THE CENTER FOR ECOLOGICAL-NOOSPHERE STUDIES NAS RA

OSCE OFFICE IN YEREVAN

CASE (CIVIC ACTION FOR SECURITY AND ENVIRONMENT)

ASSESSING A RISK OF HEAVY METAL POLLUTION OF FARM PRODUCTS IN ARMENIA

Yerevan 2011

THE NATIONAL ACADEMY OF SCIENCES RA
THE CENTER FOR ECOLOGICAL-NOOSPHERE STUDIES

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«9» march 2011

REPORT ON A PROJECT

ASSESSING A RISK OF HEAVY METAL POLLUTION OF FARM PRODUCTS OF THE RA

MANAGER

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Yerevan 2011

CONTENTS

1. INTRODUCTION

Mining production has a significant part of Armenia's economy. Due to relatively abundant reserves of metallic minerals a major share in mining production in RA falls on metallic ore mining and processing.

Huge sets of mining plants of Armenia are associated with territories having naturally elevated contents of environmental heavy metals which are called biogeochemical provinces [12]. As far back as the 1990s in the result of monitoring studies [14] a set of biogeochemical provinces enriched by Cu, Mo, Zn and Pb was discovered on Armenia's territory (*Fig. 1*). Spatial spread of those zones is mosaic-like encompassing the north and south portions of the Republic.

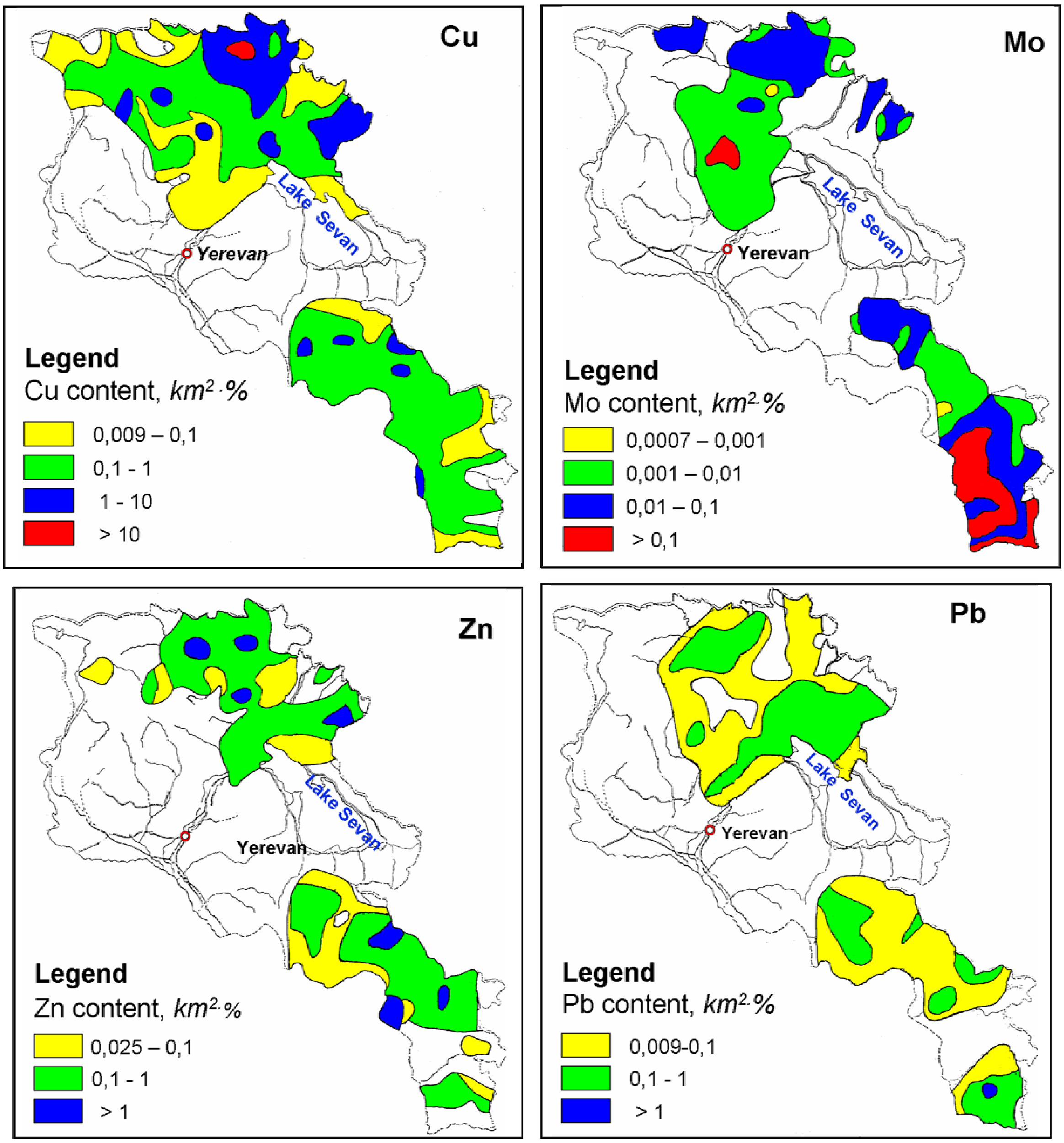

Fig. 1. *Specialized geochemical schematic maps of Cu Mo, Zn and Pb contents on Armenia's territory [14]*

By the beginning of XX century in the north of Armenia - a recognized mining center since ancient times, in the cities of Alaverdi and Akhtala industrial centers had been formed, which activities brought to numerous ecological problems. In 1989 the Alaverdi set of plants was closed by ecological reasons and resumed operation in 1997.

By a number of objective and subjective reasons, a practical norm in the RA has become the operation of mining plants lacking any cleanup facilities, mining water discharge into surface water streams, abandoned tailing repositories (*Fig. 2*), and all this continues aggravating ecological situation in the cities of Alaverdi and Akhtala and adjacent villages

Fig. 2. *Mining production – induced emissions, discharges and waste in the cities of Alaverdi and Akhtala.*

The major concern to the region is environmental pollution with heavy metals. From such positions dangerous are not only typomorphic elements – copper (Cu), zinc (Zn) and lead (Pb), but also other toxic metals – mercury (Hg), cadmium (Cd), arsenic (As) and so on. Concentrations of the latter are not high in the ore, however in the process of mining and treatment they enter in environmental compartments becoming thus a major ecological risk factor.

As environmental pollutants heavy metals have several distinctive features (*Fig. 3*). They are not involved in self-cleanup processes: in the course of migration their concentrations and forms of availability undergo changes. Being involved in all migration types and biological turnover, heavy metals lead to pollution of all vitally important natural media: water, soil, air and then – trophic chain. A property of heavy metals to concentrate in living organisms induces both the occurrence of specific diseases (congenital pathologies and disorders, chronic somatic and endocrine diseases) and weakening of the immune system and rise in general nonspecific diseases including those of allergic character.

