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Ecotoxicants in the System Water-Soil-Plant and Possible Risks to Public Health

Ashurbekova Tamila Nasirovna
FSBEI HPE Dagestan State Agricultural University named after M. M. Dzhambulatov
Makhachkala, Russian Federation
e-mail: ashtam72@yandex.ru

Gadzhimusaeva Zaira Gadzhievna
FSBEI HPE Dagestan State Agricultural University named after M. M. Dzhambulatov
Makhachkala, Russian Federation
e-mail: miracle.86@mail.ru

Isaeva Natalia Gadzhibutaevna
FSBEI HPE Dagestan State Agricultural University named after M. M. Dzhambulatov
Makhachkala, Russian Federation
e-mail: natali.himiya@mail.ru

Musinova Elmira Mugutdinovna
Dagestan State Medical University
Makhachkala, Russian Federation
e-mail: musinova@mail.ru

Abstract — **The article presents the results of a study on the content of arsenic, lead, cadmium and mercury in water, soil and in plant products that are directly used by humans for nutrition.**

During four years of observation, water analysis demonstrates high arsenic concentrations. The arsenic content ranges from 0.033 to 0.048 mc/kg versus 0.01 MAC and exceeds almost 3.3-5 times. Lead content exceeds 10 times.

In the course of the research, it was found that artesian water is the source of arsenic contamination of plant foods with arsenic. For many years, artesian water has been used by the population to irrigate cultivated plants.

Arsenic is intensively accumulated by many plants: 9 out of 20 have its concentration above the maximum permissible.

It was found that the most actively absorb and accumulate arsenic figs, potatoes and cucumber. The high content of lead is dominated in parsley, dill and watercress salad.

All detected elements have a cumulative and toxic effect and are carcinogenic and belong to the first class of danger.

Arsenic is a substance that has both carcinogenic and pronounced general toxic effects.

With this in mind, scientists have identified correlations between oncological disease and the use of water containing elevated concentrations of arsenic as sources (Alissa, Ferns, 2011; Gasanguseinava, 2010; 2018 Putilova, 2006; Ashurbekova et al., 2018).

Comparison of the results of artesian water studies used in the Terek-Kumsky basin for domestic water supply, conducted earlier at the Institute of Geology, DSC of RAS, and the results of our research show that the constant chemical composition of artesian water remains, the arsenic content exceeds the maximum permissible concentrations of WHO average 10.0 - 20.0 times, according to GOST - an average of 1.8-2.0 times.

Keywords— water, soil, plants, village Bogatyrevka, ecotoxicants, maximum permissible concentration

I. INTRODUCTION

Among the reasons that have a negative impact on the health of the population and the demographic situation, the ecological component plays a significant role. Increasingly, there is evidence of the negative contribution of environmental pollution to the acceleration of population aging, an increase in the incidence and a decrease in life expectancy. Today substances that have the ability to cumulate in the components of ecosystems (soil, water, air, plants, animals and the human body), causing violations and changes in health status are widely represented in the environment.

The level of cancer incidence in a number of administrative territories of the North Caucasus, especially the Tersko-Kumskij basin, where a high content of arsenic was found, amounts to between 250 and 136 per 100,000 thousand population (Gasangajdiyeva, 2010).

Extensive research is needed to clarify all the growth factors for cancer incidence in these areas and to develop measures for its prevention.

Water supply of settlements of Northern Dagestan is carried out mainly at the expense of underground artesian waters and is one of the main reservoirs of fresh water used by the population for household and drinking purposes. This is due not only to the lack of a sufficient amount of water from surface sources in certain countries, but also to the fact that the water from underground sources according to the content of macro - and micro-component composition meet the standards (regulatory requirements) and, as a rule, are more stable and safe for microbiological and toxicological indicators.

According to the depth of occurrence and location in relation to the terrestrial layers, all groundwater is divided into upper, middle and lower zones. The waters of the upper zone up to 1500 m are mainly used for drinking water supply (Rumyantsev, 2005).

