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IMPACT OF MINING ENTERPRISES OF THE CITY OF KAPAN ON ADJACENT AGROECOSYSTEMS

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ABSTRACT

The article highlights the research results regarding heavy metal accumulation in farm crops cultivated on lands in the vicinities of the city of Kapan. The intensity of heavy metal accumulation was assessed with help of a bioaccumulation factor. The obtained research results underpinned selection of crops that actively accumulate heavy metals and of those which pose a hazard to consumers.

Key words: *heavy metals, biological accumulation factor, risk mitigation measures*

INTRODUCTION

One of Armenia's biggest mining centers is located in the south of the republic, in the city of Kapan. The development of Kapan deposit and excavation of non-ferrous metals started as far as in V century. By the beginning of XX century, on a base of the historic mining center, a modern industrial complex had been shaped which comprised mining and ore processing plants as well as tailing repositories [3-5]. A long-term operation of the industrial complex has brought to heavy metal pollution of the environment of the city and its surroundings.

As proved by global practice, in most cases such industrial enterprises become city-forming ones [11-13]. The Kapan mining and dressing set of plants is not an exception. Gradually settlements of workers transformed into a city with appropriate infrastructure, whereas the attached sites changed into farmlands which have been a source of farm produce to cities of Kapan and neighboring settlements with total population of some 60 thousand people [10]. However, farm crops obtained in conditions of pollution are known to disagree with safety standards owing to their property to accumulate considerable contents of heavy metals.

In 2007, at the request of Kapan's municipality, the Center for Ecological-Noosphere Studies under support of the OSCE Office in Yerevan implemented a complex research aimed to the revealing of factors of ecological risks induced by operation of a set of mining plants. According to obtained results soils of farmlands adjacent to the city of Kapan are polluted with set of heavy metals, including those of 1st and 2nd category of danger. The farm crops obtained in the region is hazardous to be used as it contains standard-exceeding concentrations of a set of heavy metals [3-6].

The goal of this research was to single out farm crop species that do not accumulate heavy metals in edible parts of plants on a base of calculations of a bioaccumulation factor (BAF) [7].

MATERIALS AND METHODS

The research materials were the results of analyses of soil and farm crops cultivated on vast farmlands attached to the city of Kapan. Analyzed were the contents of nine heavy metals (Hg, Cd, As, Pb, Cr, Ni, Zn, Cu, Mo) in 20 species of farm crops growing in similar soil-climatic conditions. The analyses were done consistent with ISO methods [1] on the atomic-absorption spectrometer (PerkinElmer Aanalyst 800) in the Central Analytical Laboratory of the Center for Ecological-Noosphere Studies NAS RA accredited by ISO 17025.

A bioaccumulation factor (BAF) was calculated by a formula $BAF = Cp / Cs,$ where C_p is concentration of the element in plant tissues, and C_s – concentration of the element in soils [7].

To visualize the obtained data we made up decreasing series of heavy metals accumulation, ranged by BAF value. The summary intensity of series is an additive sum of BAF values characterizes the accumulative properties of given crop.

Statistical data treatment was done through STATISTICA 6 program [8, 14].

RESULTS AND DISCUSSION

Table gives series of heavy metal accumulation in tissues of all the studied farm crops.

A qualitative analysis of heavy metal accumulation series indicates that in plant tissues Hg accumulates most intensively. As a rule, BAF values for Hg exceed the analogous index of other elements by an order; for beat root and vegetable marrow – by two orders. Hg contents in edible parts of the four species: marrow, beat root, basil and pear – are several times excessive vs. those in soils.

Table. BAF values, heavy metal accumulation series and their summary intensity.