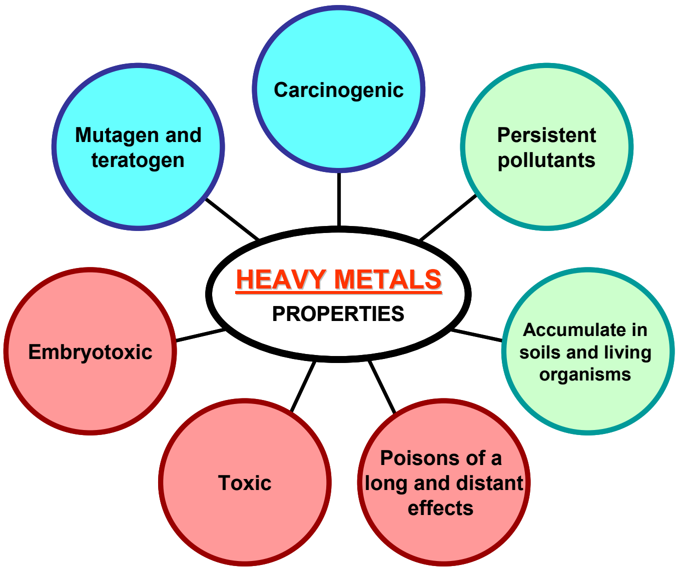

Fig. 3. *Properties of heavy metals as pollutants*

Besides direct toxic effects, typical of heavy metals are the so-called remote effects that affect underlying functions of the organism – reproductive and genetic. The level of harmfulness of heavy metals is high as they pose a threat not only to separate organisms, but also to generations to come [6, 7, 11, 12, 15]. Maximally dangerous heavy metals are to the man being on the top of trophic pyramid. Via trophic chain the human organism takes up 40-50% of toxic substances [13]. This supports a necessity of assessing farm produce obtained under conditions of pollution of natural environment.

In 2010-2011 the Center for Ecological-Noosphere Studies NAS RA under support of the OSCE Office in Yerevan implemented a study on the assessment of ecological risk of heavy metal pollution of farm produce of the RA in the frames of a CASE project (Civic Action for Security And Environment).

The research was implemented with the involvement of Dr. L. Sahakyan, PhD in geogr. sc. (the project manager), DSc in geo-mineralogy Dr. A. Saghatelyan, junior researchers O. Belyaeva and A. Sakoyan, senior lab assistant G. Tepanosyan, lab assistant M. Sarksyan; the analyses were carried out in the accredited Central laboratory of the Center for Ecological-Noospehre Studies by chemists-engineers J. Kazaryan and D. Khachyan.

This report highlights the outcomes of works implemented between March 2010 and February 2011.

1.1. Research goal and tasks

The **goal** of the research was assessing risk of pollution of farm crops grown on the territories of the cities of Alaverdi and Akhtala and adjacent villages and informing local population.

To achieve the goal, the following **tasks** were formulated and managed:

- assessing ecologo-geochemical state of farmlands,
- assessing the state of irrigation waters,
- ecotoxicological assessment of farm crops grown on model plots,
- informing and notification of local population and self-governance bodies.

2. FACTUAL MATERIAL, RESEACRH STAGES AND METHODS

The studies were performed in period 2010 to 2011 on the territories of the cities of Alaverdi and Akhtala and adjacent villages of Negots, Karkop and Chochkan.

The works were implemented by 5 basic stages: 1) preparatory works; 2) filed works, in-situ measurements and quality control; 3) lab works and quality control; 4) generalization of results and interpretation; 5) informing self-governance bodies and local population.

Figure 4 displays sampling points for collection of irrigation water, farmland soil and grown farm crop samples. Spatial fixation of sampling points was implemented through GPS for defining geographical coordinates.

LEGEND

– marks of location of model plots

Alw-1,2,3,16 – water sample numbers
Als-1,2,3,9 – soil sample numbers
Alc-1-13 – farm crop sample numbers

Fig. 4. *A schematic map of location of model plots*

From each model plot irrigation water, farmland soil and farm crop samples were collected. Totally, 5 water samples were collected, one of which (Alw-2) – from one of wells at a request of local people as they use that water for drinking and domestic purposes. The rest samples were collected from River Debed waters which are used in irrigation.

Soil samples were collected from crofts located on the territory of the city of Alaverdi and the villages of Negots and Karkop. The city of Akhtala was excluded from the research as – local people say – River Debed waters are not used for irrigation of the Akhtala farmlands.

Farm produce was sampled by two stages: directly from crofts and from the market of the city of Alaverdi with preliminary clarification of origination of the product.

In-situ measurements of pH were implemented applying Checker® pH Meter (HANNA Instruments).

Water, soils and farm produce samples were treated and analyzed in the accredited Central Analytical Laboratory of the Center for Ecological-Noopshere Studies NAS RA. The samples were analyzed for the contents of heavy metals (Hg, As, Cd, Pb, Ni, Cu, Zn) by atomic-absorption method (Perkin Elmer AAnalist 800). In water samples concentrations of metals in dissolved phase were determined, and in soil and farm produce samples – total concentrations.

The quality of field works was controlled through a method of control soil samples (25% of total amount of samples). Also, assured was in-lab quality control (10% of the amount of farm produce samples). Information on the volume and standard methods is given in *Table 1*.

Table 1

Volumes of analytical works

Index/ Element	Media			Total amount of determinations	Method
	Waters	Soils	Farm crops		
Measurements of physical indices					
pH	5	–	–	5	–
	Total amount of measurements			**5**	
Determination of chemical elements					
As	5	7	19	31	ISO-11969
Hg	5	7	19	31	ISO-5666
Pb	5	7	19	31	ISO-8288
Ni	5	7	19	31	ISO-8288
Cd	5	7	19	31	ISO-8288
Cu	5	7	19	31	ISO-8288
Zn	5	7	19	31	ISO-11885
Total amount of elements/determinations				**217**	

Note: *«–» - no data*

3. ASSESSING THE QUALITY OF IRRIGATION WATER

An irrigation water source for crofts in the study regions are River Debed waters. Following the request of the residents of the village of Karkop along with irrigation waters sampled was the water from one of wells (Alw-2) used by local people for drinking and domestic purposes without any previous analyses. The results of the analysis of irrigation water and well water samples are highlighted in *Table 2.*

Table 2

pH and concentrations of heavy metals (µg/L) in well water and irrigation waters and their collation with MAC

Location of sampling points and sample NN[0]	pH	Elements, µg/L						
		Hg	Cd	As	Pb	Zn	Ni	Cu
MAC[1]	***6-9***	***0,5***	***1***	***50***	***30***	***5000***	***100***	***1000***
Water from the well								
vil. Karkop (Alw-2)	7,21	<MDL[2]	<MDL[2]	<MDL[2]	0,418	15,75	<MDL[2]	13,33
Irrigation waters								
vil. Karkop (Alw-1)	6,78	<MDL[2]	0,048	<MDL[2]	0,93	60,02	0,772	41,68
vil. Karkop (Alw-3)	7,82	<MDL[2]	0,031	0,763	1,338	37,51	0,491	34,18
vil. Negots (Alw-4)	8,26	<MDL[2]	0,052	<MDL[2]	1,207	52,7	0,861	35,84
city of Alaverdi (Alw-16)	7,25	<MDL[2]	0,045	<MDL[2]	1,003	58,56	1,456	37,51

Note: [1]*MAC according to [1];* [2]*MDL – Maximum Detection Limit*

pH of the well and irrigation waters does not overstep acceptable limit – 6-9 (*Fig. 5*).

