



## Annals of Agrarian Science

Journal homepage: <http://journals.org.ge/index.php>



### Arsenic contamination in Racha and Lower Svaneti district of Georgia, consequences and remediation strategies

E. Bakradze<sup>a\*</sup>, T. Butkhuzi<sup>b</sup>, S. Khmiadashvili<sup>c</sup>, E. Bunin<sup>b</sup>, K. Didebulidze<sup>b</sup>, A. Gujabidze<sup>b</sup>, N. Dumbadze<sup>b</sup>, T. Glurjidge<sup>b</sup>, A. Giorgadze<sup>b</sup>

<sup>a</sup>LEPL Environmental Pollution Monitoring Department, The National Environmental Agency, David Aghmashenebeli Ave. 150, Tbilisi, 0112, Georgia

<sup>b</sup>Agricultural University of Georgia; 240, David Aghmashenebeli Alley, Tbilisi, 0159, Georgia

<sup>c</sup>LEPL National Environmental Agency, Ambient Air, Water and Soil Laboratory, Marshal Gelovani Ave. 6, Tbilisi, 0159, Georgia

Received: 20 March 2021; Accepted: 20 May 2021

#### ABSTRACT

In Georgia, arsenic mining, processing and storage has been undertaken for up to 52 years, arsenic sulfide ore mining, processing and production of arsenic containing drugs was carried out for decades in Racha-Lechkhumi and lower Svaneti. In the Article is presented studies of eco-chemical condition for soils near contaminated areas by arsenic in the villages Uravi - Ambrolauri Municipality and village Tsana. Research offers solutions - innovative remedial technology based on the ability of plants and microorganisms to absorb a wide range of chemical pollutants from the environment.

**Keywords:** Environment, Pollution, Arsenic, Remediation

\*Corresponding Author: Elina Bakradze; E-mail address: [h.bakradze@gmail.com](mailto:h.bakradze@gmail.com)

#### Introduction

Arsenic is a natural component of the earth's crust and is widely distributed throughout the environment in the air, water and land. It is highly toxic in its inorganic form. People are exposed to elevated levels of inorganic arsenic through drinking contaminated water, using contaminated water in food preparation and irrigation of food crops, industrial processes, eating contaminated food.

Therefore, it is important to prevent the pollution of the natural resources (water and soil) with arsenic and also to prevent its occurrence in the drinking water and food products. For this purpose, the legislation was developed in Georgia, Slovakia and in the European Union level as well. These legal documents were assessed and

compared to propose the changes (measures) in the legislation.

Toxicity of arsenic and its compounds is well known. In the seventies of the last century, their carcinogenic properties were established. Still, arsenic compounds are widely used in technology, agriculture, medicine, etc., Arsenic is a natural component of the earth's crust and is spread in any environment, air, water and soil. In a number of countries arsenic is naturally of high contents in the ground waters. This element is present in nature in both organic and inorganic forms, and the latter is very toxic. Long-term exposure to arsenic from consumed food can cause cancer and skin lesions [1,2]. Hence, control of arsenic content in natural waters, soils and food products and other objects and studying the regularity of redistributions

(pathways and mobility) and behaviour is one of the most important and topical issues in the world.

Arsenic is included in the list of 10 toxic elements (Hg, Pb, Cd, As, Ni, etc.) that create important problems for human health (WHO) [3].

Arsenic and arsenic compounds belong to the confirmed carcinogens, the Type I Hazard (IARC) for humans [4].

Beside the fact that skin and the respiratory tract can be the paths of the arsenic penetration into organism still mostly arsenic occurs in human body from the food and drinking water. Organic arsenic species are most often met in seafood and in units of terrestrial products. This terrestrial product is basically 3-5 valence arsenic forms. Therefore, arsenic enters the food chain mainly from contaminated soil and water [5,6].

Soil is a complex and multifactor system changeable according to the climatic and landscape characteristics of an area. Plants can maximally accumulate toxic substances from soil with their further migration to the human organism through a natural migratory circle – soil-plant-man; soil-water-man. In this connection, of importance is to study the principal contaminants of the environment (soil, water, etc.) in the region.