Species		Cu	Mo	Ni	Cr	Pb	Zn	Hg	As	Cd	Accumulation series	Summary intensity
Egg-plant	*min*	0,01	0,02	0,01	0,01	0,01	0,02	0,01	-	0,0007	Zn–Mo–Pb,Cr–Hg>Cu,Ni–Cd	0,08
	max	0,01	0,05	0,01	0,02	0,02	0,03	0,33	0,013	0,0028	Hg>Mo–Zn–Cr–Pb–As,Ni–Cu>Cd	0,49
	mean	0,01	0,05	0,01	0,02	0,02	0,03	0,33	0,013	0,0028	Hg>Mo–Zn–Cr,Pb–Ni–Cu–As–Cd	0,49
Beans	*min*	0,01	0,03	0,01	0,01	0,02	0,02	0,01	0,001	–	Mo–Zn–Pb–Cr–Hg,Ni>Cu–As	0,11
	max	0,03	0,20	0,03	0,04	0,05	0,09	0,50	0,004	–	Hg–Mo>Zn–Pb–Cr–Cu–Ni>As	0,94
	mean	0,02	0,07	0,02	0,02	0,03	0,04	0,18	0,002	–	Hg>Mo–Zn–Pb–Ni,Cu>As	0,38
Tomato	*min*	0,00	0,01	0,00	0,01	0,01	0,01	0,02	0,002	0,0003	Hg–Mo>Zn–Pb–Cr–Ni–Cu–As–Cd	0,05
	max	0,01	0,04	0,01	0,02	0,02	0,02	0,05	0,002	0,0010	Hg–Mo–Pb–Cr–Zn–Ni>Cu–As–Cd	0,17
	mean	0,00	0,02	0,01	0,01	0,01	0,01	0,04	0,002	0,0006	Hg–Mo–Zn,Pb–Cr>Ni–Cu–As–Cd	0,11
Pepper	*min*	0,01	0,04	0,01	0,01	0,02	0,03	0,13	–	0,0007	Hg>Mo–Zn–Pb–Cr–Cu,Ni>Cd	0,26
	max	0,02	0,06	0,02	0,02	0,03	0,05	0,47	–	0,0007	Hg>Mo–Zn–Pb–Cr–Ni–Cu>Cd	0,67
	mean	0,01	0,05	0,01	0,02	0,03	0,04	0,30	–	0,0007	Hg>Mo–Zn–Pb–Cr–Ni–Cu>Cd	0,46
Cucumber	*min*	0,01	0,03	0,01	0,01	0,01	0,02	0,02	0,001	0,0003	Mo–Hg–Zn–Cu–Pb,Cr>Ni–As>Cd	0,10
	max	0,01	0,03	0,02	0,02	0,02	0,02	0,11	0,013	0,0003	Hg>Mo–Zn–Cr–Ni–Pb–Cu–As>>Cd	0,23
	mean	0,01	0,03	0,01	0,02	0,01	0,02	0,06	0,007	0,0003	Hg>Mo–Zn–Cr–Pb–Cu,Ni>As	0,17
Beetroot	*min*	0,00	0,01	0,01	0,01	2,00	0,00	0,001	0,000	0,0000	Hg>>Mo>Cr–Zn–Pb–Ni–Cu–Cd	2,03
	max	0,01	0,04	0,02	0,02	0,02	0,02	10,50	0,000	0,0007	Hg>>Mo>Zn,Cr–Pb–Ni>Cu–Cd	10,62
	mean	0,01	0,02	0,01	0,02	0,01	0,02	6,25	–	0,0007	Hg>>Mo–Zn,Cr–Pb,Ni>Cu–Cd	6,33
Marrow		0,01	0,03	0,01	0,01	0,01	0,02	7,50	–	–	Hg>>Mo–Zn–Pb–Cr>Ni–Cu	7,58
Cabbage		0,002	0,03	0,003	0,01	0,01	0,01	0,35	–	0,0003	Hg>Mo–Zn>Pb–Cr–Ni–Cu	0,41
Dill	*min*	0,01	0,03	0,02	0,02	0,02	0,03	0,03	0,006	0,0028	Hg–Mo–Zn–Cr–Pb–Ni–Cu>As–Cd	0,16
	max	0,01	0,05	0,03	0,06	0,02	0,03	0,33	0,006	0,0028	Hg>Cr–Mo–Zn–Ni–Pb–Cu>As–Cd	0,54
	mean	0,01	0,04	0,02	0,04	0,02	0,03	0,18	0,006	0,0028	Hg>Cr–Mo–Zn–Ni–Pb–Cu>As–Cd	0,35
Basil	*min*	0,002	0,01	0,01	0,01	0,01	0,01	0,07	0,0003	0,0007	Hg>Mo>Cr–Zn–Pb–Ni>Cu–As,Cd	0,11
	max	0,02	0,39	0,02	0,26	0,03	0,04	4,67	0,001	0,0007	Zn>Pb–Mi–Mo–Hg–Cu–Cr–Cd>Cd	5,41
	mean	0,01	0,14	0,01	0,09	0,01	0,02	2,58	0,001	0,0007	Hg>Mo–Cr>Zn–Pb–Ni–Cu>As,Cd	2,86
Pear	*min*	0,01	0,02	0,01	0,01	0,01	0,01	0,93	0,003	0,0174	Hg>>Cd–Mo–Zn–Pb,Cu–Cr>Ni–As	1,02
	max	0,01	0,09	0,02	0,03	0,02	0,05	1,00	0,017	0,0174	Hg>Mo–Zn–Cr–Pb–Ni–Cd,As–Cu	1,26
	mean	0,01	0,05	0,01	0,02	0,02	0,03	0,97	0,010	0,0174	Hg>Mo–Zn–Cr–Pb–Cd–Ni–Cu–As	1,14
Quince		0,01	0,03	0,01	0,02	0,01	0,02	0,03	–	0,001	Hg–Mo–Cr–Zn–Pb>Cu,Ni–Cd	0,12
Apple		0,001	0,01	0,004	0,01	0,004	0,01	–	0,000	–	Mo>Cr–Zn–Pb,Ni–Cu	0,04
Cornel		0,003	0,01	0,004	0,01	0,01	0,01	0,07	–	0,0003	Hg>Zn,Cr–Pb–Mo–Ni–Cu	0,10
Blackthorn		0,003	0,003	0,02	0,01	0,01	0,01	0,01	0,03	0,001	Hg–Mo–Zn>Pb,Cr–Ni–Cu–As	0,09
Plum		0,002	0,01	0,004	0,004	0,01	0,01	–	–	–	Mo,Zn>Pb–Cr,Ni–Cu	0,04
Cherry–plum		0,005	0,01	0,01	0,01	0,01	0,01	0,01	0,02	–	Hg–Zn–Mo>Pb–Cr–Ni,Cu–Cd	0,07
Corn		0,03	0,45	0,04	0,05	0,05	0,06	–	0,001	0,002	Mo>Zn–Pb,Cr–Ni–Cu>Cd–As	0,68

