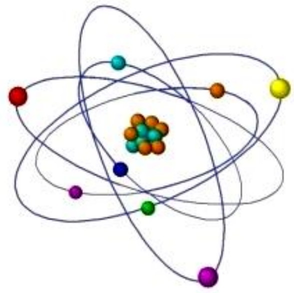
RESEARCH OR RADIONUCLIDES ACCUMULATION REGULARITY BY GEORGIAN POPULAR CULINARY HERBS FOR THE DETERMINATION OF HEALTH-CONNECTED RISKS



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ABSTRACT**:** *In all neighboring countries of Georgia, programs for the construction and operation of nuclear power plants of various capacities are being actively developed, which does not exclude the problems of radionuclide emissions and migration during technogenic accidents. A special place in this regard is occupied by the study and forecasting of possible food contamination mechanisms by taking into account the specifics of the food ration of the local population for each region. The present paper discusses the peculiarities of the accumulation of radionuclides by culinary herbs typical for Georgia. They are one of the main ingredients for Georgian national cuisine. Based on the experimental data obtained, calculations have been made on the possible risks to the health of the population in the event of extreme contamination of territories with anthropogenic radionuclides. By comparing the accumulation coefficients of radionuclides (radiocesium) in the tissues of culinary herbs with the level of the average consumption of these ingredients, additional parameters of dose load at the level of various organs of the human body have been determined. Based on the use of software modeling methods, the possible risks of radiobiological effects dangerous to health, on the example of radiation cancer development, during radionuclide contamination of culinary herbs in Georgia, through their long-term consumption for food, were identified.*

Key words: radionuclides accumulation, culinary herbs, cancer risk

INTRODUCTION

The main factors for population defense and strengthening are population nutrition conditions, raw nutrient materials, and product quality and safety [1]. During the last few years, important attention is paid to healthy nutrition, which includes food products biological, chemical and radiation safety [2,3,4,5].

The safety of food products proposes the non-existence of unacceptable risks connected to the harmful impacts on humans. Harmful impacts have resulted from the presence of pollutant substances in food, such as radionuclides that pose important dangers to human life and health.

The last decades showed that large-scale radionuclide pollution is created by technogenic problems at atomic energy facilities and the radiation industry [6,7,8,9]. On the example of the Chernobyl disaster, Georgian past years experience showed the dangers of food products radiation pollution. Despite the significant distance, due to the atmospheric migration from the catastrophic site, most of the country was polluted by short-lived, as well as, long-lived radionuclides [10].

Based on scientific research, it is determined that such pollution of different qualities has been kept during the decades [11]. At the same time, nowadays, practically in every neighboring country of Georgia, the process of construction and exploitation of nuclear power plants with different capacities is developed, which does not exclude radionuclides dispersion and migration problems. In this direction, an important role relies on the research of possible nutrient pollution mechanisms and forecasting considering local population nutrition ration specificity for each region of Georgia.

Culinary herbs represent one of the main ingredients of Georgian national cuisine. Because of this, they are not only utilized in dry and raw forms, but are also used as an additional component during the cooking in practically every region's nutrition rations. Accordingly, research of radionuclide accumulation specificity by different culinary herbs has significant scientific and practical importance for determining the level of risks during the possible pollution by technogenic radionuclides of different territories.

RESEARCH OBJECT AND METHODS

The research object was represented by popular culinary herbs for Georgian population's nutrition ration: Coriander (*Coriandrum sativum*), Dill (*Anethum graveolens*), Parsley (*Petroselinum crispum*), Salad (*Lactúca satíva*), Savory garden (*Satureja hortensis*), Cress (*Lepidium sativum*), Baselik (*Ocimum basilicum*). Soil contaminated with radiocesium was used as the radioactive substrate. Plants grown on contaminated soil and intended for radiometry were subjected to drying and shredding on an electric homogenizer until a powdery mass was obtained. The content of radionuclides was determined by gamma-spectrometry (Gamma-Beta Spectrometer, Atomtex-MKC-AT-1315 and Gamma-Spectrometer CANBERRA with liquid nitrogen cooled germanium detector).

The accumulation coefficient in different organs of the plant was calculated with the content of ^{137}Cs in the soil and plant tissues. Additionally, estimation of different parameters (Table 3-4) were performed by processed software product FRAMES (Framework for Risk Analysis in Multimedia Environmental Systems – Version 1.7), by Pacific Northwest National Laboratory (PNNL).

