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School of Public Health
Center for Health Services Research and Development

Environmental characterization of 11 metal mining and smelting communities in Armenia: lead, arsenic and other heavy metal concentrations in residential soil

Final Report

Prepared for
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EXECUTIVE SUMMARY

The AUA School of Public Health (SPH) in collaboration with Pure Earth (previously Blacksmith Institute) conducted a thorough risk assessment in 11 communities affected by mining and smelting industries in Armenia. The study aimed to quantify the amount of heavy metals such as arsenic, lead, chromium and cadmium in residential soil to assess the ecological impact of contamination on the communities and to estimate health risks that heavy metals pose to human health.

Based on the results of the rapid risk screening of toxic waste sites in Armenia the study team identified 11 most affected communities in Lori and Syunik marzes, including Alaverdi, Akhtala, Armanis, Metz Ayrum, Chochkan, Agarak, Artsvanik, Kajaran, Kapan, Lernadzor, and Syunik communities.

In total, 1930 soil samples from the target-communities were collected and tested in the laboratory. The fieldwork and laboratory operating team followed standard protocols based on international best practices for all the steps of the assessment including soil sampling, transportation, preparation (homogenization, drying and sieving) and analysis by the XRF analyzer.

Considering the level of pollution detected in each community and the population size at risk, the study team developed a priority list of communities for interventions such as cleanup activities, educational awareness raising programs to reduce human exposure to heavy metals. In addition, the SPH researchers made maps of lead and arsenic contamination for each of the 11 communities. This helped to visualize the overall trends of heavy metal contamination in the communities and the source of pollution.

The team has developed educational brochures on health risks from heavy metals, including lead and arsenic, and preventive measures and gave them to landowners, when the testing results were above the maximum allowable levels.

The SPH shared the results of the Thorough Risk Assessemnt with the Government of Armenia including Prime Minister’s Office, Ministries of Health, Nature Protection, and Emergency Situations as well as Lori marz authority, including mayor’s offices of Alaverdi and Akhtala.

INTRODUCTION

Based on the results of the rapid risk assessment of the Toxic Waste Site, thorough risk assessment was conducted in the 11 most affected communities of Lori and Syunik Marzes, including Alaverdi, Akhtala, Armanis, Metz Ayrum, Chochkan, Agarak, Artsvanik, Kajaran, Kapan, Lernadzor, and Syunik village, taking into account the level of the pollution and size of the affected community.

The number of soil samples collected from each community was determined by calculating the population size at risk in the community affected by potential sources of pollution (e.g., mining and ore processing factories, including smelters or tailing ponds). The selected communities were grouped into three categories: 1.Small-sized villages (number of soil samples collected: 90-116), 2. Medium-sized villages/small-sized towns (number of soil samples collected: 166-202), and 3. Large-sized towns (number of soil samples collected: 279-289).

Soil samples were collected from yards, gardens, schools and kindergarten playgrounds in addition to background samples at surface, 10cm and 20 cm depth outside and inside all of the 11 communities. In Akhtala, soil samples were also collected from the Akhtala church yard and nearby closed tailing pond currently covered with soil and trees. In all the communities, with the exception of Alaverdi community, the research team processed the collected soil samples at the environmental laboratory and then tested them using an XRF analyzer. In Alaverdi, the direct in-situ/grab soil testing method was utilized with the XRF spectrometer. Standard protocols developed according to international best practices, including continuous quality assurance procedure(s), were followed during the in-situ testing, soil sample collection, preparation and testing procedures[1,2].

Table 1 presents the details of the 11 communities. For the thorough risk assessment in 11 selected communities 1930 soil samples were collected and tested, additional 313 testings were done for the quality assurance purposes (including the calibration, blank and double testings). The testing results were compared with three reference levels: Maximum Allowable Concentrations (MAC), Clean up Levels (CL) and Highest Background Level (HBL) at 10cm and 20 cm depth (see Table 2).