Note: "–" the given element did not detected in a corresponding organ of a plant.

Commonly, Hg in the series of heavy metal accumulation is followed by Mo, which holds the first position in respect to two herb (parsley, celery) and two fruit (apples, plums) species (*Table*).
Subsequent positions in accumulation series are held by Zn, Pb and Cr. As a rule, BAF values of the noted elements are close. So, plant tissues accumulate with comparable intensity the toxic Pb and biophile Zn and Cr (*Table 1*).
Accumulation of biophile Ni and Cu in farm crops is less active. As a rule, BAF values of the elements are close, but in most cases Ni precedes Cu (*Table*).
Toxic As and Cd are characterized by the lowest values of BAF, closing heavy metal accumulation series (*Table*).
BAF values for Hg vary very widely (*Fig. 1*), the median being profoundly shifted towards the lower quartile. The latter testifies to a presence of high peaks against a general background of low values of BAF recorded for Hg.
The range of variations of BAF values of the rest elements is noticeably narrower, distribution of BAF values if even, median is close to mean (*Fig. 1*).
The highest value of summary intensity of the accumulation series is determined for beat roots and marrow. In this respect noteworthy are also basil and pear (*Fig. 2*). High values of summary intensity of the accumulation series of the

mentioned farm crops are explained by intense accumulation of Hg, its contents in plant organs vs. the soils being excessive by orders and dozens of times.