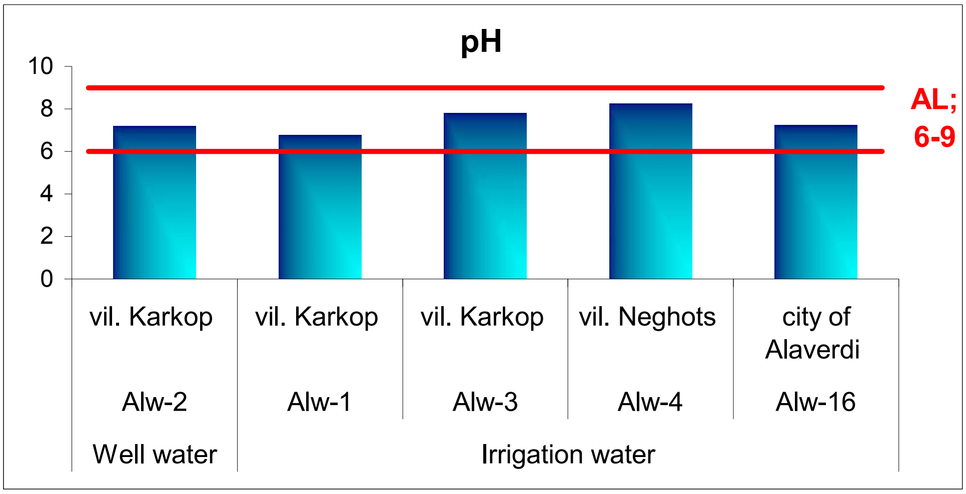

Fig. 5. *pH of the well water and irrigation waters.*

Concentrations of heavy metals in the studied waters are considerably lower as compared with MAC [1]. Hg concentrations are lower than MDL. Correlations of actual concentrations of metals in waters and MAC are given in *Figure 6.*

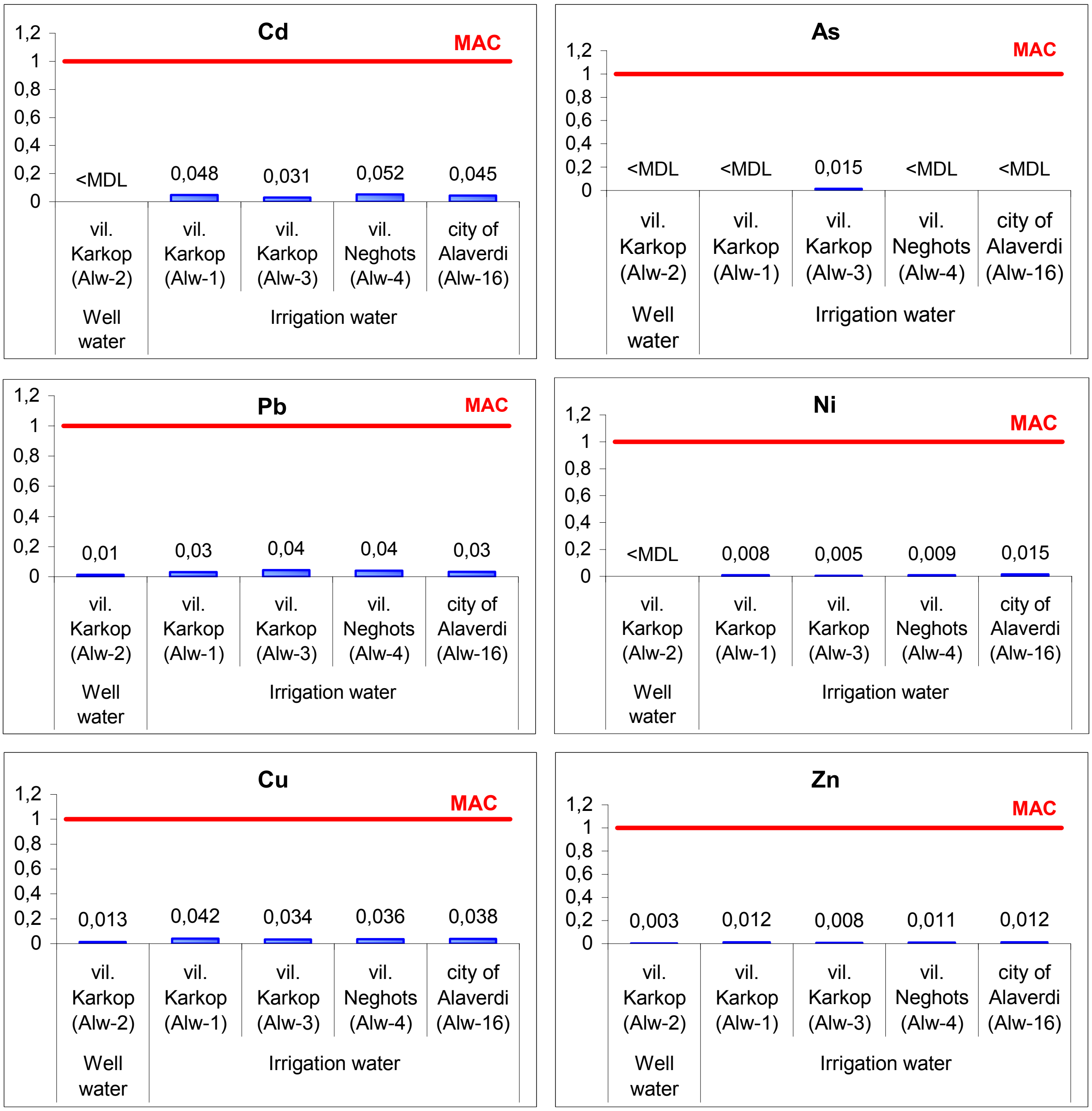

Fig. 6. *Correlation of actual contents of heavy metals and MAC in waters.*

It should be noted that while implementing the research, uncontrolled discharges of waste waters into River Debed were detected, which, as local people say, have a periodic character. An example may be the waters of River Akhtalka as well as a waste water aqueduct not far from the city of Akhtala (*Fig. 7*).