Table 3 presents the total undetected and those undetected measurements that have estimated LOD above the MAC. The most concerning results are noticed with Cadmium

samples: the analyzer failed to detect any Cadmium concentration in 98.5% of the samples. However, the calculated LOD for all these samples were above MAC. Failure to detect concentrations of Cadmium does not necessarily mean in reality low Cadmium concentrations in the samples, but the physical characteristics of the soil or other factors might disrupt the detection ability of the instrument. For other analytes of interest, the percentage of the undetected samples are quite low (e.g., 4.7% for Arsenic, 0.3% for Lead, 8.73% for Chromium) and the calculated LOD for the undetected samples exceeded MAC for Arsenic (2.5% of the samples out of the total samples) and Chromium (5.9% of the samples out of the total samples).

Table 4 comparatively summarizes the results above MAC, CL, and HBL for Arsenic, Lead, Chromium and Cadmium for all the communities. The study team developed maps of lead and arsenic contamination for each of the 11 communities to visualize the overall trends of heavy metal contamination in the communities and the source of pollution (see Figures).

In order to prioritize the affected communities for implementing interventions, such as cleanup activities and educational awareness raising programs that could reduce people's exposure to heavy metals, the following criteria are considered:

1) Highest number of community samples that are above CL for Lead

2) Highest number of community samples that are above CL for Arsenic

3) Highest number of community samples that are above MAC for Arsenic

Weighting coefficients of 2:2:1 was applied for criteria 1, 2 and 3 accordingly. The highest weight is given to criteria 1 and 2 since they both (CL for Lead and Arsenic) target the necessity of remediation activities and are based on the health effects of the population-at-risk. Weighting was done for large-sized towns, medium-sized villages/small-sized towns and small-sized villages separately.

Table 5 summarizes the priority list for interventions. Results show that among large-sized towns, Alaverdi community is the most contaminated and should be a priority for interventions. Among medium-sized villages/small-sized towns, the most polluted community is Akhtala and Armanis is the most contaminated community among small-sized villages.

Table 1. Communities Selected for Environmental Thorough Risk Assessment by Population Size and Soil Sample Type and Number

Community	Population size*	N of Soil Samples				Background				N of schools and kindergartens	N of samples from schools and kindergartens	Total N of soil samples
		Yard	Gardens	Church	Tailing Pond	Inside community		Outside community				
						10 cm	20 cm	10 cm	20 cm			
Artsvanik	652	66	30			1	1	1	1	2	10	113
Lernadzor	634	63	37			1	1	1	1	2	10	116
Mets Ayrum	986	60	30			1	1	1	1	2	10	106
Syunik village	1,023	51	23			1	1	1	1	2	10	90
Agarak town	4,800	91	75			2	2	1	1	2	10	185
Akhtala	2,400	111	37	20	5	2	2	1	1	4	20	202
Chochkan	2,138	100	50			0	0	1	1	2	10	166
Alaverdi	16,500	251				5	5	1	1	4	20	289
Kajaran	8,436	250				2	2	1	1	4	20	279
Kapan	45,711	251				2	2	1	1	4	20	281
Armanis	620	51	26			1	1	1	1	2	20	103

*The population was taken from the official websites of marzes of Armenia ("*marzname*".gov.am)

Table 2. Reference Levels for Comparison

Heavy Metals	MAC mg/kg	CL mg/kg	HBL (depth 10cm, 20 cm) mg/kg										
	Residential/ Agricultural		Alaverdi[1]	Akhtala	Armanis	Metz Ayrum	Chochkan	Agarak	Artsvanik	Kajaran	Kapan	Lernadzor	Syunik village
As	12	100	20	40	31	56	83	17	10	35	39	61	55
Pb	400	400	29	59	140	75	94	178	11	129	157	60	26
Cr	64	-*	99	147	391	203	203	215	123	238	177	221	147
Cd	14/1.4	-*	ND[2]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

* Not identified

[1] In Alaverdi highest outside measurement was considered

[2] ND – Not detected

Table 3. Total Undetected Measurements and Undetected Measurements with the Calculated LOD above MAC