With increasing depth and slowing water exchange is increasing mineralization of groundwater. Simultaneously with the growth of the general mineralization of underground waters, their chemical composition also changes. The formation of the chemical composition of groundwater is influenced by: the nature and intensity of the processes of interaction of water with rocks (leaching of rocks, redox reactions, cation exchange reactions, etc.); the composition of the initial water in the sedimentation basin; the degree of washing of rocks with infiltration waters; the intensity of mixing and mutual displacement of waters of different origin and composition, as well as a number of other processes. Also influenced by such factors as the availability of solved structures where the aquifers are connected with surface in the areas of supply and discharge, large capacity and high permeability of the aquifer rocks as well as ascending tectonic movements (Kurbanov, 2003).

However, the use of groundwater for household drinking water supply is often dangerous due to the presence of elevated concentrations of such elements, arsenic, cadmium, lead, etc., exceeding the maximum permissible concentration (MPC).

One of the serious problems with the use of natural groundwater for household and drinking supply is the problem of arsenic pollution of groundwater. This problem is typical for about 20 countries, including Bangladesh, Chile, Taiwan, the northwestern United States, where people in a number of places consume arsenic-contaminated water for a long time.

On the territory of the Russian Federation, regions with arsenic content in groundwater include the territories of Zabaikalsky, Perm, Stavropol, Khabarovsk Krai, the Republic of Tuva, the Magadan and Penza regions, the Chechen Republic, and the Republic of Dagestan.

In Russia, groundwater (artesian water) with a high arsenic content for drinking water supply is used for a long time by the population living in the Tersko-Kumskij artesian basin, which covers the northern and central parts of the Republic of Dagestan (Alkhasov, 2008).

For residents of the village of Bogatyrevka of the Republic of Dagestan for a long time, the main source of water is artesian wells. The artesian waters of this territory are characterized by a high content of arsenic. They are the main source for drinking and household needs (Astarkhanova, Bagavdinova, Ashurbekova, 2013).

As a reason for the appearance of arsenic, a complex of conditions is considered: geochemical conditions, the presence of arsenic ions forming soluble complexes with metals in rocks and anthropogenic factors (Ayotte, Szabo, Focazio, Eberts, 2011).

According to the International Agency for the Study of Cancer (IASC), arsenic poses a great danger to public health, since its excess occupies a significant place in the formation of ecological-dependent pathology and therefore belongs to the first, most dangerous, group of carcinogens (Kurbanov, 2003).

II. Problem Statement

Thus, the problem of arsenic contamination today is relevant. As a result of studying the quality of groundwater in the Republic of Dagestan and proceeding from general geochemical prerequisites, it was found that in the northern part of the republic as a result of natural processes a regional hydrogeochemical province of groundwater is formed with a high content of normalized chemical elements (Kurbanov, 2003; Kurbanova et al., 2013). The province is dedicated to the Tersko-Kumskij artesian basin.

III. Research Questions

The health of the population and the quality of the environment in the village of Bogatyrevka is the subject of attention of research teams and the administration of the village. The scale of the tasks is determined by the territory, morbidity of the population, the number and power of the sources of influence.

Over the past 5 years, the rates of oncological morbidity and morbidity in the urinary system in the village of Bogatyrevka are almost 1.5–2 times higher than the national average.

Among the problems associated with environmental pollution, the greatest danger to health is pollution of water, soil and plants.

The carcinogenic risk depends mainly on the concentrations of ecotoxicants (Gasangadzhieva, 2010, Putilova, 2006)).

IV. Purpose of The Study

The purpose of the study is to determine the content of arsenic and heavy metals in the water-soil-plant system and to compare the accumulation of toxic substances in agricultural plants.

The relevance of such a comparison can be illustrated by the answers to the questions: the concentration of ecotoxicants in the water-soil-plant system, the analysis of their migration in agricultural plants and the study of possible risks in the village of Bogatyrevka.

V. Research Methods

The object of the study was water samples from wells, soil samples and plant samples. The material underlying the proposed article was obtained in the period from 2015-2018. Sampling of water was carried out in plastic containers with a volume of 0.5 l. The wells differed in depth, location and service life. Sampling of artesian water to determine the quantity and quality of the parameters to be determined was carried out for four years and in accordance with the requirements of GOST. Samples were taken from sources of direct water consumption in the study area.