Fig. 7. *Waste water discharge into River Debed.*

The implemented research indicated that for the studied period River Debed waters contained no excessive concentrations of heavy metals in dissolved phase. However, the experience of studying chemical composition of rivers evidences rivers transport significant quantities of chemical elements including heavy metals in suspended state. So for comprehensive assessment of the quality of River Debed waters and their suitability for farmland irrigation further investigations of solid river runoff are needed.

Taking into consideration uncontrolled, not systematic discharges of waste water, studies and monitoring of the quality of irrigation waters must be permanent and continuous.

The water from the well used by local people contains no harmful concentration of heavy metals, however for assessing suitability of the noted water as potable, microbiological surveys are required.

4. ECOLOGO-GEOCHEMICAL ASSESSMENT OF SOILS OF CROFTS

Soil samples were collected from crofts located on the territory of the city of Alavedi, not far from a copper smelting plant (Als-9), villages of Negots (Alw-3) and Karkop (Alw-1 and Alw-2). The city of Akhtala was excluded from the study, as River Debed waters are not used for irrigation of Akhtala's farmlands.

Actual contents and MACs of heavy metals in soils are given in *Table 3*.

Table 3

Heavy metal concentrations in soils (mg/kg)

Location of sampling points and soil sample NN[0]	Elements *mg/kg*						
	I grade of danger[1]					II grade of danger[1]	
	Hg	Cd	As	Pb	Zn	Cu	Ni
MAC[2]	***2,1***	***2***	***2***	***65***	***220***	***132***	***80***
vil. Karkop (Als-1)	<MDL[3]	0,22	**3,892**	20,87	**331,02**	**170,24**	7,725
vil. Karkop(Als-2)	<MDL	0,268	**6,756**	12,78	219,50	**290,48**	5,774
vil. Hegots (Als-3)	<MDL	0,329	**10,67**	20,66	**416,66**	**533,78**	8,436
city of Alaverdi (Als-9)	0,176	0,725	**10,43**	**78,95**	**277,78**	**2547,29**	12,790

Note: [1]*Grade of danger according to [2];* [2]*MAC [3];* [3]*MDL – Maximum Detection Limit; in red – MAC exceeding concentrations.*

Of all the studied elements, no excessive contents of Hg, Cd and Ni were determined. Hg was detected only in the soils of the city of Alaverdi; Cd and Ni were found out in all the soil samples.

MAC-exceeding [2] concentrations of heavy metals are given in *Figure. 8.*

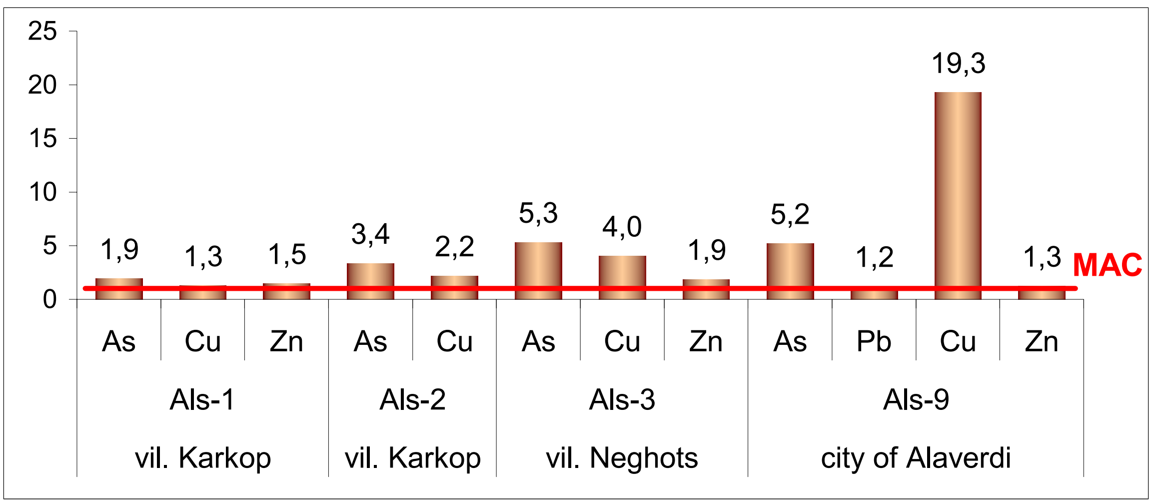

Fig. 8. *Excessive contents of heavy metal in soils vs. MAC [2].*

As contents in soils considerably exceeded MAC – by 1,9-5,3 times. The values of excesses of Zn concentrations vs. MAC are close: 1,3-1,9 MAC. Cu concentrations overstep MAC in all the soil samples, maximal excess – 19,3 MAC being determined in the soil of a model plot in the city of Alaverdi.

For soils series have been made up ranked by relations of actual concentrations of heavy metals to MAC (*Tab. 4*).

Table 4

Sanitary and hygienic series and their summary intensity

Location of sampling points and sample numbers	Sanitary and hygienic series	Summary intensity
vil.Karkop (Als-1)	$As_{(1,9)}$–$Zn_{(1,5)}$ –$Cu_{(1,3)}$	4,7
vil.Karkop (Als-2)	$As_{(3,4)}$–$Cu_{(2,2)}$	5,6
vil. Hegots (Als-3)	$As_{(5,3)}$–$Cu_{(4,0)}$–$Zn_{(1,9)}$	11,3
city of Alaverdi (Als-9)	$Cu_{(19,3)}$> $As_{(5,2)}$–$Zn_{(1,3)}$–$Pb_{(1,2)}$	27,0

The analysis of the given series indicates that the leading position is held by As and only in the soils of a plot of the city of Alaverdi As gives its leading position to Cu. Sanitary and hygienic series involves Zn, too, with a maximal 1,9 time excess vs. MAC. Standard-exceeding concentration of Pb was indicated in the soil of Alaverdi.

The intensity of sanitary and hygienic series rises towards the city of Alaverdi. Correlations of shares of heavy metals in summary intensity of sanitary and hygienic series are given in *Fig. 9*.

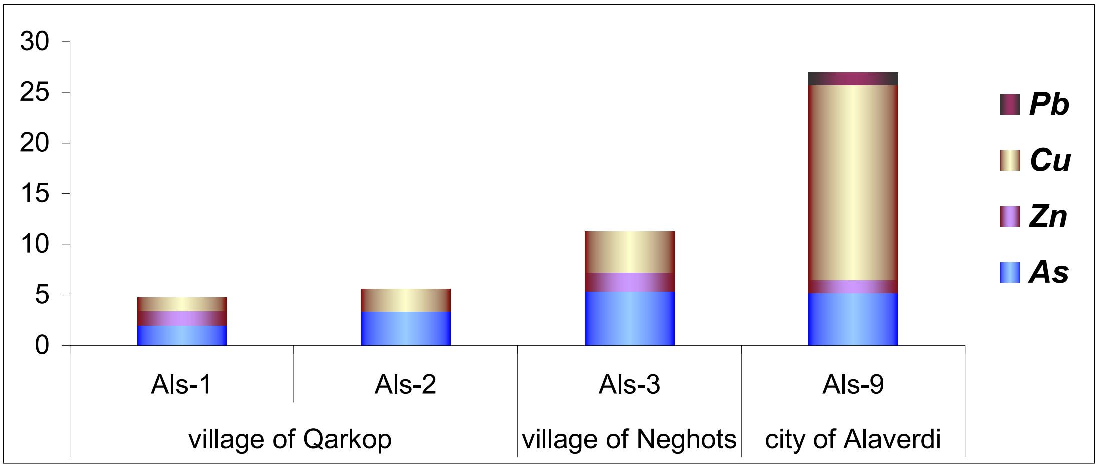

Fig. 9. *Correlation of heavy metal shares in summary intensity of sanitary and hygienic series of soils*

The level of soil pollution with chemical elements is determined by concentration of the element in soil consistent with a scale given in *Table 5*.