Heavy Metals	MAC mg/kg	% of undetected measurements out of total n/N Range of LOD's mg/kg	% out of total above MAC n/N Range of LOD's above MAC mg/kg
	Residential/ Agricultural		
As	12	4.7% 91/1930 4-304	2.5% 48/1930 13-304
Pb	400	0.3% 5/1930 7-13	0% 0/1930 -
Cr	64	8.73% 155/1930 37-299	5.9% 114/1930 65-299
Cd	14/1.4	98.5% 1902/1930 15-80	98.5% 1902/1930 15-80

Table 4. Results above MAC, CL, HBL for All Communities

		Communities										
		Lori Marz					Syunik Marz					
		Alaverdi	Akhtala	Armanis	Metz Ayrum	Chochkan	Agarak	Artsvanik	Kajaran	Kapan	Lernadzor	Syunik village
As	% above MAC	100.0%	93.6%	82.3%	99.0%	91.4%	31.0%	51.0%	97.4%	96.7%	92.2%	83.1%
	% above CL	73.4%	2.9%	1.0%	0.0%	0.6%	0.0%	0.0%	0.7%	2.9%	0.0%	0.0%
	% above HBL	98.6%	44.0%	7.3%	1.9%	0.6%	5.1%	76.9%	30.3%	11.2%	0.0%	2.2%
Pb	% above MAC	22.6%	26.7%	5.8%	0.0%	1.2%	0.5%	0.9%	3.2%	4.3%	0.9%	0.0%
	% above CL	22.6%	26.7%	5.8%	0.0%	1.2%	0.5%	0.9%	3.2%	4.3%	0.9%	0.0%
	% above HBL	99.0%	90.1%	25.2%	19.8%	12.1%	3.8%	91.2%	20.5%	19.6%	32.8%	74.4%
Cr	% above MAC	100.0%	97.9%	100.0%	100.0%	96.9%	96.2%	96.2%	100.0%	99.6%	99.1%	97.8%
	% above HBL	100.0%	49.5%	6.2%	6.9%	7.4%	7.0%	47.2%	39.8%	21.1%	15.2%	23.6%
Cd	% above MAC	100.0%	100.0%	100.0%	---	---	---	---	100.0%	100.0%	---	100.0%
	% above HBL	---	---	---	---	---	---	---	---	---	---	---

Table 5. Priority List: Interventions for the Affected Communities

Large-Sized Towns Population (8436-45711)	**Medium-Sized Villages/ Small-Sized Towns Population (2138-4800)**	**Small-Sized Villages Population (620-1023)**
Alaverdi	Akhtala	Armanis
Kapan	Chochkan	Lernadzor
Kajaran	Agarak	Artsvanik
		Mets Ayrum
		Syunik Village

RESULTS

I. Lori Marz Communities

1. Alaverdi Community

The in-situ testing of residential soil samples in Alaverdi was performed by XRF analyzer from July 25 to 27 of 2013. The entire town was divided into five sectors (see Picture 1.) and 50 soil samples were tested from each sector, in addition to 20 soil samples from two school yards and two kindergartens. In total, 271 soil samples were tested: 251 samples from residential yards, 10 from the school yards and 10 from the kindergarten yards. In addition, 18 soil samples were tested to assess the background exposure to heavy metals (see ranges of background measurements in Table 1.0). To ensure quality assurance, 52 tests were performed: 19 calibration tests, 18 blank tests and 15 double sample tests. The duration of the testing time was 60 seconds. The testing results were compared with three reference levels: Maximum Allowable Concentrations (MAC), Clean up Levels (CL) and Highest Background Level (HBL) of 10cm, 20 cm depth (see Table 1.1). The reference level for background was considered to be the highest concentration of heavy metals. Considering the fact that the smelter inside Alaverdi has been operating for more than two centuries causing pollution of deeper layers of soil, only the outside community background sample was considered.

