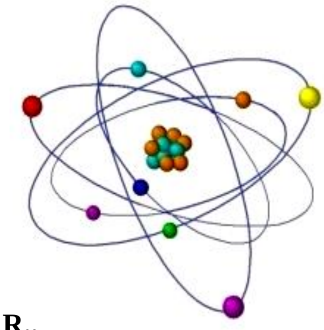
RADIOACTIVITY CONCENTRATION AND ASSESSMENTOF GAMMA-RADIATION EXPOSURE FROM THE SOIL OF DIFFERENT TYPE IN TERRITORY OF TBILISI CITY



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ABSTRACT

There are given results of radioactivity research in different types of soil within the territory of some districts of Tbilisi. Twenty samples of brown and alluvial types have been selected from 20 locations. Up to 22 radionuclides were identified. Concentration of radionuclides of Th-232 family was in limits from 16.8 to 41.4 Bq/kg (average value of 22.6 Bq/kg), U-238 family – from 17.7 to 67.8 Bq/kg (average value of 29.3 Bq/kg), U-235 family - from 1.09 to 3.76 Bq/kg (average value of 1.77 Bq/kg). Also individual radionuclides have been identified: K-40 – from 365 to 618 Bq/kg (average value of 465 Bq/kg), Cs-137 – from 1.5 to 118 Bq/kg (average value of 19.9 Bq/kg); trace amounts of Be-7 were determined in several samples. Radium equivalent activity varied from 71.5 to 148 Bq/kg (average value of 95.8 Bq/kg. Annual effective dose varied from 0.042 to 0.088 mSv/y (average value of 0.058 mSv/y). There were marked some features of radionuclides distribution, in particular, depending on the type of soil and sampling locations. Several activity ratios of radionuclides were considered, in particular, U-238/U-235, U-238/Th-232, Ra-226/U-238 and Pb-210/Ra-226.

Key words: radionuclides, soil, radioecological monitoring.

INTRODUCTION

Natural and technogenic radioactivity of soil is one of the main components of the Earth’s radioactive background. As numerous studies have shown, the radioactivity in various areas of the globe differs considerably – from units up to hundreds of Bq/kg. In many works the activity ratios of different radionuclides have been investigated, indicating a certain level of interest in understanding various geochemical processes in rocks and soils. For example, the activity ratio, U-238/U-235, which is a constant equal to 21.7 in rocks and soils [1, 2]is often investigated for the purpose of identification of technogenic pollution by uranium. A number of other activity ratios, for example, U-238/Th-232, and also Ra-226/U-238, Pb-210/Ra-226 [reflecting disbalance in radioactive chain U-238 in zones of hypergenesis (weathering)], are often a subject of investigation [3, 4, 5].Therefore, it is important that such studies be carried out in each territorial region.

So, for example, in the work [3] there were studied soil samples selected in the territory of the Arnás River Catchment in the central part of the Spanish Pyrenees where six types of soil are widely distributed–Calcaric Fluvisols, Eutric Gleysols, Calcaric Regosols, Rendsic Leptosols, HaplicKastanozems and HaplicPhaeozems; it was determined activity concentration of Th-232, U-238, Ra-226, Pb-210, Pb-210_{ex}, K-40, Cs-137; correlation between soil radioactivity and its mineralogical content was investigated; values of activity ratios U-238/Ra-226 and Th-232/Ra-226 were calculated.

In another work [6] it was investigated activity of radionuclides Th-232, U-238, K-40, Cs-137 in samples, collected from uncultivated fields within the territory around Kestanbol (Çanakkale), Turkey;

there were calculated values of radium equivalent activity; authors noted that these values of the study area are higher than the limit value of 370 Bq/kg.

Similar researches of naturally occurring radioactive materials (NORM) - Th-232, U-238, Ra-226, U-235, K-40 - in anthrosol-type soil nearby Belgrade have been carried out in the work [7]. In another work [8] soil samples collected from undisturbed sites (oil field) in the Niger Delta region of Nigeria were studied; the specific gamma activity concentration of Ra-226, Th-232 and K-40 was determined, and values of radium equivalent were calculated; authors noted that all the linear fit of the measured parameters were significantly further away from unity (1) which shows that the concentration of NORM were mainly influenced by the oil exploration and production activities in the area and not from the geological constituent of the area.