RESULTS AND DISCUSSION

Radiation safety issues of food products are characterized by global, alongside with national, specificities. First of all, the importance of this idea relies on the consumption of different food products, which has significant regional and national specificity. The undeniable importance of the aforementioned work is a determination of plant species and varieties specificities in terms of radionuclide accumulation which can lead to the calculation of the dose-load in a single organism of the specific population. For the research, we chose popular Georgian culinary herbs. Conducted radiometric analysis showed significant differences in radioactive cesium accumulation levels. For example, if in *Petroselinum crispum* tissues isotope accumulation level was only 920 Bq/kg, in *Lepidium sativum* and *Satureja hortensis* variants the same indicators were 4890 Bq/kg and 6081 Bq/kg, accordingly. Relatively intermediate accumulation levels in research objects had the following species: Coriander, Dill, Cress, and Basilic.

Table 1 - Activity of ^{137}Cs in culinary herb tissues, cultivated on radionuclide polluted soil.

#	Expermental Plant	Radioactivity of plant tissues (Bq/kg, calculated from dry weight)
1	Coriander (*Coriandrum sativum*)	1125±65
2	Dill (*Anethum graveolens*)	3955±79
3	Parsley (*Petroselinum crispum*)	920±81
4	Salad (*Lactúca satíva*)	2640±84
5	Savory garden (*Satureja hortensis*)	6081±71
6	Cress (*Lepidium sativum*)	4890±91
7	Basilic (*Ocimum basilicum*)	1210±63
	Activity of radiocesium polluted soil	12200±39

It is acknowledged that the radionuclide accumulation issue, mainly, depends on the soil contamination levels, as well as specific plant cultivation conditions. To standardize and make a relative analysis of the obtained results, we used an accumulation coefficient indicator. As it is seen from figure 1, individual varieties of experimental plants are characterized by specific indicators of radiocesium accumulation level.

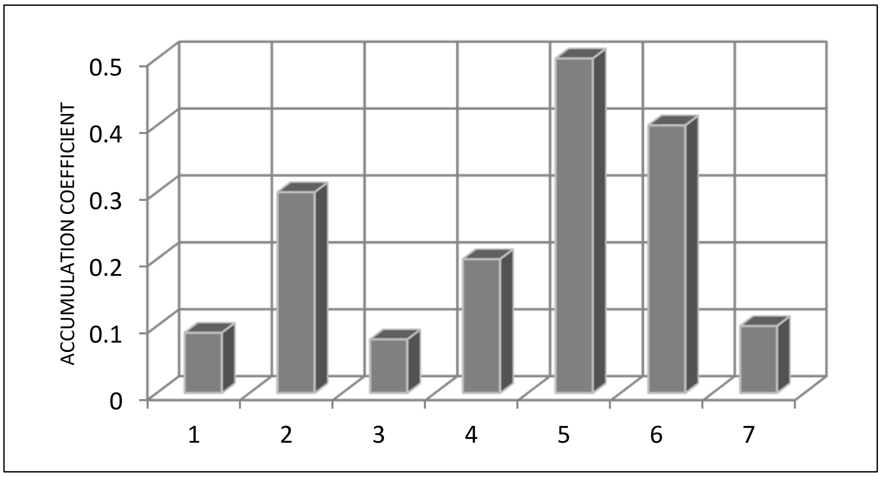

Fig. 1 -^{137}Cs accumulation coefficient in plant tissues, cultivated on radionuclide polluted soil. 1 - Coriander (*Coriandrum sativum*), 2 - Dill (*Anethum graveolens*), 3 - Parsley (*Petroselinum crispum*), 4 - Salad (*Lactúca satíva*), 5 - Savory garden (*Satureja hortensis*), 6 - Cress (*Lepidium sativum*), 7 - Baselik (*Ocimum basilicum*).

As it is known, every radionuclide, natural or anthropogenic origins, is characterized by common radiological signs as far as they can enter the organism through consumption of food and water, as well as through breathing, where radionuclides can be mixed up with the air particles. However, some forms of human activity, such as industrial, medical, or agricultural, can increase radiation exposure at the expense of those radionuclides which exist naturally in the environment [12]. Additionally, the exclusive danger is created by long-lived anthropogenic radionuclides [13,14]. ^{137}Cs is an example of such radionuclide. Alongside the other dangerous features for human health, this isotope is characterized by cumulative properties [15]. For the latter reason, when using radionuclide-contaminated culinary herbs in food, to investigate possible risks, it is necessary to determine characteristics such as indicator of daily consumption of such plant ingredients, calculation of further extrapolation of this data for longer periods, and radionuclide absorption as a result of their use.