Table 1.0 Alaverdi community: Range of background measurements

Heavy metals	**Inside community Range (mg/kg)**	**Outside community Range (mg/kg)**
As	20-222	19-24
Pb	19-333	14-33
Cr	180	99
Cd	-	-

Table 1.1. Alaverdi Community: Reference Levels for Comparison

Heavy Metals	**MAC mg/kg**	**CL mg/kg**	**HBL (10cm, 20 cm depth) mg/kg**
	Residential/ Agricultural		
As	12	100	20
Pb	400	400	29
Cr	64	-*	99
Cd	14/1.4	-*	Not detected

* Not identified

Some measurements of the community soil samples from residential yards, schools and kindergartens were below the LOD the XRF analyzer. The results of undetected measurements are presented in Table 1.2. When the analyzer could not detect the analyte of interest, calculated LOD was provided which is counted as three times the error of counting statistics of each measurement. Interestingly, calculated LOD differed for each measurement. Arsenic was not detected in 1% of all samples tested and the calculated LOD was above MAC. Lead was not detected in 0.3% of all samples tested but calculated LOD was below the MAC. Chromium was not detected in 36.7% cases and the LOD was above MAC. Cadmium was not detected in 99.7% of all samples tested and the LOD for these samples were above MAC.

Table 1.2. Alaverdi Community: Undetected Measurement

Heavy Metals	MAC mg/kg	% of undetected measurements out of total n/N Range of LOD's mg/kg	% out of total above MAC n/N Range of LOD's above MAC mg/kg
	Residential/ Agricultural		
As	12	1.0% 3/289 16-35	1.0% 3/289 16-35
Pb	400	0.3% 1/289 13	0.0% 0/289 -
Cr	64	36.7% 106/289 107-299	36.7% 106/289 107-299
Cd	14/1.4	99.7% 288/289 31-80	99.7% 288/289 31-80

All undetected measurements were excluded from further analysis. Table 1.3 presents percentage of all samples that exceeded the three reference levels: MAC, HBL (depth 10cm, 20

cm), CL as well as the GM and the range of all detected measurements. Results indicate that 100% of all samples exceeded MAC for Arsenic, Chromium and Cadmium and 22.6% of all samples exceeded MAC for Lead. GM for Arsenic exceeded the MAC more than 13 times. For Arsenic, 73.4% of soil samples need clean-up while only 22.6% samples for Lead. CL for Chromium and Cadmium were not identified during the literature review and standards were substantially different across countries. For Arsenic, Lead and Chromium (Cadmium was not detected in the soil) results exceeded HBL by 98.6%, 99.0% and 98.4% accordingly, suggesting that even for Arsenic and Chromium background levels exceeded MAC. This suggests that even in comparison with the highest background levels, the surface level exposure is high, which is an indication of external pollution.

Table 1.3. Alaverdi Community: Comparison of Results to MAC, HBL (depth 10 cm, 20 cm) and CL

Heavy Metals	MAC mg/kg Residential/ Agricultural	% above MAC out of detected n/N GM and Range of all detected mg/kg	CL mg/kg	% above CL level out of detected n/N GM and Range of all detected mg/kg	HBL (depth 10cm, 20 cm)	% above HBL out of detected n/N GM and Range of all detected mg/kg
As	12	100% 286/286 159.9 15-1064	100	73.4% 210/286 159.9 15-1064	20	98.6% 282/286 159.9 15-1064
Pb	400	22.6% 65/288 237.5 14-3703	400	22.6% 65/288 237.5 14-3703	29	99.0% 285/288 237.5 14-3703
Cr	64	100.0% 183/183 341.7 72-6063	---*	---	99	98.4% 180/183 341.7 72-6063
Cd	14/1.4	100% 1/1 41 41	---*	---	Not Detected	---

* Not identified

Table 1.4 presents the results exceeding MAC by sample type, GM and range of all detected measurements. The results show that Arsenic and Chromium levels in all samples from yards, schools and kindergartens are above MAC. Lead exceeds MAC in 21.6% yard soil samples and 55.0% of school and kindergarten samples. Cadmium was detected only in one sample and the results exceeded MAC. In yard samples, GM exceeds MAC for Arsenic by 13.5 times and Chromium by 5.6 times. GM for Arsenic in school and kindergarten samples exceeds MAC by 18.8 times and Chromium by 4.6 times. Lead also exceeds MAC among these samples.