The radiological quality of sand from the beaches along the coastlines in Ghana was studied in the work [9]. It was established that only naturally occurring radionuclides were identified in studied samples.

Activity concentration of Th-232, Ra-226 and K-40 in soil samples from the Fen Complex area (Norwegian county of Telemark) was determined in the work [10].

In Georgia regular researches of natural (and also technogenic) radioactivity were not actually carried out. Rather detailed researches of radioactivity in various environmental objects have been carried out in 1986, after failure on the Chernobyl atomic power station and, basically, concerned technogenic radionuclides [11, 12, 13]. In these works it has been shown, that during this period in the territory of the Western Georgia, basically in the strip adjoining to the sea the big concentrations of technogenic radionuclides were observed (in particular, Cs-137 concentration made from several hundreds to some thousands of Bq/kg). It is possible to note also works [14, 15] in which results of research of radiation condition of coast of water area of Black sea during later period are given, in particular, presence of 7 natural (Ac-228, Ra-226, Bi-214, Pb-214, Pb-212, Pb-210, K-40) and 1 technogenic radionuclide (Cs-137) has been fixed in soil in some areas of Adzharia (Batumi, Gonio, Sarpi, Chakvi, Kvariati). Some results of the last period are given in a study by Kekelidze et al [16]. Urushadze and Manakhov studied content of technogenic radionuclides Cs-137 and Sr-90 in different types of soil in the territory of Georgia [17].

In the present work there are given results of radioactivity research of different soil types within the territory of several districts of Tbilisi city – the largest city and the capital of Georgia.

MATERIALS AND METHODS

Study area

The territory of Tbilisi city and its suburb, which is located around contact of the Adjara-Trialetian folded zone and the Georgian block, represents the crossed mountain area within average watercourse of the River Mtkvari. Tbilisi occupies deep kettle-shaped valley which width changes from 3000 - 4000 m to 35 - 40 m. River Mtkvari crossing a city almost in meridional direction, divides it on two parts: more raised right-bank and considerably lowered left-bank. In the right-bank part of the city among the main forms of a relief it is necessary to allocate Teleti ridge, Tabori ridge, Sololaki ridge, mountain Mtatsminda, Tskneti height. Teleti and Tabori ridges are divided by Krtsanisi depression on which River Tabahmelastskali proceeds, between Tabori and Sololaki ridges locate deep gorge of River Tsavkisistskali. 20 soil samples (Table 1) were selected in this territory from 20 control points (nearby settlements and districts of city – Kiketi (Ky), Didgori (Dr), Kojori (Kj), Tabakhmela (Tx), Shindisi (Sx), Krtsanisi (Kx), Ortachala (Ot), ZemoPonichala (Zp), KvemoPonichala (Pl), University street (Un), Bagebi (Bb), Mtatsminda(Md), Sololaki (Sl), Botanic garden (Bg), Nakikala (Nr), Tabori (Ty). Types of selected samples are the following:

- cinnamonic – 16 samples (including cinnamonic calcareous (Cn-Cr) – 12 samples (220, 223, 229, 255, 264, 268, 272, 281, 286, 295, 303, 313), cinnamonic (Cn) – 4 samples (235, 238, 250, 253);
- alluvial – 4 samples (including alluvial calcareous (Al-Cr) – 4 samples (203, 204, 215, 217))

Table 1
List of control points (CP), field numbers (FN) of investigated samples and their types (ST)

#	CP	Lt(N); Ln(E)	FN	ST
1	Ky-2	41.64574; 44.64459	235	Cn
2	Dr-3	41.66658; 44.65155	238	-“-
3	Kj-7	41.65925; 44.69699	250	-“-
4	Tx-1	41.65475; 44.74512	253	-“-
5	Sx-2	41.67025; 44.76433	255	Cn-Cr
6	Kx-12	41.67191; 44.80206	229	-“-
7	Kx-3	41.66384; 44.80876	223	-“-
8	Kx-11	41.67016; 44.81483	220	-“-
9	Ot-2	41.67087; 44.83550	217	Al-Cr
10	Ot-3	41.66283; 44.87747	215	-“-
11	Zp-1	41.64281; 44.89925	204	-“-
12	Pl-1	41.63803; 44.93040	203	-“-
13	Tj-2	41.70367; 44.70393	295	Cn-Cr
14	Un-7	41.71841; 44.70726	313	-“-
15	Bb-8	41.70564; 44.73715	303	-“-
16	Md-2	41.69876; 44.79234	286	-“-
17	Sl-7	41.69055; 44.79087	264	-“-
18	Bg-6	41.68726; 44.80043	281	-“-
19	Nr-2	41.68791; 44.80956	272	-“-
20	Ty-2	41.68606; 44.81288	268	-“-