Arsenic is the most toxic of the elements that people use in their various areas of activity. Arsenic and its compounds are included in the composition of various pesticides, widely used in the manufacture of various types of glass, anticorrosive alloys, coatings, ammunition, accumulators. High purity arsenic is a necessary component in solar batteries, light-emitting diodes, lasers, integrated circuits, semiconductors, etc. Sh. Until the 70s of the last century, inorganic arsenic compounds were used in medicine as well; in particular, this element contained leukemia, psoriasis and asthma.

Arsenic tops the list of the 20 most dangerous compounds compiled jointly by The Agency for Toxic Substances and Disease Registry (ASTDR) and the US Environmental Protection Agency (EPA). Arsenic and its compounds are also considered by the World Health Organization (WHO) to be the most problematic substances for human health [7], and the International Agency for Research on Cancer (IACR) ranks them as the first category of carcinogenic hazards [8]. The Basel Convention of 22 March 1989, concerning the transboundary movement of hazardous waste and its disposal, classified arsenic as controlled waste. All of the above indicates that Arsenic is included in the list of

standardized substances [9].

Arsenic containing compounds can be entered from food and drinking water, also penetrate through skin and respiratory system. In food chain arsenic is entered from polluted soil and water. Arsenic has the different oxidation state -3, 0, +3, +5. The most abundant are arsenic (III) oxide  $As_2O_3$  and arsenic (V) oxide. According toxicity, important compounds are arsenic (III) chloride ( $AsCl_3$ ), hydrogen compound – arsine ( $AsH_3$ ) and salts, such as lead (II) arsenate, copper (II) acetarsenate and etc. For fresh water the main sources of contamination are arsenopyrite ( $FeAsS$ ), auripigment (orpiment) ( $As_2S_3$ ) and other compounds. Contamination is mostly performed from former manufacturing factories, that results in the accumulation of arsenic containing compounds in water, soil and plants at nearby territory. This causes the transferring of arsenic in animal tissue and milk, and finally in human body. Eventually arsenic is accumulated in skin, nails, hair, as well as bones and muscles.

The As in water sources and soils consist mainly of natural source and anthropogenic source. Industrial and agricultural activities raise arsenic concentration in the natural environment, such as mining, smelting, burning of fossil fuels, using of pesticides and fertilizers. In the past it was found that pilot region areas have faced to the problems with the arsenic pollution.

Arsenic contamination is a pressing issue in Georgia, where there are many natural or anthropogenic sources. Arsenic ore extraction, processing and production of arsenic-containing preparations have been carried out on the territory of Georgia, particularly in Racha and Kvemo Svaneti for decades [10].

The processing of the ore, which is located in Ambrolauri region started in 1937. Main products of production were metallic arsenic of high purity,  $As_2O_5$ ,  $As_2S_5$  and tin arsenate. In the former Soviet Union countries these products were used for military purposes as well as civil purposes (manufacturing of leather, chemicals, electronics). It should be mentioned that technological cycle in factory was very simple and includes thermal treatment of ore. Amount of waste is about 60 tons, which contains up to 1%  $As_2O_5$ . Waste was not used and it was stored at Kajiani territory in special hydrotechnical building, called tailings. The mining of ore was carried out at Lukhuni ore, processing was performed in the factory nearby village Uravi. Lukhuni ore deposit is special, because arsenic which is produced from

this place does not contain “forbidden” elements for microelectronics, and gives possibility to get metallic arsenic of appropriate purity with low cost. The factory has stopped functioning since 1991. Nowadays Uravi factory, with all additional buildings and full infrastructure is destroyed. The waste dump of the Uravi plant, located 14 km from the plant, is not canned. The roof tiles in some places are submerged, precipitated water meets toxic waste, then leaks out of the tomb and into the environment. The tomb is also in Uravi, in the factory area, which is canned but not hermetically sealed - its roof damaged. There is a risk that if the Lukhuni River bursts, the storage wall will be washed away and a large amount of arsenic can enter the river. Also, the preparations for the production of metallic arsenic and preparations for the production of white arsenic roasting at “Jvari” were destroyed.