Table 1.4. Alaverdi Community: Results above MAC by Sample Type

Heavy metals	MAC Mg/kg	Soil Sample Type			
		Yard		School & Kindergarten	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	100.0% 250/250	162 24-1064	100.0% 20/20	225.7 71-594
Pb	400	21.6% 54/250	246.1 40-3703	55.0% 11/20	402.3 116-841
Cr	64	100.0% 165/165	355.9 135-6063	100.0% 14/14	296.9 199-582
Cd	14/1.4	- -	- -	100.0% 1/1	41* 41*

* Only one measurement was done

Table 1.5 shows the results above MAC by sections. In all sections, Arsenic and Chromium levels are above MAC in 100.0% of samples. Lead levels exceed MAC in 14.0% of samples from Section 1 and 42.9% of samples, the highest percentage, from Section 2, which is closest to the smelter. Lead levels also exceed MAC in 7.1% of samples from Section 3, 30.9% of samples from Section 4 and 16.7% of samples from Section 5.

Table 1.6 shows results that are above MAC by CL. Results show that 75.2% of yard soil samples exceed CL for Arsenic and 21.6% for Lead. Samples from school and kindergartens

exceed CL in 85% for Arsenic and in 55.0% for Lead.

Table 1.7 summarizes soil sample test results above the CL collected from the designated five sections. GM mean for Arsenic is the highest in section 2 (241.1 mg/kg - exceeded CL by 2.4 times), in this section 88.9% of samples exceeded CL. The next most contaminated section is number 4, where GM is 218.2 mg/kg and exceeded MAC by 2.2 times. In section 1 65.5% of testing exceeded CL for Arsenic and GM exceeded CL by 1.3 times, in section 3 54.7% testing exceeded CL for Arsenic and GM exceeded CL by 1.1 times and in section 5 68.5% exceeded CL for Arsenic and GM is above CL for Arsenic by 1.3 times.

GM exceeded for Lead exceeded CL for Lead in section 2 and the 42.9% of testing exceeded CL in this section. In section 1 14.0% exceeded Cl for Lead, in Section 3 – 7.1%, in Section 4 – 30.9% and in Section 5 16.7% exceeded MAC for Lead.

Table 1.5. Alaverdi Community: Results above MAC by Sections

Heavy metals	MAC mg/kg	Sections									
		1		2		3		4		5	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	100.0% 58/58	125.7 24-507	100.0% 63/63	241.1 64-1064	100.0% 53/53	110.6 19-568	100.0% 55/55	218.2 55-912	100.0% 54/54	127.6 24-605
Pb	400	14.0% 8/57	222.7 44-771	42.9% 27/63	409.4 86-3703	7.1% 4/56	155.3 39-995	30.9% 17/55	296.8 52-857	16.7% 9/54	189.3 19-1013
Cr	64	100.0% 37/37	418	100.0% 50/50	372.7 135-6063	100.0% 24/24	302.1 157-2009	100.0% 35/35	388.8 176-2074	100.0% 34/34	367.1 200-1537
Cd	14/1.4	100.0% 1/1	41	-	-	-	-	-		-	-

* Only one measurement was done

Table 1.6. Alaverdi Community: Results above CL by Sample Type

Heavy Metals	CL mg|kg	Sample Type			
		Yard		School & Kindergarten	
		% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg
As	100	75.2% 188/250	162 24-1064	85.0% 17/20	225.7 71-594
Pb	400	21.6% 54/250	246.1 40-3703	55.0% 11/20	402.3 116-841

Table 1.7. Alaverdi Community: Results above CL by Sections

Heavy Metals	CL mg|kg	Sections									
		1		2		3		4		5	
		% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg
As	100	65.5% 38/58	125.7 24-507	88.9% 56/63	241.1 64-1064	54.7% 29/53	110.6 19-568	90.9% 50/55	218.2 55-912	68.5% 37/54	127.6 24-605
Pb	400	14.0% 8/57	222.7 44-771	42.9% 27/63	409.4 86-3703	7.1% 4/56	155.3 39-995	30.9% 17/55	296.8 52-857	16.7% 9/54	189.3 19-1013

Picture 1. Alverdi Community: Map with highlighted sectors.