Note. Lt(N) – latitude (north); Ln(E) – longitude (east)

Sampling and analysis

Sampling

__Samples were selected used the special hand auger directly in plastic containers (volume up to 2.0 L). After drying in laboratory conditions samples were grinded and sieved for their homogenization. Then samples were dried at the temperature 105 - 110°C to constant weight and their bulk density and weight were determined. These values were used at the description of sample geometry. The samples were sealed in Marinelli beaker (besides polyvinyl chloride adhesive tape was used also for hermetic sealing) and stored for more than 4 weeks to achieve secular equilibrium between Ra-226 and Rn-222.

Measurement of gamma radiation activity

Measurements were carried out using a Canberra GC2020 gamma spectrometer with a semiconductor germanium detector with a relative efficiency of 24%. The gamma spectra acquisition time was 72 h. For the analysis, the software Genie-2000 S500 was used with additional modules, in particular, S506 – the Interactive Fit Program. The activity concentrations of Th-232 were determined (averaged values were reported for Ac-228, Ra-224, Pb-212, Bi-212, and Tl-208, of which the determination error varied from 2.2% to 6.5%), U-238 (by the Th-232 line of 63.3 keV with an error in the diapason varying from 5.6% to 8.2%), Ra-226 and U-235 (by the 186 keV line, which was divided using the S506 program with error of 11.0%-24.4% for Ra-226, and 6.8%-12.0% for U-235), Pb-214 and Bi-214 (with error from 2.3% to 2.8%), Pb-210 (by the 46.54 keV line with an error from 9.4% to 20.4%). Also identified were Be-7, K-40, and the technogenic radionuclide Cs-137. In samples “super-equilibrium” (allochthonous) Pb-210 ($\mathrm{Pb}_{\mathrm{al}}$) was often observed, the value of which was determined as the difference between measured activity values of Pb-210 and Ra-226 [3].

With an account taken of the influence of matrix composition, the chemical composition of samples were determined on the basis of reference data [18], which were then used with the special software (LabSOCS) for efficiency calibration at the calculated activity concentration. The LabSOCS system allows the creation of calibrations by laboratory quality efficiency without application of radioactive calibration sources. For radionuclides identification, a special library containing lines of 41 radionuclides and other specific sources (in total 351 lines) was used. The database NuDat [19] was used for library creation. For the activity calculation, background radiation was subtracted.

Assessment of radium equivalent activity $\mathrm{Ra}_{\mathrm{eq}}$ (Bq/kg) and annual effective dose equivalent AEDE (mSv/y) depending on the soil type was carried out under formulas [20]:

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

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

$$AEDE = D \times N_h \times k_1 \times k_2 \qquad (2)$$

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, 0.7×10^3mSv/Gy, k_2 – outdoor occupancy factor (the fraction of time spent in the open air) which equals to 0.2, D – absorbed dose rate D (nGy/h):

$$D = k_U A_U + k_{Th} A_{Th} + k_K A_K \qquad (3)$$

wherek_{U}, k_{Th}, k_{K} – so-called dose coefficients which are equal to 0.462, 0.604 и 0.0417, respectively.

When allochthonousPb was present, the contribution of its “allochthonous” parents Pb-214 and Bi-214 (and, accordingly, the activity $Ra_{eq\text{-}al}$ of allochthonous Ra-226) to radioactivity was considered (under the assumption that its concentration is connected with excess radon in a soil layer), the contribution of which, according to Saito and Jacob [21], makes up a part equal to 98.5% of the gamma flow of the energy of U-238 radionuclides. In this case the term equal to $0.985 \bullet A_{Ra\text{-}al}$was added into the calculation formula (1) where $A_{Ra\text{-}al}$ is equal to$A_{\mathrm{Pb\text{-}al}} = A_{\mathrm{Pb}} - A_{\mathrm{Ra}}$ [3]. The similar term ($0.456 \bullet A_{Ra\text{-}al}$) was added into equation (3) for the absorbed dose rate D_{al} and, accordingly, was considered for calculation of AEDE_{al}.