Table 5

Soil pollution levels depending on gross concentration of chemical elements in soils by [3]

Elements		Pollution level				
		level I allowable	level II low	level III medium	level IV high	level V extremely high
		mg/kg				
I grade of danger	Hg	<2,1	2,1-3	3-5	3-10	>10
	Cd	<2	2-3	3-5	5-10	>10
	As	<10	20-30	20-30	30-50	>50
	Pb	<65	65-130	130-250	250-600	>600
	Zn	<220	220-450	450-900	900-1800	>1800
II grade of danger	Cu	<132	132-200	200-300	300-500	>500
	Ni	<80	80-160	160-240	240-500	>500

When defining the level of pollution if the study soils, a leading role is given to Cu (*Fig. 10*). Thus, the level of Cu pollution of soils of the Karkop plot soils is low, of soils of a plot located 2 *km* far from the village of Karkop toward the city of Alaverdi – medium, and soils of plots in the village of Negots and the city of Alaverdi are characterized by high level of copper pollution.

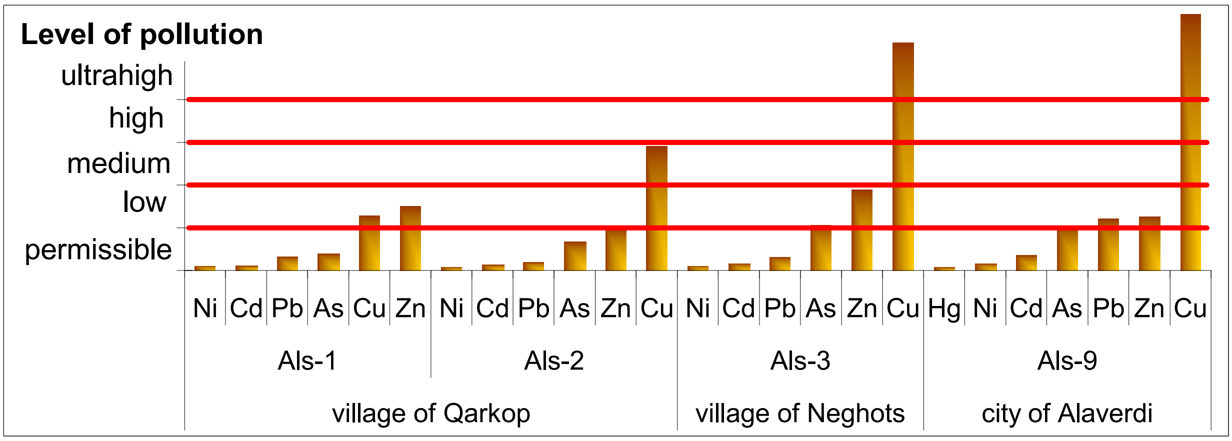

Fig. 10. *Levels of heavy metal pollution of soils.*

Thus, in the soils of crofts excessive concentrations of a whole series of heavy metals, including those of I (As, Pb, Zn) and II (Cu) grades of danger, were indicated. Taking into consideration high level of pollution of soils of crofts in Negots and Alaverdi, more detailed investigations are required not only of small crofts, but also of vast farmlands close to the city of Alaverdi.

5. ECOTOXICOLOGICAL ASSESSMENT OF FARM PRODUCE

For ecotoxicological assessment of farm produce obtained in the region, from the noted plots total 15 species of crops were collected. Besides, in the frame of research from the market of the city of Alaverdi local farm products were bought. The results of analyses of farm produce samples and their collation with MAC are provided in *Table 6* and *Figure 11*.

Table 6

Heavy metal concentrations in farm produce and their MACs

N[0] of sample	Species	Elements, mg/kg						
		Hg	Cd	As	Pb	Ni	Cu	Zn
MAC[1]	*Vegetables*	*0,02*	*0,03*	*0,2*	*0,5*	–	–	–
	Fruits				*0,4*			
MAC[2]	*Vegetables*	*0,02*	*0,03*	*0,2*	*0,5*	*0,5*	*10*	*10*
	Fruits	*0,01*			*0,4*			
village of Karkop								
Alc-1	Raspberry	n/d[3]	0,009	n/d	n/d	**0,68**	**13,19**	**54,88**
Alc-8	Beans	n/d	0,001	n/d	0,18	**1,67**	8,72	**26,05**
Alc-9	Black fig	**0,23**	0,001	n/d	0,22	**2,00**	8,57	**16,12**
Alc-10	Fig	**0,05**	0,002	n/d	0,30	**2,22**	8,72	**16,84**
village of Karkop								
Alc-2	Mulberry	n/d	**0,098**	n/d	0,03	**1,39**	6,94	**33,30**
Alc-11	Potatoes	n/d	0,007	n/d	0,36	**1,89**	**14,58**	**21,70**
Alc-12	Corn	**0,20**	0,002	**0,34**	0,12	**1,81**	2,35	**20,93**
village of Negots								
Alc-3	Parsley	n/d	**0,046**	n/d	0,05	**1,24**	**19,53**	**67,07**
Alc-4	Raspberry	n/d	**3,957**	n/d	0,02	**18,38**	**18,75**	**358,29**
Alc-5	Coriander	**0,09**	**0,086**	**0,68**	0,04	**2,67**	**12,50**	**68,29**
Alc-6	Spring onions	n/d	0,022	**0,42**	0,06	0,50	9,03	**27,77**
Alc-13	Beans	**0,15**	0,002	n/d	0,25	**2,19**	**15,27**	**40,32**
city of Alaverdi								
Alc-7	Cherry	n/d	0,030	n/d	0,12	**3,35**	**17,91**	**25,01**
Farm produce from the market city of Alaverdi								
Alc-15	Celery	n/d	0,008	**4,98**	**1,04**	**2,28**	**24,30**	**59,33**
Alc-16	Grapes	n/d	0,002	n/d	**0,47**	**2,19**	**13,88**	**11,83**
Alc-17	Apples	n/d	0,001	n/d	0,23	**2,17**	**11,97**	**12,66**
village of Chochkan								
Alc-14	Grapes	n/d	0,002	0,08	0,30	**1,42**	8,68	8,33