2. Akhtala Community

The thorough risk assessment field work in Akhtala community took place in October 2013. The town was divided into four sectors with the churchyard being considered a separate testing area. The investigators collected 202 soil samples: 111 from yards, 37 from gardens (used for agriculture), 20 from schools and kindergartens, 9 for background purposes at surface, 10cm and 20cm depth inside and outside of the community (out of them, one background measurement was done in churchyard to understand the level of contamination and results not considered while defining HBL, range of remaining background measurements presented in the Table 2.0), 20 from the churchyard and 5 from the surface of the recultivated tailing pond.

Soil samples were prepared in the laboratory following the protocol developed based on review of international guidelines. The preparation process for soil samples took place in November of 2013 and it included drying, homogenization and sieving. The prepared soil samples were tested by the XRF analyzer (INNOV-X α-2000) based on the protocol developed for soil testing. The testing process took place in December of 2013 using 90 seconds as the duration of testing time. Samples displaying test results below the LOD and above the MAC were retested again in March (or April) of 2014 using 240 seconds as the testing time. The testing results were compared with three reference levels: Maximum Allowable Concentrations (MAC), Clean up Levels (CL) and Highest Background Level (HBL) of 10cm, 20 cm depth (see Table 2.1).

Table 2.0 Akhtala community: Range of background measurements

Heavy metals	Range (mg/kg)
As	20-58
Pb	36-123
Cr	101-160
Cd	-

Table 2.1. Akhtala Community: Reference Levels for Comparison

Heavy Metals	MAC mg/kg	CL mg/kg	HBL (10, 20 cm depth) mg/kg
	Residential/ Agricultural		
As	12	100	40
Pb	400	400	59
Cr	64	-*	147
Cd	14/1.4	-*	Not Detected

* Not identified

Some measurements of the community soil samples (in yards, schools and kindergartens) were below the LOD of the XRF analyzer. The results of undetected measurements are presented in Table 2.2. When the analyzer could not detect the analyte of interest, calculated LOD was provided which is counted as three times the error of counting statistics of each measurement. Interestingly, calculated LOD differed for each measurement. Table 4 presents undetected measurements for which the calculated LOD was above MAC. Results of Table 4 show that for Arsenic and Cadmium, the calculated LOD of all undetected measurements exceeded MAC. This means that undetected measurements are not a sign of low concentration of analyte of interest rather the physical matrix of soil disrupts the detection ability of the instrument. For Chromium, out of the 5% undetected measurements only 0.5% exceeded MAC.

Table 2.2. Akhtala Community: Undetected Measurements

Heavy Metals	**MAC mg/kg**	**% of undetected measurements** **n/N** **Range of LOD's mg/kg**	**% above MAC** **n/N** **Range of LOD's above MAC mg/kg**
	Residential/ Agricultural		
As	12	13.4% 27/202 17-146	13.4% 27/202 17-146
Pb	400	0% 0/202 -	0% 0/202 -
Cr	64	5.0% 10/202 50-66	0.5% 1/202 66
Cd	14/1.4	91.6% 185/202 17-38	91.6% 185/202 17-38

All undetected measurements were excluded from further analysis. Table 2.3 presents percentage of all samples that exceeded the three reference levels: MAC, HBL (depth 10cm, 20 cm), CL as well as the GM and the range of all detected measurements. According to the results,

93.6% of all detected measurements exceeded MAC for Arsenic, 26.7% for Lead, 97.9% for Chromium and 100% of Cadmium. GM of detected measurements for Arsenic exceeded MAC by 3.1 times. For Arsenic, 2.9% of soil samples need clean-up and 26.7% for Lead. CL for Chromium and Cadmium were not identified during the literature review and standards were substantially different across countries. According to the test results, 44.0% of Arsenic, 90.1% of Lead and 49.5% of Chromium exceeded the highest background measurements (Cadmium was not detected in the soil). This indicates that the surface level exposure was higher even in comparison with the highest background measurement thus suggesting external pollution.