For samples characterization by degree of radioactivity taking into account the accepted limiting value Ra_{eq}- 370 Bk/kg (equivalentto γ-radiations dose of 1.5 mSv/y) [22] there were established several groups of samples by value of radium equivalent activity, in particular: 1st group - not radioactive samples with activity no more than 30 Bq/kg; 2nd group – with a low radioactivity in the range from 30 to 100 Bq/kg; 3rd group – with an average radioactivity in the range from 100 to 300 Bq/kg; 4th group – samples with the raised radioactivity[1] in the range from 300 to 1000 Bq/kg. The technique is described in more detail in works [23, 24].

RESULTS

Based on the results of the gamma spectral analysis, up to 22 radionuclides were identified in samples: the Th-232 family (Ac-228, Th-228, Ra-224, Pb-212, Bi-212, and Tl-208), the U-238 family (Th-234, Pa-234, Th-230, Ra-226, Pb-214, Bi-214, and Pb-210), the U-235 family (U-235, Th-231, Th-227, Ra-223, Rn-219, and Pb-211), the individual radionuclides Be-7, K-40, and the techogenic radionuclide Cs-137 (some specific gamma lines were also identified, originated as a result of cosmic rays interacting with the material of the detector or the sample).The activity of identified radionuclides of the different families varied from 1.09 Bq/kg (for U-235 family) to 72.9 Bq/kg (for U-238 family). Among individual radionuclides K-40 had the greatest activity (up to 618 Bq/kg). The activity of several radionuclides in some samples was below the minimal detectable activity (MDA).Activity concentrations of the main radionuclides in the studied samples, equivalent radioactivity with no account taken of allochthonous $Pb\text{-}210_{al}$ (Ra_{eq}) and taking this into account ($Ra_{eq\text{-}al}$) and, accordingly, annual effective dose (AEDE and $AEDE_{al}$), activity ratios, their average (*av*), minimal (*mn*) and maximal (*mx*) values, and other data are given in Tables 2-5.

General characteristics

Within families of radionuclides, activity varied within sufficiently wide limits (Table 2). In particular, the range (mean) was 16.8-41.4 (22.6) Bq/kg for Th-232, 17.7-67.8 (29.3) Bq/kg for U-238, and 1.09-3.76 (1.77) Bq/kg for U-235. The activity of K-40 varied from 365 to 618 Bq/kg (mean, 4665). Trace amounts of radionuclide Be-7 was determined in several samples. Cs-137 was measured in all samples and ranged from 1.5 to 118 Bq/kg (mean, 19.9). The activity ratio U-238/U-235 (within ±10%) was 21.7 (accepted for natural objects). The ratios U-238/Th-232 and Ra-226/U-238 for majority of samples deviated (more than 10%) from the average value of 0.81 (for closed systems) – varied in the range 0.78-2.62 (1.35), and from the equilibrium value (1.00) – varied in the range 0.66-1.76 (1.04); the ratio Pb-210/Ra-226 for majority of samples was appreciably (more than 20%[2]) greater than the equilibrium value (the greatest value of 8.51). Radionuclides in chain Th-232 - Tl-208 were essentially in equilibrium (except for Th-228, for which the determination error was appreciably more than for other radionuclides). The greatest proportion of samples (75.0%), by the level of equivalent activity, belonged to the group with low radioactivity, and a small proportion ofsamples (25.0%) belonged to the group with average values of equivalent activity (Table 5); it is worthy of note that if one considers allochthonous activity, the majority of samples (85.0%) were in the average group.

Table 2

Activity concentrations (Bq/kg) of families' radionuclides Th-232, U-238, Ra-226, Pb-210, and U-235, radionuclides K-40, and Cs-137, equivalent activities with no account taken of allochthonous Pb-210$_{al}$ (Ra$_{eq}$) and taking this into account (Ra$_{eq-al}$), annual effective doses (AEDE and AEDE$_{al}$),activity ratios U-238/U-235, U-238/U-235, Ra-226/U-238, and Pb-210/ Ra-226.