Chemical mining factory in village Tsana, Lentekhi region started working is 1938. The main products were metallic arsenic and refined “white arsenic” ( $As_2O_3$ ) (I grade – 99.9%, II grade – 99.5%). This substance is poorly soluble in water and permanently can have great negative influence on environment. Processing of ore was carried out from the mining near the territory the village Kuruldashi, as well as Racha ores. The factory in Tsana, administrative buildings and warehouse farming are fully destroyed and collapsed. There is no fence around the territory. Arsenic kilns and containers are taken from the ground. Local population activities cause the distribution of arsenic and its ores all over the territory. There are scattered opened containers with arsenic ore, with capsules of white arsenic. Approximately 800 to 1000 opened containers of arsenic ore are located above the territory of factory. The territory of factory and nearby territory is extremely polluted by production waste.

Thus the problem is arsenic containing waste and soils. Until today the great amount of toxic waste of arsenic production is stored in villages Uravi and Tsana [7,10], near the territory of the factories (more than 120 000 tons waste, containing 4-9 % of white arsenic), which was not located safely and there was a high risk of ecological disaster in rivers, and soils, especially risks of natural disasters (floods, rockslide, erosion and etc.). Uravi’s concrete burial ground, which covers up to 60,000 tons of arsenic, was crushed by the side of Lukhuni River and washed directly in the river, further exacerbating the expected dangers [11].

The arsenic can occur in compounds in four oxidation levels (+ V, + III, 0, -III), its highest representation is in oxidation levels (+ V) and (+ III). In nature, it occurs especially in minerals and ores (arsenopyrit – grey arsenic,  $FeAsS$ ; arsenolit – white arsenic,  $As_2O_3$ ; realgar – red arsenic,  $As_4S_4$ ; auripigment – yellow arsenic,  $As_2S_3$ ).

In water environment, the arsenic naturally occurs usually in a soluble form as As (II) - As(III) and As(V). The occurrence of these forms in natural water depends especially on oxidation-reduction potential and pH of water.

The arsenic toxicity and carcinogenicity depend on forms of its occurrence [12]. In general, it is presented that the form As (III) is more toxic than the form As(V). The toxicity of the form As (III) is almost 70-times higher than the organic form As and 10-times higher than the form As (V). Many studies [13] indicated that drinking of water with higher arsenic content may cause the cancer of kidneys, skin, bladder, liver, lungs. It has also non-cancer effects including cardiovascular, lung, immunologic, neurological, reproductive and endocrine problems.

## Objectives and methods

The aim of the study was to establish the basis for arsenic-contaminated soils and cleaning technology in Georgia, which will use diagnostic and remediation technologies [14]. In order to achieve the aim the following objectives are set: 1. Determination of arsenic content in contaminated soil and water; 2. Creation of DNA-chip and study of microbiota in polluted environment by using of chip; 3. Isolation and characterization of active strains of microorganisms from contaminated soil; 4. Study the possibility of cleaning water polluted with arsenic by using of alga *Spirulina*; 5. Selection of plants that have ability to uptake arsenic; 6. Test of selected microorganisms and plants for phytoremediation of soil polluted with arsenic.

The expedition was conducted for sampling activities of soils and waters. Racha-Kvemo Svaneti, Time and date - 10/08/2020 - 16/08/2020. The samples were taken from the source of pollution 100, 300, 500 and 1000 m, the upper (0-10 cm) of the soil and lower (20-25 cm) layers ISO 10381-1, 10381-2 and 5667-4: 1987 According to the methodology. Locations were fixed by GPS. Total 61 samples have been taken from 6 locations, namely:

Gadamshi (control);  
 Uravi - 1;  
 Uravi - 3;  
 Tskhenistskali (control);  
 Tsana 2;  
 Koruldashi Factory.