Table 2.3. Akhtala Community: Comparison of Results to MAC, HBL (depth 10 cm, 20 cm) and CL

Heavy Metals	MAC mg/kg Residential/ Agricultural	% above MAC out of detected n/N GM and Range of all detected mg/kg	CL mg/kg	% above CL level out of detected n/N GM and Range of all detected mg/kg	HBL (depth 10, 20 cm)	% above HBL out of detected n/N GM and Range of all detected mg/kg
As	12	93.6% 169/175 37. 6 9-276	100	2.9% 5/175 37. 6 9-276	40	44.0% 77/175 37. 6 9-276
Pb	400	26.7% 54/202 293.8 15-30,083	400	26.7% 54/202 293.8 15-30,083	59	90.1% 182/202 293.8 15-30,083
Cr	64	97.9% 188/192 147.4 55-525	---*	---	147	49.5% 95/192 147.4 55-525
Cd	14/1.4	100% 17/17 53.6 21-281	---*	---	Not Detected	---

* Not identified

Table 2.4 presents the results exceeding MAC by sample type, GM and the range of all detected measurements. The most significant finding is that 95% of churchyard samples exceeded MAC for Lead. Table 7 presents the results by sections suggesting that the most contaminated districts

of the town are located near the tailing pond and the churchyard – 40.5% and 27.0% of samples in “Transport” and “Svinets” districts respectively exceeded MAC for Lead, whereas only 4.0% and 10.6% of testing in “Sarahart” and “Barit” Districts exceeded MAC for Lead.

Table 2.4. Akhtala Community: Results above MAC by Sample Type

Heavy metals	MAC Mg/kg	Soil Sample Type									
		Yard		Garden		School & Kindergarten		Churchyard		Tailing Pond	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	97.2%	36.9	94.3%	36.1	95.0%	49.4	100.0%	58.7	100.0%	21.5
		104/107	9-177	33/35	10-92	19/20	12-276	2/2	46-75	5/5	17-36
Pb	400	18.9%	230.1	27.0%	264.3	5.0%	130.5	95.0%	4841.1	0.0%	37.7
		21/111	15-12,562	10/37	76-8,174	1/20	19-592	19/20	263-30,083	0/5	26-110
Cr	64	98.1%	152.0	97.1%	136.3	95.0%	149.5	100.0%	157.3	100.0%	88.5
		103/105	62-525	33/34	59-253	19/20	55-280	20/20	80-378	4/4	70-114
Cd	14/1.4	100.0%	55.3	100.0%	100.3	-	-	100.0%	45.2	-	-
		4/4	23-106	3/3	37-182	-	-	9/9	21-281	-	-

Table 2.5. Akhtala Community: Results above MAC by Sections

Heavy metals	MAC mg/kg	Sections							
		1-"Transport" District		2- "Svinets" District		3- "Sarahart" District		4- "Barit" District	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	93.9% 31/33	28.2 11-92	100.0% 37/37	41.3 17-129	98.0% 48/49	38.6 11-177	93.5% 43/46	43.0 9-276
Pb	400	40.5% 15/37	326.5 25-12,562	27.0% 10/37	56-2,565 279.5	4.0% 2/50	129.0 15-705	10.6% 5/47	221.9 19-2,731
Cr	64	90.3% 28/31	116.2 59-165	100.0% 36/36	161.2 82-525	100.0% 49/49	154.1 65-393	97.8% 45/46	154.1 55-280
Cd	14/1.4	100.0% 3/3	71.5 23-150	100.0% 3/3	88.8 52-182	-	-	100.0% 1/1	37* -

* Only one measurement was done

Table 2.6 and 2.7 illustrate the results above CL by sample type and section. In all detected yard samples, 2.8% needed clean-up for Arsenic and 18.9% for Lead. Among garden samples, 27.0% needed clean-up for Lead and among kindergarten and school samples 10.0% needed clean-up for Arsenic and 5.0% for Lead. Among churchyard samples, 95.0% needed clean-up for Lead. According to Table 9, 40.5% and 27.0% of samples in "Transport" and "Svinets" Districts respectively exceeded clean-up level for Lead, whereas only 4.0% and 10.6% of samples in "Sarahart" and "Barit" Districts exceeded MAC for Lead.