#	CP	Th-232	U-238	Ra-226	Pb-214	Bi-214	Pb-210	U-235	K-40	Cs-137	Pb-210$_{al}$	Ra$_{eq}$	Ra$_{eq-al}$	U-238/ U-235	U-238/ Th-232	Ra-226/ U-238	Pb-210/ Ra-226	AEDE mSv/y	AEDE$_{al}$, mSv/y
1	Ky-2	19.4	28.0	27.6	26.6	25.9	78.3	1.85	494	6.5	50.7	89.8	140	21.9	1.87	0.76	2.84	0.060	0.089
2	Dr-3	20.0	25.0	24.2	25.8	24.6	37.8	1.23	418	2.6	13.6	82.0	95	22.0	1.36	0.89	1.56	0.052	0.059
3	Kj-7	18.1	23.4	26.2	24.6	24.4	48.6	1.77	445	3.3	22.4	83.2	105	22.3	1.31	1.10	1.86	0.050	0.062
4	Tx-1	22.9	34.9	34.2	37.5	31.1	75.3	1.89	450	19.5	41.0	98.4	139	22.0	1.33	1.13	2.2	0.057	0.080
5	Sx-2	41.4	47.7	49.4	48.5	46.8	77.6	2.73	562	18.5	28.3	148	176	21.5	1.20	0.99	1.57	0.088	0.104
6	Kx-12	25.6	67.8	72.9	71.6	70.5	74.9	3.76	451	15.4	2.0	141	143	21.9	2.62	1.09	1.03	0.080	0.081
7	Kx-3	21.3	20.2	17.1	20.9	20.3	58.2	1.29	415	19.7	41.1	76.7	117	22.3	1.22	0.66	3.4	0.052	0.075
8	Kx-11	22.8	37.5	44.8	38.3	37.5	56.2	2.16	404	4.9	11.5	106	117	22.4	1.66	1.18	1.26	0.059	0.066
9	Ot-2	19.2	20.1	26.2	21.8	21.2	114	1.71	422	21.0	88.0	83.2	170	21.2	0.78	1.76	4.35	0.044	0.094
10	Ot-3	19.2	17.7	19.5	18.2	17.3	40.8	1.30	430	18.2	21.2	77.2	98.1	21.1	0.91	1.11	2.09	0.046	0.058
11	Zp-1	21.8	33.5	35.9	34.6	34.2	51.6	1.97	414	1.5	15.6	96.0	111	21.7	1.69	0.98	1.44	0.058	0.067
12	Pl-1	20.3	23.7	27.6	24.0	24.1	47.7	1.30	422	8.7	20.1	86.1	106	21.2	1.03	1.32	1.73	0.049	0.060
13	Tj-2	16.8	18.3	20.4	19.1	18.4	20.7	1.09	385	2.8	0.24	71.5	71.7	21.5	1.07	1.14	1.01	0.042	0.043
14	Un-7	22.8	25.2	29.3	26.0	26.5	53.8	1.53	518	3.1	24.6	98.1	122	22.4	1.12	1.15	1.84	0.058	0.072
15	Bb-8	23.0	29.6	25.9	29.3	29.8	83.0	1.72	541	28.4	57.2	96.7	153	21.7	1.52	0.74	3.21	0.065	0.097
16	Md-2	24.0	25.5	28.8	25.6	24.3	60.2	1.52	556	1.5	31.4	102	133	21.3	1.12	1.07	2.09	0.062	0.079
17	Sl-7	20.7	31.9	31.2	33.1	31.9	37.0	1.82	520	5.1	5.8	97.2	103	22.3	1.88	0.80	1.18	0.064	0.067
18	Bg-6	26.1	29.0	33.2	30.1	28.8	223	2.05	618	118	190	114	301	22.3	1.09	1.17	6.73	0.067	0.174
19	Nr-2	19.6	22.3	18.6	24.1	23.6	103	1.32	365	62.1	84	72.1	155	20.8	1.32	0.72	5.51	0.048	0.095
20	Ty-2	27.3	24.3	26.4	24.5	24.5	224	1.41	468	36.9	198	98.2	293	21.3	0.91	1.06	8.51	0.058	0.169
	av	*22.6*	*29.3*	*31.0*	*30.2*	*29.3*	*78.3*	*1.77*	*465*	*19.9*	*47.3*	*95.8*	*142*	*21.8*	*1.35*	*1.04*	*2.77*	*0.058*	*0.085*
	mn	*16.8*	*17.7*	*17.1*	*18.2*	*17.3*	*20.7*	*1.09*	*365*	*1.5*	*0.24*	*71.5*	*71.7*	*20.8*	*0.78*	*0.66*	*1.01*	*0.042*	*0.043*
	mx	*41.4*	*67.8*	*72.9*	*71.6*	*70.5*	*224*	*3.76*	*618*	*118*	*198*	*148*	*301*	*22.4*	*2.62*	*1.76*	*8.51*	*0.088*	*0.174*