__Note__: *[1]MAC according to [4]; [2]MAC according to [5], [3]n/d – not determined; in red – MAC exceeding concentrations.*

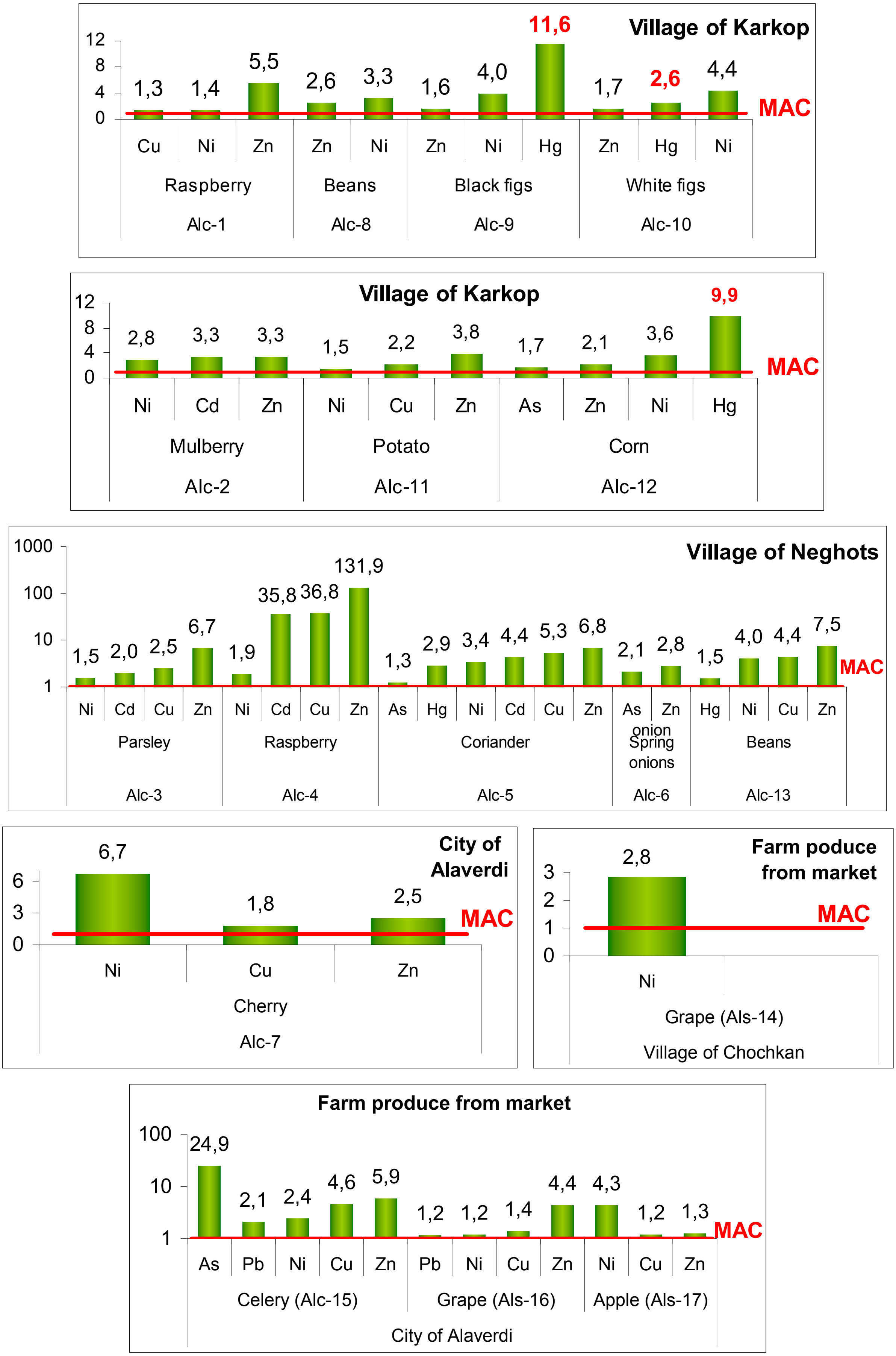

Fig. 11. *Excessive contents of heavy metals in farm produce vs. MAC [4, 5]*

Mercury (Hg) is a super-toxicant. Its toxic effect is seen even under small doses, toxicity threshold being as much as 50 *µg* [16]. In the first instance, affects nervous system; is a carcinogen. Specially sensitive to Hg are children and pregnant women [8].
Hg was identified in 5 samples of fruits, vegetables and herbs and was 2,6-11,6 times excessive vs. MAC (*Tab.6, Fig.11*). Maximal concentration was determined in black figs, gathered in the village of Karkop.
Cadmium (Cd) is a strongly toxic element. Substitutes calcium in bones, favoring deformation and fragility of bones and thus is especially dangerous in the period of fetal development and for infant organism. In human organisms accumulates mainly in liver, kidney, and duodenum and affect their functioning. Cd contents elevate depending on age and become a cancer occurrence factor [10,16].
Cd was identified in all the studied fruits, vegetables and herbs; in 4 samples excesses vs. MAC were indicated (*Tab. 6, Fig. 11*). One should emphasize raspberry from the village of Negots: Cd concentrations in which were 131,9 times excessive vs. MAC. In the rest farm produce samples excesses were considerably lower than MAC – by 1,5-3,3, times.
Arsenic (As) is attributed to conditionally essential immunotoxic elements. Long-term administration of small doses of arsenic favors occurrence of cancer [8, 16].
In most farm produce samples no As was determined (*Tab. 6, Fig. 11*), showing however in four samples a 1,7-24,9 time excess vs. MAC. Maximal excess against MAC – by 24,9 times – was indicated in celery, bought from the Alaverdi market.
Lead (Pb) is carcinogen and teratogen; has a property to substitute calcium in the skeleton. With age, the contents of Pb in the organism heighten [8, 16]. Pb was indicated in all vegetable samples (*Tab. 6, Fig. 11*), but a 1,2 and 2,1 time excesses vs. MAC were determined only in grapes and celery bought from the Alaverdi market.
Zinc (Zn), copper (Cu) and nickel (Ni) are necessary microelements for normal functioning of the organism. But above-standard concentrations of those metals in food favor disorders in functions including reproductive and genetic ones [9, 16].
Zn contents in the studied farm products were high and in 94% of cases exceeded MAC values (*Tab. 6, Fig. 11*). Maximal excess – by 35,8 times – was determined for raspberry samples collected from the village of Negots. The excesses of the rest samples were considerably lower – by 1,2-6,8 times.
Ni concentrations in almost all farm produce samples were high vs. MAC. In analogue with Cd and Zn, maximal contents of Ni, 6,8 times excessive vs. MAC, were detected in the raspberry samples collected form the village of Negots. The excesses were notably lower for rest fruits and vegetables – by 1,4-6,7 times, and in spring onions samples taken from the village of Negots Ni concentration did not overstep MAC approaching anyway to maximal acceptable limit.
10 out of 17 studied farm product samples showed 1,2-2,4 times excessive Cu contents vs. MAC.