**Map.1** *sampling points*



Preparation for preliminary processing and chemical analyzes of soil samples (drying, plotting, exchanging, excretion, etc.) were conducted according to methods - ISO-11464; EPA 3050; EPA- TCLP-1111. Determining the common forms of arsenic in the soil samples (A + 3, As + 5) - ISO 11885: 2007; According to EPA 200.2, which is based on Evins's method, which implies as a caliper, as well as direct iodometry (ST.15642052-002-98). This method is a very strong acid digestion that dissolves almost all elements that could become "environmentally available."

All samples were mixed thoroughly to achieve homogeneity and sieve, if appropriate and necessary, using a USS #10 sieve. All equipment used for homogenization were cleaned according to the guidance to minimize the potential of cross-contamination. For each digestion procedure, soil was weighed to the nearest 0.01 g and transferred to a 1 g sample (dry weight) to a digestion vessel.

For the digestion of samples for analysis were added 2.5 mL conc.  $\text{HNO}_3$  and 10 mL conc. HCl

to a 1-2 g sample (dry weight) and covered with a watch glass or vapor recovery device. Samples were digested by the digester. After digestion procedure samples were cooled. Filtered where it was necessary through Whatman No. 41 filter paper (or equivalent) and filtrate were collected in a 100-mL volumetric flask. filter paper was washed, while still in the funnel, with no more than 5 mL of hot (~95EC) HCl, then with 20 mL of hot (~95EC) reagent water. washings were collected in the same 100-mL volumetric flask.

For each batch of samples that were processed, a method blank was used throughout the entire sample preparation and analytical process according to the frequency described in method Chapter One. These blanks are useful in determining if samples are being contaminated. After the QA-QC Procedures samples were analyzed by the spectrometry.

ICP-OES (Inductively coupled plasma - optical emission spectrometry) is a technique in which the composition of elements in (mostly water-dissolved) samples can be determined using plasma and a spectrometer. The solution to analyze is conducted by a peristaltic pump through a nebulizer into a spray chamber. The produced aerosol is lead into an argon plasma. Plasma is the fourth state of matter, next to the solid, liquid and gaseous state. In the ICP-OES the plasma is generated at the end of a quartz torch by a cooled induction coil through which a high frequency alternating current flows. As a consequence, an alternate magnetic field is induced which accelerated electrons into a circular trajectory. Due to collision between the argon atom and the electrons ionization occurs, giving rise to a stable plasma. The plasma is extremely hot, 6000-7000 K. In the induction zone it can even reach 10000 K. In the torch desolvation, atomization and ionizations of the sample takes place. Due to the thermic energy taken up by the electrons, they reach a higher "excited" state. When the electrons drop back to ground level energy is liberated as light (photons). Each element has an own characteristic emission spectrum that is measured with a spectrometer. The light intensity on the wavelength is measured and with the calibration calculated into a concentration.