Table 3

Generalized data – average (av), minimal (mn), and maximal (mx) values of concentrations of radionuclides of families (Th-232, U-238 and Ra-226, U-235), and individual radionuclides (Be-7, K-40, and Cs-137) – depending on soil type (ST).

#	ST	Th-232			U-238			Ra-226			Pb-210			U-235			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
1	Cn	20.1	18.1	22.9	27.8	23.4	34.9	28.0	24.2	34.2	60.0	37.8	78.3	1.69	1.23	1.89	452	418	494	8.0	2.6	19.5
2	Cn-Cr	24.3	16.8	41.4	31.6	18.3	67.8	33.2	17.1	72.9	89.3	20.7	224	1.84	1.09	3.76	484	365	618	26.3	1.5	118
3	Al-Cr	20.1	19.2	21.8	23.8	17.7	33.5	27.3	19.5	35.9	63.5	40.8	114	1.65	1.32	2.05	422	414	430	12.4	1.5	21.0

Table 4

Generalized data – average (av), minimal (mn), and maximal (mx) values of equivalent activities with no account taken of allochthonous Pb-210$_{al}$ (Ra$_{eq}$) and taking this into account (Ra$_{eq-al}$), activity ratios, and annual effective doses (AEDE and AEDE$_{al}$) – depending on soil type (ST).

№	ST	Ra$_{eq}$			Ra$_{eq-al}$			U-238/Th-232			Ra-226/U-238			Pb-210/Ra-226			AEDE, mSv/y			AEDE$_{al}$, mSv/y		
		av	mn	mx	av	mn	mx	av	mn	mx	av	mn	mx	av	mn	mx	av	mn	mx	av	mn	mx
1	Cn	88.4	82.0	98.4	120	95.4	140	1.47	1.31	1.87	0.97	0.76	1.13	2.11	1.56	2.84	0.055	0.050	0.060	0.073	0.059	0.089
2	Cn-Cr	102	71.5	148	157	71.7	301	1.39	0.91	2.62	0.98	0.66	1.18	3.11	1.01	8.51	0.062	0.042	0.088	0.093	0.043	0.174
3	Al-Cr	85.6	77.2	96.0	121	98.1	170	1.10	0.78	1.69	1.29	0.98	1.76	2.40	1.44	4.35	0.049	0.044	0.058	0.070	0.058	0.094

The range of limits is expanded, because determination error of Pb-210 reached up to 20%.

Table5

Distribution of average value Ra_{eq-av} (Bq/kg) of equivalent activity Ra_{eq} by the activity group (GA), their quantity (N_s) and percentage (r, %).

#	GA	$A_{eq,}$ (Bq/kg)	A_{av}, (Bq/kg)	N_s	r (%)
1	II	30 - 100	87.1	15	75.0
2	III	100 - 300	122	5	25.0

DependenceontheType

The highest values of equivalent activity (Table 3, Table 4) were observed for soil type Cn-Cr, with average value of 102 Bq/kg,

and rather less for soils Cn and Al-Cr – 85.6 and 88.4 Bq/kg. The activity ratio U-238/Th-232 for soils of all types GCD exceeded (within ±10%) the average value of 0.81. The ratio Ra-226/U-238 in all soil types met (within ±10%) or exceeded the equilibrium value. The highest excess values for ratio Pb-210/Ra-226 were determined for Cn-Cr soil.

Radiological Parameters

Determined minimal and maximal values of annual effective dose varied in the range 0.042-0.088 mSv/y (Table 2). These values (as well as equivalent activity) increase (annual effective dose - in the range 0.043-0.174 mSv/y) at the assumption, that allochthonous Pb-210 is caused by excess soil radon.