For visualization of farm produce pollution with heavy metals, series are arranged that are ranked by element concentration excesses vs. MAC (*Tab. 7*).

Table 7

Sanitary and hygienic series of fruits, vegetables and herbs and their summary intensity

Species	A sanitary and hygienic series	Summary intensity
village of Karkop		
Beans (Alc-8)	$Ni_{(3,3)}$–$Zn_{(2,6)}$	5,9
Rasberry (Alc-1)	$Zn_{(5,5)}$–$Ni_{(1,4)}$–$Cu_{(1,3)}$	8,2
Fig (Alc-10)	$Ni_{(4,4)}$–$\mathbf{Hg_{(2,6)}}$– $Zn_{(1,7)}$	8,7
Black fig (Alc-9)	$\mathbf{Hg_{(11,6)}}$>$Ni_{(4,0)}$–$Zn_{(1,6)}$	17,2
village of Karkop		
Potatoes (Alc-11)	$Ni_{(3,8)}$–$Zn_{(2,2)}$–$Cu_{(1,5)}$	7,5
Mulberry (Alc-2)	Cd,$Zn_{(3,3)}$–$Ni_{(2,8)}$	9,4
Corn (Alc-12)	$\mathbf{Hg_{(9,9)}}$>$Ni_{(3,6)}$–$Zn_{(2,1)}$–$As_{(1,7)}$	17,3
village of Negots		
Spring onions (Alc-6)	$Zn_{(2,8)}$–$As_{(2,1)}$	4,9
Parsley (Alc-3)	$Zn_{(6,7)}$–$Ni_{(2,5)}$–$Cu_{(2,0)}$–$Cd_{(1,5)}$	12,7
Beans (Alc-13)	$\mathbf{Hg_{(7,5)}}$–$Ni_{(4,4)}$–$Zn_{(4,0)}$–$Cu_{(1,5)}$	17,4
Coriander (Alc-5)	$Zn_{(6,8)}$–$Ni_{(5,3)}$–$\mathbf{Hg_{(4,4)}}$–$As_{(3,4)}$–$Cd_{(2,9)}$–$Cu_{(1,3)}$	24,1
Raspberry (Alc-4)	$\mathbf{Cd_{(131,9)}}$>$Ni_{(36,8)}$–$Zn_{(35,8)}$>$Cu_{(1,9)}$	206,4
city of Alaverdi		
Cherry (Alc-7)	$Ni_{(6,7)}$–$Zn_{(2,5)}$–$Cu_{(1,8)}$	11,0
Farm produce from the market city of Alaverdi		
Celery (Alc-15)	$As_{(24,9)}$>$Zn_{(5,9)}$–$Ni_{(4,6)}$–$Cu_{(2,4)}$–$Pb_{(2,1)}$	39,9
Grapes (Alc-16)	$Ni_{(4,4)}$–$Cu_{(1,4)}$–Pb,$Zn_{(1,2)}$	8,2
Apple (Alc-17)	$Ni_{(4,3)}$–$Zn_{(1,3)}$–$Cu_{(1,2)}$	6,8
village of Chochkan		
Grapes (Alc-14)	$Ni_{(2,8)}$	2,8

As seen from *Table 7*, metal intake by plants depends predominantly on the plant species. Fruits of different plant species grown within the limits of same crofts, under identical soil conditions, accumulate different elements, metal accumulation levels being also different. It is noteworthy, that figs, green mass of coriander, corn, and beans accumulate Hg which was not detected in the soil. Such a fact could be explained by episodic Hg pollution of transit medias: the air and surface waters.

Accumulation of high concentrations of Ni and Cd in farm products evidences domination of mobile forms of those elements in soils. In contrast to the two noted elements, As concentrations in soils were considerable, but plants mainly do not accumulate As except

celery which showed manifold excess vs. MAC (by 24,9 times).
Shares of heavy metals in summary intensity of series made up for farm products are displayed in *Figure 12*.