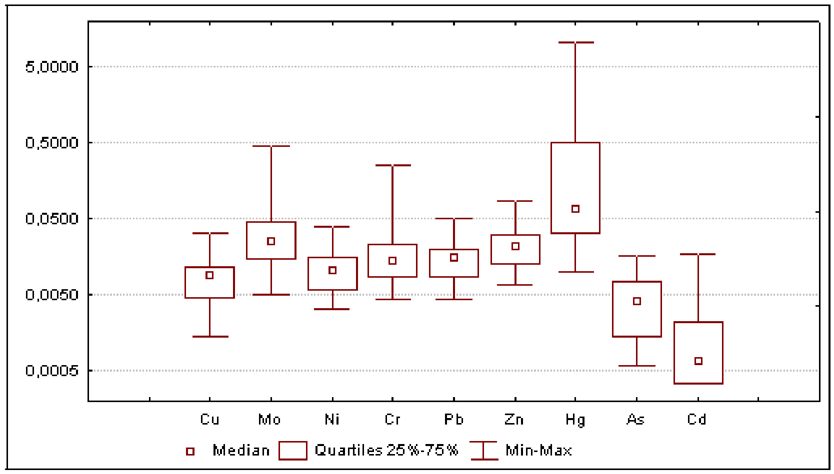

Fig. 1. Variation limits of BAF values of heavy metals in farm crops obtained from sites adjacent to the city of Kapan.

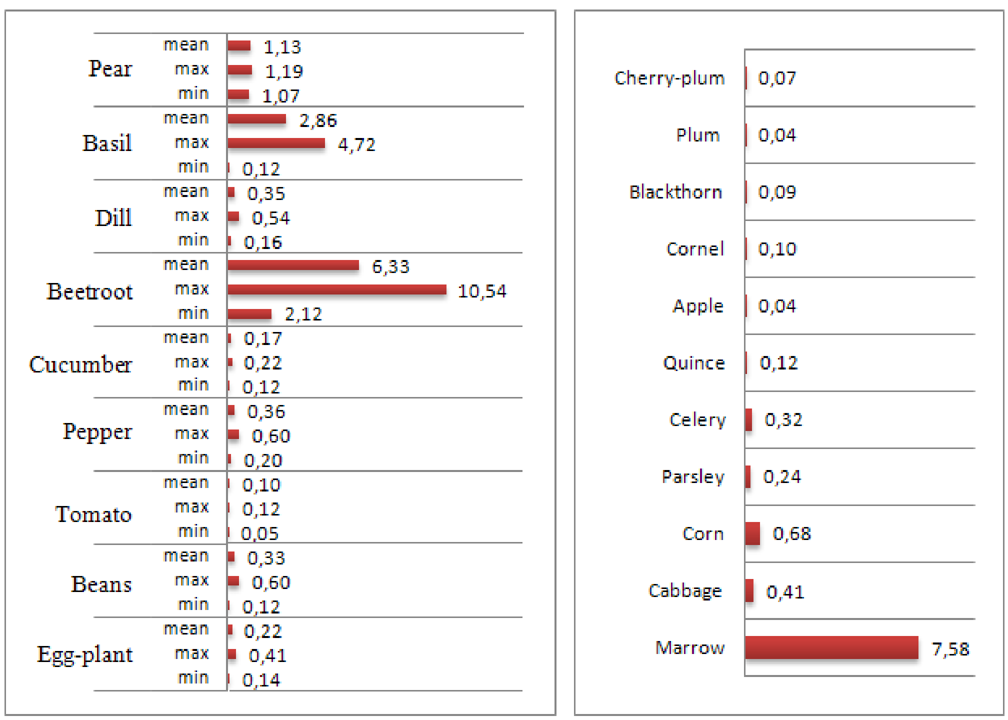

Fig. 2. Summary intensity of heavy metals accumulation in different crops.

Collating between intensities of heavy metal accumulation in different farm crops indicates that most intensively heavy metals accumulate in vegetative mass of herbs, less intensively – in vegetables and cereals, and least intensively – in fruits (*Fig. 3*).