## Results

**Table 1.** *Resultes of the analyses of the samples taken In Racha and Lower Svaneti district - Georgia*

Sample #	Sampling place	Depth, cm	Coordinates	Sampling date	Arsenic concentration, ppm	
1	Gadamshi-1100	0-10	N-42.62343	10.08.2020	67	
2	Gadamshi-1100	20-25	E-43.34136		140	
3	Uravi-3 1100-1	0-10	N-42.66743	11.08.2020	130	
4	Uravi-3 1100-1	20-25	E-43.30085		160	
5	Uravi-3 1100-2	0-10	N-42.66760		600	
6	Uravi-3 1100-2	20-25	E-43.30048		6300	
7	Uravi-3 1100-3	0-10	N-42.66768		140	
8	Uravi-3 1100-3	20-25	E-43.30021		110	
9	Uravi-3 1250-1	0-10	N-42.66495		290	
10	Uravi-3 1250-2	0-25	E-43.29653		330	
11	Uravi-3 1050-1	0-10	N-42.66854		150	
12	Uravi-3 1050-1	20-25	E-43.30276		410	
13	Uravi-3 1050-2	0-10	N-42.66816		820	
14	Uravi-3 1050-2	20-25	E-43.30333		140	
15	Uravi-3 1050-3	0-10	N-42.66615		440	
16	Uravi-3 1050-3	20-25	E-43.30277		290	
17	Uravi-1 850-1	0-10	N-42.63792		12.08.2020	330
18	Uravi-1 850-1	20-25	E-43.28826			74
19	Uravi-1 850-2	0-10	N-42.63776	82		
20	Uravi-1 850-2	20-25	E-43.28778	180		
21	Uravi-1 850-3	0-10	N-42.63724	2900		
22	Uravi-1 850-3	20-25	E-43.28884	93		
23	Uravi-1 850-4	0-10	N-42.63766	110		
24	Uravi-1 850-4	20-25	E-43.28700	74		
25	Tsana-2 1350-1a	0-10	N-42.81442	13.08.2020	260	
26	Tsana-2 1350-1a	20-25	E-43.11556		290	
27	Tsana-2 1350-2a	0-10	N-42.81425		100	
28	Tsana-2 1350-2a	20-25	E-43.11586		7400	
29	Tsana-2 1350-3a	0-10	N-42.81422		1100	
30	Tsana-2 1350-3a	20-25	E-43.11592		560	
31	Tsana-2 1350-4a	0-10	N-42.81411		220	
32	Tsana-2 1350-4a	20-25	E-43.11601		290	
33	Tsana-2 1350-5a	0-10	N-42.81394		100	
34	Tsana-2 1350-5a	20-25	E-43.11608		74	
35	Tsana-2 1350-1b	0-10	N-42.81418		11200	
36	Tsana-2 1350-1b	20-25	E-43.11539		13000	
37	Tsana-2 1350-2b	0-10	N-42.81403		11900	
38	Tsana-2 1350-2b	20-25	E-43.11567		10400	
39	Tsana-2 1350-3b	0-10	N-42.81396		9700	
40	Tsana-2 1350-3b	20-25	E-43.11580		1600	

41	Tsana-2 1350-4b	0-10	N-42.81382	13.08.2020	93
42	Tsana-2 1350-4b	20-25	E-43.11588		370
43	Tsana-2 1350-5b	0-10	N-42.81381		280
44	Tsana-2 1350-5b	20-25	E-43.11595		93
45	Tsana-2 1350-1c	0-10	N-42.81392		930
46	Tsana-2 1350-1c	20-25	E-43.11548		197
47	Tsana-2 1350-2c	0-10	N-42.81416		280
48	Tsana-2 1350-2c	20-25	E-43.11572		187
49	Tsana-2 1350-3c	0-10	N-42.81452		187
50	Tsana-2 1350-3c	20-25	E-43.11597		47
51	Tsana-2 1800	0-10	N-42.82259	14.08.2020	93
52	Tsana-2 1800	20-25	E-43.11097		740
53	Tsana-2 1600	0-10	N-42.813906		370
54	Tsana-2 1600	20-25	E-43.193175		187

Of the numerous minerals containing arsenic, the following sulfide ores are the most important:  $As_2S_3$  – Arsenic sulfide,  $As_4S_4$  – Pararealgar,  $FeAsS$  – arsenopyrite,  $FeAs_2$  –loellingite. Rarely is arsenic found as an element. The oxygen containing compound of arsenic present in the waste in the form of arsenic trioxide-  $As_2O_3$ , is formed in nature as a result of depletion of arsenic ores in nature. Also arsenic (III) oxide as a residue is formed during the combustion of arsenic containing ores. In our opinion, from eco-chemical point of view, according to the contact duration with soil and water and physico-chemical conditions, conversion of arsenic (III) oxide ( $As_2O_3$ ) and sulfides can be carried out based on their main characteristic chemical reactions. Dissolution of arsenic (III) oxide in water is very slow process, but it is enhanced in the presence of hydrogen ions and hydroxide ions. Unlike oxides sulfides are not dangerous for environment due to their low solubility. However, sulfide ores and fumes can be converted into mobile forms in oxidizing conditions.