Analysis of arsenic, cadmium, mercury and lead was carried out by atomic absorption spectroscopy using an atomic absorption spectrometer with an electrothermal atomization “MGA-915MD” after appropriate preparation of the starting material.

Ecological and geochemical assessment of soil cover was carried out on the basis of (Hygienic standards, 2006).

In accordance with (Sanitary Rules and Norms, 2003), arsenic, cadmium, mercury, and lead belong to the first class of danger.

Methods of measurement of the mass fraction of water-soluble forms of metals (lead) in soil samples by atomic absorption analysis-RD 52.18.286 - 91.

Methods of measuring the mass fraction of arsenic in soil and sediment samples by atomic absorption spectrometry with electrothermal atomization-RD 52.18.571-2011.

Methods of measuring the mass fraction of mercury in soil and sediment samples by atomic absorption spectrometry (cold vapor method)-m-MVI-80-2008.

Samples of soil samples were taken on the plots of land. Sampling was carried out by the envelope method (Afanasyev, Fomin, Menshikov, 2001). Sample preparation and analysis of samples was carried out in accordance with the methods of MU 31-0404. Soil sampling was performed according to GOST 28168-89,2008.

Vegetables and fruits were selected in the backyards of the village of Bogatyrevka.

Atomic absorption method was used to analyze toxic elements in food products and food raw materials - MU 01-19/47-11.

VI. Findings

The content of arsenic and heavy metals in water according to the results of studies performed over 4 years are presented in Table 1. For the entire period of studies, changes in ecotoxicants were observed.

The analysis of the obtained results shows that the arsenic content at the time of the research ranged from 0.033 to 0.048 mc/ kg against 0.01 MPC.

The obtained results allow us to identify continuous arsenic water pollution in the village of Bogatyrevka. The average concentration of arsenic in waters was 0.042 mg / kg, which is 4.2 times higher than the hygienic standard for arsenic in drinking water.

The highest concentrations of arsenic were recorded in 2018. The lowest - in 2015.

Cadmium content is below the MPC. The lead content ranges from 0.1-0.09 mc/kg against 0.01 MPC and exceeds almost 10 times.

TABLE I. The content of arsenic and heavy metals in water

Object of research water	Pb mg/kg	Cd mg/kg	As mg/kg	Hg mg/kg
	MPC			
Years	**0.01**	**0.001**	**0.01**	**0.0005**
2015	0.002-0.08	0.0000039-0.0000062	0.003-0.033	-
2016	0.001-0.09	0.000015-0.000072	0.002-0.045	-
2017	0.005-0.1	0.000011 0.000072	0.001-0.042	-
2018	0.004-0.09	0.000025 0.000047	0.012-0.048	-

Other researchers also noted high concentrations of arsenic in water in this area (Astarkhanova et al., 2013).

Analyzing the obtained results, it should be noted that the soil has a high adsorption capacity and accumulates toxic elements in the surface layer, although their content remains below the maximum permissible concentrations. It should be noted that with the depth of the concentration of arsenic and heavy metals decrease almost 2-3 times. This suggests that these elements are intensively absorbed by plants. All this can have a negative impact on the life of plants and soil biota. Considering that the pollutants entering the soil have a negative impact on many intra-soil biochemical processes, and are able to be transmitted through geochemical and food chains to adjacent environments (surface and groundwater, plants) and therefore pose a danger to human health.

TABLE II. The content of arsenic and heavy metals in the soil

Object of research Soil	Depth of selection	Pb mg/kg	Cd mg/kg	As mg/kg	Hg mg/kg
		MPC			
Years		**60**	**1.0**	**15**	**0.1**
2015	0-20cm	2.3-6.0	0.039-0.69	0.25-0.48	0.0015-0.057
	20-40cm	1.9-4.3	0.071-0.49	0.099-0.28	0.0022-0.0039
2016	0-20cm	2.2-5.3	0.029-0.57	0.28-0.51	0.0011-0.036
	20-40cm	1.1-4.2	0.019-0.37	0.019-0.33	0.0017-0.0065
2017	0-20cm	2.4-3.7	0.029-0.21	0.015-0.36	0.012-0.043
	20-40cm	1.7-2.3	0.011-0.36	0.034-0.26	0.00052-0.0039
2018	0-20cm	1.9-5.9	0.021-0.37	0.34-0.54	0.0018-0.056
	20-40cm	1.6-3.3	0.009-0.17	0.059-0.38	0.0019-0.0034