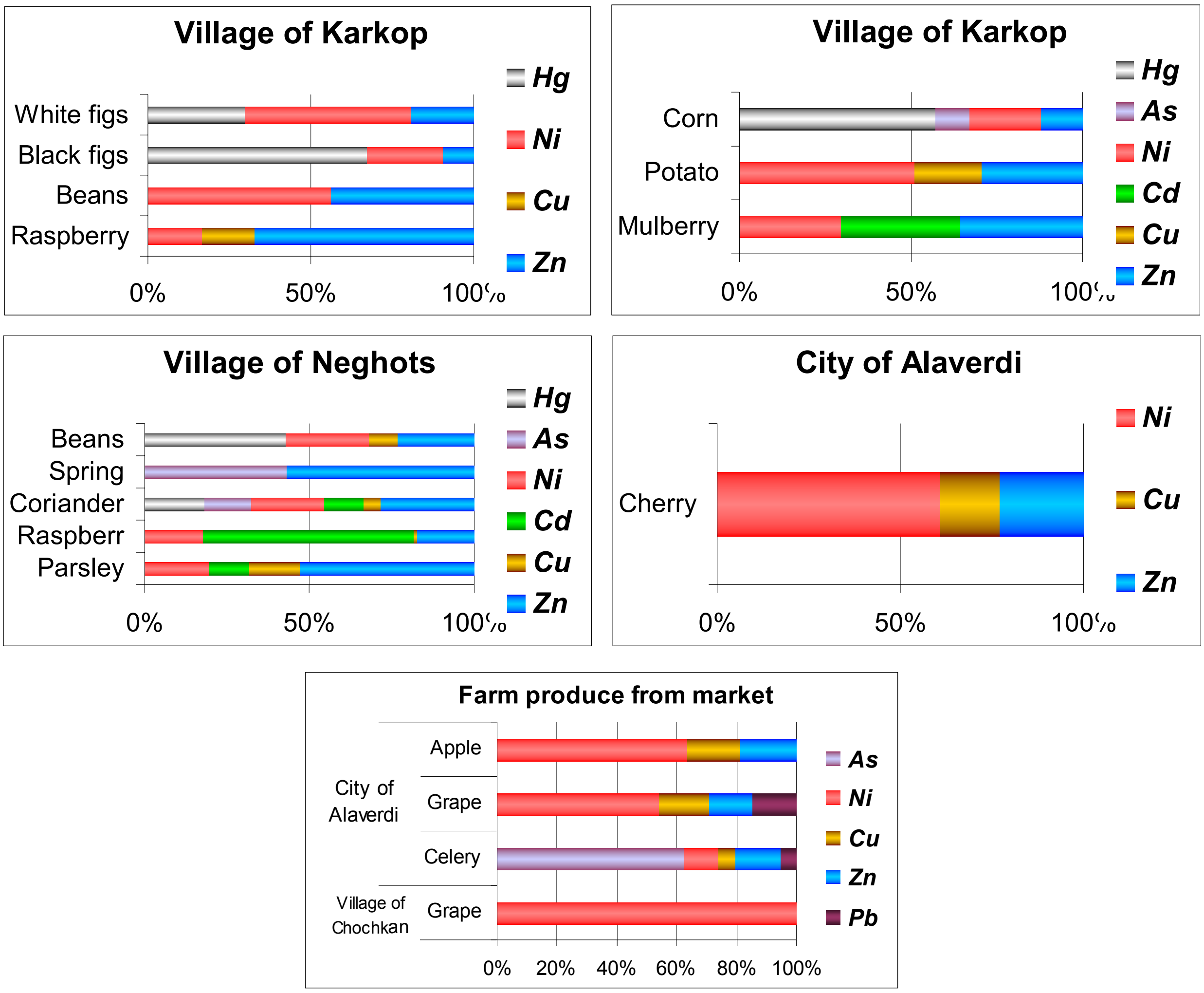

Fig. 12. *Shares of heavy metals in summary intensity of sanitary and hygienic series of farm produce*

The expertise in ecotoxicological investigations of vegetable farm products testifies to the fact that vigorous accumulators of heavy metals including such toxic elements as Hg, Cd and As are berries and herbs. The results of this particular research also pinpoint significant accumulation of heavy metals in raspberry, coriander and celery.

Thus, farm products obtained in the city of Alaverdi and adjacent villages (Negots, Karkop, and Chochkan) disagree with food safety standards accepted in the RA [4] and abroad [5]. Harmful farm products are used not only by producers, but also are taken to the local market, this posing a risk factor to the health of people. Final conclusions may be made after larger-scale ecotoxicological investigations.

6. CONCLUSIONS

The implemented research supports the following conclusions:

1. River Debed waters used for farmlands irrigation contain no above-standard concentrations of heavy metals in dissolved phase.
2. Soils of crofts display above-standard concentrations of a whole set of heavy metals including those of I (As, Pb, Zn) and II (Cu) grades of danger.
3. Established is an extremely high level of metal pollution of the soils of the city of Alaverdi and the village of Negots. The soils of the village of Karkop are characterized by medium and low levels of pollution.
4. Farm produce obtained in the city of Alaverdi and adjacent villages (Negots, Karkop, Chochkan) contains above-standard concentrations of toxic metals (Hg, Cd, As, Pb) and microelements (Zn, Cu, Ni).
5. Farm products that don not meet food safety requirements is a risk factor to the health of people. The products are used not only by producers, but also are taken to the local market.

7. RECOMMENDATIONS FOR RISK MINIMIZATION

7.1. Improving soil condition

- ✓ A whole set of technologies is known for soil recovery – chemical washout, absorption of harmful substances – which require special skills, training as well as substantial financial resources.
- ✓ Improving soil conditions by own efforts is possible through substitution of upper 20-40 *cm* deep soil layer.
- ✓ The acceptable and cost-effective technique is application of organic fertilizers: dung, avian manure, turf. Organic substances they contain bind heavy metals decreasing the level of their accumulation in eatable parts of farm crops.

7.2. Minimizing a risk to the health

To minimize a risk to the health while using harmful farm produce it is necessary to follow several simple rules:

- ✓ Obligatory wash of vegetables, fruits and herbs with tap water. Such a procedure helps remove harmful substances from the surface of products.
- ✓ Thermal treatment helps remove some heavy metals including toxic elements Hg, Cd, As out of food products. Thus it is desirable using local vegetables boiled or baked, and fruits – as preserves.
- ✓ It is undesirable drying local fruits as a process of drying favors concentration of elements in final product.
- ✓ As some berries (raspberry, mulberry) and herbs (celery, coriander) uptake large quantities of toxic elements, so such species shouldn't be cultivated or gathered nearby the city of Alaverdi.

8. INFORMING LOCAL POPULATION AND SELF-GOVERNANCE BODIES

Local population and self-governance bodies were kept informed on all stages investigations.

At a preparatory stage, public hearings were held on 28 April, 2010 in the Aarhus center of the city of Alaverdi (*Fig. 13*), which brought together representatives of self-governance bodies from the cities of Alaverdi and Akhtala and adjacent villages, workers from industrial enterprises, members of public organizations, agrarians and journalists. The project manager Dr. Lilit Sahakyan presented the essence of the issue, the project goals and tasks, research stages and expectable results (Annex 1 on CD). Representatives from self-governance bodies brought forward questions, answers to which they expected to get in the result of investigations.

Fig. 13. *Fragments of public hearings held in the* Aarhus *Center of the city of Alaverdi on April 28, 2010.*

After completion of hearings the project manager Dr. Lilit Sahakyan gave an interview to a journalist of the Alaverdi TV- canal “Ankyun plus 3”. The interview was broadcasted during evening news. The record of the interview is given in Annex 2 (see CD).

During field works (25-27 June and 29-30 October 2010) information was disseminated directly while meeting local people (*Fig. 14*). The field team members highlighted ecological issues of the regions, the goals and tasks of that particular project, surveyed local people. Sampling plan was built on issues that concerned the people. On the second stage of field works local people were kept informed on preliminary research results and identified risk mitigation actions.

The Director of the Center for Ecological-Noosphere Studeis NAS RA, Dr. Sc. Armen Saghatelyan gave an interview to a journalist of an electronic newspaper “Hetk online” (Annex 3, see CD).

Fig. 14. *Interviewing Dr. Sc. Armen Saghatelyan and informing local people during field works.*

On the stage of generalization and interpretation of research results Dr. Lilit Sahakyan and Dr. Sc. Armen Saghatelyan took part in a press-conference devoted to ecological issues of the industrial cities of the RA; reported were also nature conservation issues of the cities of Alaverdi and Akhtala and neighboring villages (Annex 4, see CD).

In her interview to the AZG (a newspapper) Dr. Lilit Sahakyan presented major research results. The interview is given in Annex 5 (see CD).

After generalizing the project results on 18 February 2011, public hearings were organized at the Aarhus Center of the city of Alaverdi (*Fig. 15*). Presented were the research outcomes, identified ecological risks as well as such risks mitigation actions (Annex 6, see CD). The information is briefed in a brochure (Annex 7, see CD), which was disseminated to the attendees.

Fig. 15. Public hearings at the Ohrus Center of the city of Alaverdi on 18 February, 2011.

After the hearings had been completed, Dr. Lilit Sahakyan gave an interview to a journalist from a local TV canal “Ankyun plus 3” (Annex 8, see CD); the interview was broadcasted during evening news. One more interview of Dr. Lilit Sahakyan have published in an electronic newspaper “Hetk online” on 24 February 2011 (Annex 9, see CD).

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ANNEXES