Based on conducted investigations it is established that contamination of soils is especially important with industrial waste. Soot that is accumulated in the warehouses of chemical mining factories in Racha and Lower Svaneti, represent loose, porous material.

Regardless of several attempts to dispose of arsenic industrial waste, industrial recycling process was not performed, so arsenic industrial waste remains a powerful anthropogenic source of environmental pollution.

For evaluation an intervention value for soil (20

cm) of 200 mg/kg for agricultural and residential land uses was applied.

54 sample were analyzed and in 30 samples were exceeding the norm.

Maximum was in Tsana-2 1350-1b; 20-25 cm - 65 times the norm;

Minimum was in Gadamishi-1100; 0-10 cm (67 mg/kg).

The best solution is to make a phytoremediation, which will be based on the local microflora, and the soil samples will be used to be analyzed, taking into consideration arsenic content.

## Conclusions

This study highlighted once again the dangerous ecological situation created in Ambrolauri and Lentekhi regions of Georgia and environment related security risks that may arise from this old soviet legacy. After the plants producing arsenic concentrate were closed in the 90s., plant premises were demolished and drums with arsenic waste material remain scattered around openly on the sites, polluting the environment and causing risks to human health. About 100,000 tons of wastes containing arsenic are accumulated in the villages of Tsana and Uravi. The sites are located in the basin of the Tskhenistskhali and Rioni rivers and there is an existing high risk of arsenic leakage. In the past the Ministry of Environment took several efforts as well as initiated discussions on the issue with different line ministries, scientific institutions, NGOs, other experts as well as local population to develop and implement effective measures. The importance of the matter is underlined in the

National Environmental Action Programme for 2012-2016 and the issue is identified as particularly dangerous. In accordance with the agreement reached in 2012 with the government of the Kingdom of the Netherlands a project for arsenic containing mine waste in Georgia is conducted by "Witteveen+Bos", Dutch consultancy 22nd OSCE Economic and Environmental Forum "Responding to environmental challenges with a view to promoting cooperation and security in the OSCE area" FIRST PREPARATORY MEETING Vienna, 27-28 January 2014 Session IV cont. Georgia, EEF. DEL/6/14/Add.1 28 January 2014 ENGLISH only and engineering firm. A study of arsenic-containing ashes and sludge in villages of Tsana and Uravi has been conducted. Nevertheless, implementation of the urgent measures, sarcophagus construction and safe disposal of arsenic containing waste materials requires additional funding for insuring the population and environmental safety in Georgia.

Arsenic (As) is a top human carcinogen widely distributed in the environment. As-contaminated soil exists worldwide and poses a threat on human health through water/food consumption, inhalation, or skin contact. More than 200 million people are exposed to excessive As concentration through direct or indirect exposure to contaminated soil. Therefore, affordable and efficient technologies that control risks caused by excess As in soil must be developed. The presently available methods can be classified as chemical, physical, and biological. Combined utilization of multiple technologies is also common to improve remediation efficiency. This research article presents the research progress on different remediation technologies for As-contaminated soil. For chemical methods, common soil washing or immobilization agents were summarized. Physical technologies were mainly discussed from the field scale. Phytoextraction, the most widely used technology for As-contaminated soil, was the main focus for bioremediation. Further research directions are proposed based on literature analysis.

It is important not only to evaluate the extent of arsenic removal from water and soil, but also to assess its biological impacts on ecosystems using ecotoxicological biotests. A number of aquatic toxicity testing methods have been published to assess the effects of substances on aquatic ecosystems. Based on the obtained ecotoxicological data, it is possible to assess ecological risks and propose possible new

approaches to the regulation and control of toxic chemicals in various ecosystems.

### Acknowledgments

This work was supported by grant # CARYS-19-179 from Shota Rustaveli National Science Foundation (SRNSF).