To obtain these indicators, we determined the average rate of daily consumption of culinary herbs' 75 families, cultivated in different parts of Georgia. Furthermore, calculations were performed for each type of culinary herb consumption, and the level of equivalent radioactive cesium content was determined. As it is seen from Table 2, all presented plant species are distinguished with species peculiarities in terms of radioisotope contents, as well as their quantitative consumption level. Thereby, the total dose of radiocesium daily penetration in the organism during the consumption of food with different culinary herbs was formed into the grams quantitative ratio (for standardization, which was represented by dry weight calculation) of the daily consumption mass to the total activity of ^{137}Cs in each variant.

Table 2. Average daily consumption norm of culinary herbs contaminated by radiocesium and its absorption indicator

#	Experimental Plant	Average daily consumption norm (g/dry weight calculation)	Activity of ^{137}Cs, taken with food (Bq/kg)
1	Coriander (*Coriandrum sativum*)	9	10,1
2	Dill (*Anethum graveolens*)	2	7,9
3	Parsley (*Petroselinum crispum*)	6	5,7
4	Salad (*Lactúca satíva*)	5	13,2
5	Savory garden (*Satureja hortensis*)	0,5	3
6	Cress (*Lepidium sativum*)	3	14,7
7	Basilic (*Ocimum basilicum*)	4	4,8
	Total Indicator	**29,5**	**59,4**

Based on the experimental results we gained, in case of extreme contamination of different territories by anthropogenic radionuclides, calculations were done on the possible risks of population health and cultivation of different species of culinary herbs used for consumption.

It is established that in terms of organism's different responses to the exposure of radiation, issues of the radial carcinogenesis process become very important. They represent a constant attention area for numerous scientific centers (ICRP, UNSCEAR). Such particular interest is conditioned form the fact that radiation-caused carcinogenesis materials create the radiation impact risk assessment basis. Data on the carcinogenic effects of radionuclides are fundamental to understanding the general patterns of pathogenesis and tumor growth, to developing methods for the prevention and therapy of malignant neoplasm, and to determining the dose load of radionuclides induced in the body. During the radionuclide absorption into the organism, depending on the exposure dose, early, as well as distant, effects can be developed. It is assumed that early effects have a threshold nature. The damages occur only after the exposure dose exceeds the threshold dose. These effects can be formed during accidental situations when a significant amount of radionuclides enter the organism. However, in practice, the massive radionuclide penetration in the organism is conditioned by the consumption of food products. Because of this, one of the main and especially dangerous distant effects of incorporated radiation is the development of various types of cancer. To study the specific case of the penetration of radionuclides into the body through the use of culinary herbs for food, we used the methods of calculating the possible risks related to the differential radiation load on individual human organs, as well as the consumption of culinary herbs popular in Georgia. Namely, the equivalent dose and effective dose were evaluated (Tab.3) for each ingestion exposure pathway using the ingestion dose coefficients (Federal Guidance Report 13, ICRP 60) [16] assessed as follows:

$$\mathbf{IH_{cigT}}\ (\mathbf{t}) = I_{cig}\ (\mathbf{t})\ \mathbf{HC_{igcT}}$$

where $\mathbf{IH_{cigT}(t)}$ = equivalent dose to organ **T** from ingestion intake of radionuclide **i** in food crop **c** for an individual in age group **g** for exposure over time period **t** (Sv), $\mathbf{I_{cig}(t)}$ - ingestion intake of radionuclide **I** in food crop **c** for individuals in age group **g** for exposure over time period **t (Bq)**

$\mathbf{HC_{igcT}}$ = equivalent dose coefficient to organ **T** for ingestion intake of radionuclide **i** of class **c** for an individual in age group **g (Sv/Bq).**

Additionally, the evaluation of the food crop (leafy vegetables) intake parameter was performed as follows:

$$\mathbf{I_{cig}(t) = C_{ci}\ (t)\ U_{cg} T_{cg}\ ED_{\ cg}}$$

Where $\mathbf{I_{cig}(t)}$= total intake radionuclide i in food crop **c** over the period **t** from ingestion for individuals in age group **g** (Bq),

$\mathbf{C_{csi}(t)}$ = average concentration in food crop **c** at agricultural location **s** for radionuclide

I (Bq/kg),

Ucg = ingestion rate of food crop c by an individual in age group **g**(kg/d)

$\mathbf{T_{cg}}$= annual intake factor giving the days per year that food crop **c** is eaten by individuals in age group **g** (d/y),

$\mathbf{ED_{cg}}$= exposure duration for consumption of food crop **c** for individuals in age group **g** (y).