It is noteworthy, that the vegetables are characterized by higher values of BAF for toxic elements Hg, Cd and As, whereas herbs and corn grains more intensively accumulate microelements Mo, Cu, Zn and Cr (*Fig. 4*). The research results we obtained enabled us to recommend local people that they must not grow some species of kitchen herbs and vegetables on the investigated areas. In the given conditions it is advisable cultivating fruit trees and shrubs as fruits display minimal values of BAF in respect to all the studied heavy metals. Cultivation of crops that have poor accumulative properties in combination with earlier recommended irrigation water and soil cleanup measures will help yield farm crops that would pose no risk to the health of consumers.

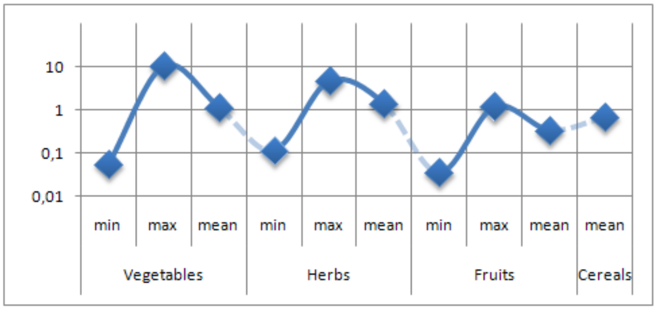

Fig. 3. Summary intensity of heavy metals accumulation by different farm crops groups.

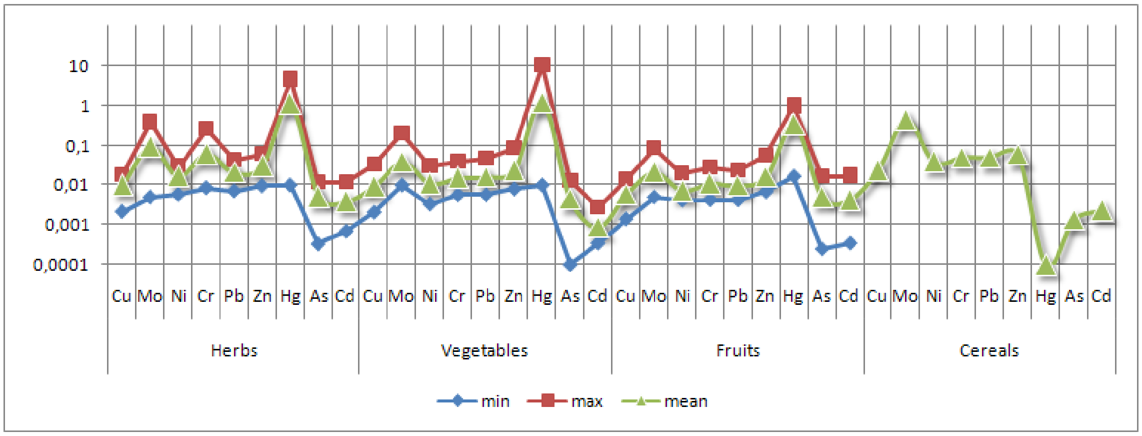

Fig. 4. Minimum, maximum and average values of BAF for different farm crops groups.

CONCLUSIONS

The performed research enabled us to make the following conclusions. Farm crops obtained in conditions of pollution accumulate heavy metals in edible parts. In the most intensive way the studied crops accumulate Hg which contents in some species is several times higher vs. those in soils. Hg concentrators are beat roots, marrows, basil and pear. The intensity of accumulation of microelements (Mo, Cu, Zn, Ni, Cr) and toxic Pb is close and compatible. The highest intensity of heavy metal accumulation is detected in green mass of herbs and vegetables, the lowest – in fruits. The obtained results underpin a recommendation that cultivation of herbs and vegetables emphasizing beat root, marrow, basil and dill should be forbidden on some territories. The assortment of advisable farm crops should include diverse species of fruit trees and shrubs, e.g. apple quince, plum, cornel, blackthorn

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