DISCUSSION

Concentration of radioactive elements in soils is determined by radioactivity of initial rocks and set of the subsequent soil formation processes. Content and concentration of naturally occurring radionuclides, in general, correspond to those usually observed for different soils [4]. In soil samples due to specific processes of their formation (the big role of migratory processes therefore hashing of various minerals occurs much more effectively, than in rocks) range of activity changes of natural radionuclides in them is much less, than in rocks (where they are in the “sealed” condition). Owing to these reasons also, as it is apparent from results, it is not observed the noticeable expressed dependence on soil type. Certain interest represents disbalance between Ra-226 and Pb-210 observed in the work, in particular, high values of the ratio Pb-210/Ra/226. In a number of works presence of “superequilibrium” (allochthonous) Pb-210 is noticed that connects with radon migration from the bottom layers of earth in the top (and further in atmosphere). So, in the work [25]it is noticed, that Pb-210 is capable to accumulate on the walls of pores and faults at the passage of radon flow through soil. At the passage of radon through a layer from underlying horizons there is an accumulation in a layer of excess Pb-210, not supported by radium, formed by the expense of decay of radon arriving from below. Radioactive balance in soil is thus broken towards increase in activity of Pb-210, i.e. ratio Pb-210/Ra-226 > 1 is realized. Activity ratio Pb-210/Ra-226 in soils is the integrated characteristic of existence in system of a constant or pulse ascending radon flow for a long time. In a number of works presence of “superequilibrium” Pb-210 in soil is connected with its deposition from atmospheric air. Prominent feature of activity ratio Pb-210/Ra-226 observed in the samples, in particular, considerable excess of equilibrium value of activity size in the majority of samples - apparently denotes appreciable effect of the factor of radioactive gas radon exhalation from deep soil layers or subsoil rocks. It is possible to assume, that considerably raised values of ratio Pb-210/Ra-226 can serve as the certain identifier of the territory with the raised seismic dangerous.

This question represents certain interest and the further researches in this direction are necessary. The question of the nature of nonequilibrium Pb-210 is of interest also from the radiological point of view. The radionuclide Be-7, which is formed in the upper atmosphere as a result of interaction with space radiation and then combines with deposits in the soil, was detected in trace amounts in several samples. Its absence from the other samples could be associated with the long period of samples storage, which could have led to a reduction in concentration to values below the minimal detectable level.

Data for the technogenic radionuclide Cs-137 are of special interest. As it is apparent from results, it was observed in all samples in sufficiently appreciable amounts. Usually its occurrence is connected with failure of the Chernobyl atomic power station in 1986. By a number of data, in particular, according to systematic observations for the flat areas of East Georgia [26], values of Cs-137 activity are now, basically, in the range 1 - 10 Bq/kg. With certain degree of convention it is possible to consider this level as background value for the whole territory of Georgia. Average value (19.9 Bq/kg) is greater this quantity that can be due to non-uniform precipitations following the accident. However it is impossible to exclude completely that the pollution fact could have rather recent history, considering presence of nuclear objects in surrounding geographical region. Results received for location Bg-6 (see Table 2) are of the special interest that identifies necessity of additional researches for these places.

The distribution of the naturally occurring radionuclide K-40 was similar to values observed by Kogan et al. [4].

The calculated values of annual effective dose do not exceed 1 mSv/y dose limit recommended for public radiation exposure control [27, 28, 29].

Some reference data from studies carried out in other regions of the world are cited in Table 6. The values in the current study were, on average, much lower than in other regions as well as compared to worldwide average values. In conclusion it is necessary to note, 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.