Tab.3 Distribution of radiocesium to Organs, absorbed from the food intake (Based on computational model)

Duration of chronic exposure	Year
Constituent	**^{137}Cs**
Dataset	**usr2:Soil**
Pathway	**Leafy vegetables**
Route	**Ingestion**
Measure	**dose (μSv)**
Dose Organ	Ages 0 to 70
Adrenals	305
Bld Wall	314
B Surface	299
Brain	256
Breasts	243
Esophagus	284
St Wall	291
SI Wall	304
ULI Wall	313
LLI Wall	363
Kidneys	293
Liver	295
Lungs	275
Muscle	272
Ovaries	311
Pancreas	313
R Marrow	285
Skin	233
Spleen	293
Testes	273
Thymus	284
Thyroid	284
Uterus	314
Total	**6697**

Tab.4 Carcinogenesis risk indicator, as a result of long-term consumption of radiocesium contaminated culinary herbs

Duration of chronic exposure	Year
Constituent	**^{137}Cs**
Dataset	**usr2:Soil**
Pathway	**Leafy vegetables**
Route	**Ingestion**
Measure	**risk (cancer incidence)**
Cancer Organ	Ages 0 to 70
Esophagus	3.36E-07
Stomach	1.2E-06
Colon	5.47E-06
Liver	4.73E-07
Lung	2.34E-06
Bone	3.91E-08
Skin	2.1E-08
Breast	1.79E-06
Ovary	5.32E-07
Bladder	1.56E-06
Kidneys	2.37E-07
Thyroid	7.38E-07
Leukemia	1.57E-06
Residual	5.58E-06
Total	**2.19E-05**

For estimation processed software product FRAMES (Framework for Risk Analysis in Multimedia Environmental Systems) Version 1.7, by Pacific Northwest National Laboratory (PNNL) was used.

During the regular consumption of radionuclide polluted nutrient herbs, on the basis of individual human organ dose load data, in the form of distant effects, development of different types of cancer risk was determined through the following method: for performing the assessment of health impacts, calculation was done using organ-dependent health effect conversion factors (Federal Guidance Report No.13) [17,18]. The risk from ingestion of food crops (leafy vegetables) is evaluated (Tab.4) as follows:

$$\mathbf{RH_{cigT}\ (t) = I_{csig}\ (t)\ RC_{igocT}}$$

where **RH_{cigT}(t)** - risk to organ **T** from ingestion intake of radionuclide **i** in food crop **c**

for an individual in age group **g** for exposure over time period **t** (risk)

I_{cig}(t)- ingestion intake of radionuclide i in food crop **c** for individuals in age group **g** for exposure over time period **t(Bq**)

RC_{igocT} - risk coefficient to organ **T** for food ingestion intake of radionuclide **I** of class

c for an individual in age group **g** (1/Bq).

CONCLUSION

In general, based on the conducted studies, the forms of realization of radiation pollution of food products were determined during possible technical problems at the nuclear facilities located in the neighboring countries of Georgia. Significant data are currently available on the specifics of the migration of radionuclides in the food chain under different ecological conditions, although the universality of this data varies greatly depending on the vegetation structure of a particular region and the nature of the food at the national level. Our studies have shown particular level of accumulation of radionuclides in culinary herbs widespread in Georgia. It is clear that in the ration of the Georgian population, similarly to the diet of European population, plant products are significantly used, although the active consumption of culinary herbs in Georgia creates an additional level of dose load. By comparing the accumulation coefficients of radionuclides (for example radiocesium) in the tissues of culinary herbs with the level of average consumption of these ingredients, additional parameters of dose loading at the level of various organs of the human body were determined. Based on the use of software modeling methods, the possible risks of radiobiological effects dangerous to health, on the example of radiation cancer development, during radionuclide contamination of culinary herbs in Georgia, trough their long-term consumption for food, were identified.

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