### References

- [1] L. Shavliashvili, E. Bakradze, M. Arabidze, G. Kuchava, Arsenic pollution study of the rivers and soils in some of the regions of Georgia, international Journal of Current Research. 9, 2 (2017) 47002 – 47008.
- [2] M.V. Gagoshidze, M.O. Antelava, A.G. Zedgenidze. Influence of the arsenic contaminated environment on the genetic apparatus of children and adolescents Georgian Medical news, 117 (2004) 59-62. (In Russian).
- [3] 10 chemicals of public health concern, <https://www.who.int/news-room/photo-story/photo-story-detail/10-chemicals-of-public-health-concern>; 2020 (accessed 14.10.2021).
- [4] Arsenic and Arsenic Compounds IARC Monographs – 100C, (IARC, 1980, 1987, 2004) <http://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C-6.pdf> (accessed 14.10.2021).
- [5] M.V. Gagoshidze, M.O. Antelava, A.G. Zedgenidze., N.Sh. Manjavidze, Influence of the ecological situation on the morbidity of children with acute respiratory diseases. Georgian Medical news. 1, 118 (2005) 49-52. (In Russian).
- [6] M.G. Skalnaya, A.V. Skalny, V.A. Demidov, Dependence of the increased oncologic morbidity rate from the excessive contents of arsenic and other toxic chemical elements in environment. (2001) 32-35.
- [7] A. Chirakadze, Z. Buachidze, I.O. Khomeriki, V. Gvakharia, M. Stamateli, N. Chakvetadze, M. Chokheli, W.A. Toscano, K. Chigogidze, L. Gvertseteli, N. Bagrationi, Arsenic pollution of soils and morbidity prevalence in Racha-lower Svaneti district of Georgia International Journal of Global Warming (2016) <https://experts.umn.edu/en/publications/arsenic-pollution-of-soils-and-morbidity-prevalence-in-racha-lowe-2>.
- [8] IACR monographs on the identification of carcinogenic hazards to human. Last update:

- 27 September, 2021. <https://monographs.iarc.who.int/agents-classified-by-the-iarc/>
- [9] The Basel Convention on the "Control of Transboundary Movements of Hazardous Wastes and their Disposal" 1989, 22 March, Basel (Switzerland) Georgia is a party of the convention from (1999).
- [10] N. Bagrationi, V. Gvakharia, A. Chirakadze, L. Gverdtsiteli. General analysis of ecochemical study results of soils of contaminated territory of Racha and lower Svaneti. Georgian Chemical Journal, 15, 2 (2015) 190-198.
- [11] I. Gurguliani, Arsenic contamination in Georgia Environment related security risks from old soviet legacy; 22nd OSCE Economic and Environmental Forum (2014). [https://www.osce.org/files/f/documents/a/a/110702.pdf?fbclid=IwAR3kxzaNbiAOxqTprXPefadxizIkaQQNx\\_HBeGjr6MhC\\_oLLWJFDWYHvvGc](https://www.osce.org/files/f/documents/a/a/110702.pdf?fbclid=IwAR3kxzaNbiAOxqTprXPefadxizIkaQQNx_HBeGjr6MhC_oLLWJFDWYHvvGc) (accessed 14.10.2021).
- [12] E. Bakradze, Y. Vodyanitskii, T. Urushadze, Z. Chankseliani, M. Arabidze. About rationing of the heavy metals in soils of Georgia. Annals of Agrarian Science. 16 (2018), 1-6.
- [13] K. Laperashvili, Food safety. Georgian strategic researches and development center Bulletin N111 (2008).
- [14] G. Khatishashvili, T. Varazi, M. Kurashvili, M. Pruidze, E. Bunin, K. Didebulidze, T. Butkhuzi, E. Bakradze, N. Asatiani, T. Kartvelishvili, N. Sapojnikova, Remedial Approaches against Arsenic Pollution (July 2nd 2021). Remedial Approaches against Arsenic Pollution [Online First], IntechOpen, DOI: 10.5772/intechopen.98779. <https://www.intechopen.com/online-first/77387>.