Table6

Activity concentration of radionuclides in soil in different regions of the world

SR	ST	Th-232	U-238	Ra-226	Pb-210	U-235	K-40	Cs-137	Ra$_{eq}$	Ra$_{eq-al}$	U-238/ Th-232	Ra-226/ U-238	Pb-210/ Ra-226	AEDE, mSv/y	AEDE$_{al}$ mSv/y	Ref
Tk	UnS	192 151.91-275.63	115 82.32-166.99				1207 1015.48-1484.93	18.1 0.37-36.03	498 430-626							[6]
Nr		3280–8395		89–171			404–654									[10]
Gh	Bs	42.6 16.8-231.2	20.08 11.1-31.8	31.4 10.9-103.7		0.91 0.51-1.5	110 68.3-184		101.0 59.5-445		0.79 0.11-1.56	1.27 0.42-4.17		0.066 0.037-0.251		[9]
Sp		34.6 23.7-49.4	40.2 19.9-60.0	26.7 20.8-34.9	74.0 26.7-140.0		586.2 446-799	30.9 4.4-64.7								[3]
Ng	UnS	17.41 9.72-34.13		29.61 16.27-52.19			263 135-395		74.7 51.0-101							[8]
Sb	An	53.1 45-62	67.4 49-90	48.1 39-59		3.6 2.7-4.6	642 565-755									[7]
Ar		29-60^{3}	28-70^{3}	32-77			310-420									[30]
Az		10-56^{3}	26-50^{3}	15-35			60-180									-"-
Ww		45^{3}	33^{3}	32			412									-"-
Ge	Cn	20.1 18.1-22.9	27.8 23.4-34.9	28.0 24.2-34.2	60.0 37.8-78.3	1.69 1.23-1.89	452 418-494	8.0 2.6-19.5	88.4 82.0-98.4	120 95.4-140	1.47 1.31-1.87	0.97 0.76-1.13	2.11 1.56-2.84	0.055 0.050-0.060	0.073 0.059-0.089	Pr. study
-"-	Cn-Cr	24.3 16.8-41.4	31.6 18.3-67.8	33.2 17.1-72.9	89.3 20.7-224	1.84 1.09-3.76	484 365-618	26.3 1.5-118	102 71.5-148	157 71.7-301	1.39 0.91-2.62	0.98 0.66-1.18	3.11 1.01-8.51	0.062 0.042-0.088	0.093 0.043-0.174	-"-
-"-	Al-Cr	20.1 19.2-21.8	23.8 17.7-33.5	27.3 19.5-35.9	63.5 40.8-114	1.65 1.32-2.05	422 414-439	12.4 1.5-21.0	85.6 77.2-96.0	121 98.1-170	1.10 0.78-1.69	1.29 0.98-1.76	2.40 1.44-4.35	0.049 0.044-0.058	0.070 0.058-0.094	-"-

Note. 1) Studied regions (SR): Tk – Turkey; Nr – Norway; Gh – Ghana; Sp – Spain; Ng – Nigeria; Sb – Serbia; Ar – Armenia; Az – Azerbaijan; Ww - Worldwide average values; Ge – Tbilisi, Georgia.

2) Soil types: UnS- uncultivated, undisturbed soil; Bs – beach sand; An – anthrosol-type soil; Al-Cr – alluvial calcareous; Cn – cinnamonic; Cn-Cr – cinnamonic calcareous.
3) Values are given for Th-232 and U-238, correspondingly.

CONCLUSION

1. Up to 22 radionuclides are identified in soil samples selected from the 20 locations in the territory of several districts of Tbilisi city: Th-232 family – Ac-228, Th-228, Ra-224, Pb-212, Bi-212, Tl-208; U-238 family – Th-234, Pa-234, Th-230, Ra-226, Pb-214, Bi-214, Pb-210; U-235 family – U-235, Th-231, Th-227, Ra-223, Rn-219, Pb-211; other naturally occurring radionuclides – Be-7, K-40, and also technogenic radionuclide Cs-137
2. Activity of naturally occurring radionuclides depending on the soil type and location differs a little – the highest values of equivalent activity were observed for samples of cinnamonic calcareous soil (average value of 102 Bq/kg), and rather less for samples of cinnamonic and alluvial calcareous soils (average values 85.6 and 88.4 Bq/kg, respectively).
3. Several activity ratios, in particular, U-238/U-235, U-238/Th-232, Ra-226/U-238 and Pb-210/Ra-226 have been considered, and some features in their distribution have been established; it was shown that for ratio Pb-210/Ra-226 it is observed considerable deviations in the greater way from equilibrium value.
3. Several radiological parameters, in particular, annual effective doses were calculated; it was shown that these values are lowering in comparison with recommended norms.
4. Comparison with reference data as well as analysis of obtained results and some of their features was carried out.

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