The content of arsenic and heavy metals in cultivated plants is presented in table 3. The analysis of the obtained results shows that arsenic is intensively accumulated by quite a few plants. Especially actively absorb arsenic from the environment of the plant: cucumber, pumpkin, potatoes, dill, watercress, black and red currants, pear, figs and contain respectively 0.59: 0.43: 0.62: 0.22: 0.33 : 0.29: 0.31: 0.27: 0.69 MPC of arsenic.

High concentrations of this element are noted in figs (3.5 MPC), potato tubers (3.1 MPC), cucumber (3.0 MPC), black and red currant berries (1.5-1.7 MPC), in cress lettuce (1.7 MPC) and in the leaves of the young dill (1.1 MPC).

Food plants actively absorb lead from the soil: parsley (1.8 MPC), dill (1.3 MPC), and watercress (1.2 MPC).

Also, there is a high content of cadmium in figs - 2.6 MPC and sweet pepper fruits - 2.2 MPC.

TABLE III. THE CONTENT OF ARSENIC AND HEAVY METALS IN PLANT PRODUCTS

№	Object of research plants	P. mg/kg	Cd. mg/kg	As. mg/kg	Hg. mg/kg
		MPC for fruits and vegetables			
		0.4-0.5	**0.03**	**0.2**	**0.02**
1	Cucumber	0.038	0.0013	**0.59**	0.0012
2	Pumpkin	0.11	0.0052	**0.43**	0.001
3	Tomato	0.12	0.0038	0.01	0
4	Eggplant	0.19	0.0032	0.0028	0.0053
5	Onion	0.17	0.0029	0.0021	0.001
6	Sweet pepper	0.24	**0.066**	0.0028	0.0048
7	Potatoes	0.4	0.0079	**0.62**	0.0031
8	Dill	**0.52**	0.023	**0.22**	0.004
9	Cilantro	0.33	0.0047	0	0
10	Parsley	**0.72**	0.0021	0.16	0.0065
11	Watercress	**0.49**	0.033	**0.33**	0.0041
12	Black currant	0.27	0.0033	**0.29**	0.0044
13	Red currant	0.27	0.0031	**0.31**	0.0044
14	Plum	0.043	0.0004	0.043	0.002
15	Cherry plum	0.057	0.003	0.0023	0.007
16	Grapes	0.07	0.0019	0.017	0.0032
17	Apples	0.065	0.0017	0.022	0.00012
18	Pear	**0.41**	0.0011	**0.27**	0.0042
19	Quince	0.095	0.0034	0.012	0.00042
20	Figs	**0.44**	**0.078**	**0.69**	0.0044

Thus, the study of the water-soil-plant chain allows us to understand the mechanism of the risk of disease development.

Organic vegetable products grown in the conditions of the village of Bogatyrevka are tomato, eggplant, onion, cilantro, plum, cherry plum, apples, quince and grapes.

The monitoring of water resources, soil and plants allows: to assess the risk to human health of certain chemical pollutants, as well as to use the materials obtained for planning to reduce the adverse effects of pollution; to develop the necessary measures aimed at improving the health of the population.

VII. CONCLUSION

1. Figs, cucumbers, potatoes the most actively accumulate arsenic.
2. The content of lead dominates in young greens of dill, cilantro, parsley.
3. In order to obtain environmentally friendly plant products in the conditions of the village of Bogatyrevka, we consider it expedient to grow tomatoes, eggplants, and fruit crops: plum and grapes.

Thus, high concentrations of arsenic in the drinking water of the artesian basin, in the soil and in vegetables and fruits cause high risks of developing non-infectious diseases, which, in turn, determine these waters as unsuitable for household use and drinking.

In this regard, the further use of these waters for drinking water supply requires a systematic study to monitor the impact on human health and the environment, and the development of effective methods for purifying arsenic from water before using them for household purposes.

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