Table 2.6. Akhtala Community: Results above CL by Sample Type

Heavy Metals	CL mg|kg	Sample Type									
		Yard		Garden		School & Kindergarten		Churchyard		Tailing Pond	
		% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg
As	100	2.8% 3/107	36.9 9-177	0.0% 0/35	36.1 10-92	10.0% 2/20	49.4 12-276	0.0% 0/2	58.7 46-75	0.0% 0/5	21.5 17-36
Pb	400	18.9% 21/111	230.1 15-12,562	27.0% 10/37	264.3 76-8,174	5.0% 1/20	130.5 19-592	95.0% 19/20	4841.1 263-30,083	0.0% 0/5	37.7 26-110

Table 2.7. Akhtala Community: Results above CL by Sections

Heavy Metals	CL mg|kg	Sections									
		1 -"Transport" District		2 - "Svinets" District		3 - "Sarahart" District		4 - "Barit" District		5 - Churchyard	
		% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg
As	100	0,0% 0/33	28.2 11-92	2,7% 1/37	41.3 17-129	2,0% 1/49	38.6 11-177	6,5% 3/46	43.0 9-276	0.0% 0/2	58.7 46-75
Pb	400	40.5% 15/37	326.5 25-12,562	27.0% 10/37	279.5 56-2,565	4.0% 2/50	129.0 15-705	10.6% 5/47	221.9 19-2,731	95.0% 19/20	4841.1 263-30,083

Picture 2. Akhtala Community: Map with highlighted sectors.

After careful testing of 202 residential soil samples in the Akhtala Community, the results indicate that 93.6% of all detected measurements exceeded MAC for Arsenic, 26.7% for Lead, 97.9% for Chromium and 100% for Cadmium. Background testing (aimed to identify the natural level of heavy metals in the community and to compare the soil sample results with background levels) showed that Lead is below MAC and Cadmium is not detected in the measurements. Background level of Arsenic and Chromium exceeded the MAC in 44.0% and 49.5% of samples. According to the results, soil samples that need cleanup for Arsenic were observed in 2.9% of samples (3 yard samples and 2 samples from a school and a kindergarten) and 26.7% for Lead. Out of 54 samples that need cleanup due to lead contamination, 19 were from the churchyard (35.2%). Therefore immediate actions should be taken to remediate the churchyard soil, which is the most popular public meeting and entertainment location in the community.

3. Armanis Community

Agricultural and residential soil samples were collected and tested from the Armanis Community when performing the field work for the thorough risk assessment in September of 2013. A total 103 soil samples (51from yards, 26 from gardens, 20 from a school and a kindergarten and 6 for background measurements at surface,10 and 20cm depth inside and outside of the community) were collected throughout the community, prepared in the laboratory and tested via XRF Spectrometer. The testing process took place in December of 2013. The duration of testing time was 90 seconds. Samples with below LOD test results were retested again with the testing time of 240 seconds in March (or April) of 2014. The testing results were

compared with three reference levels: Maximum Allowable Concentrations (MAC), Clean up Levels (CL) and Highest Background Level (HBL) of 10cm, 20 cm depth (see Table 3).

Table 3.0 Armanis community: Range of background measurements

Heavy metals	**Range (mg/kg)**
As	9-25
Pb	68-140
Cr	98-391
Cd	-

Table 3.1. Armanis Community: Reference Levels for Comparison

Heavy Metals	**MAC mg/kg**	**CL mg/kg**	**HBL (10, 20 cm depth) mg/kg**
	Residential/ Agricultural		
As	12	100	31
Pb	400	400	140
Cr	64	-*	391
Cd	14/1.4	-*	Not detected

* Not identified

Some measurements of the soil samples were below LOD of the XRF analyzer. The results of undetected measurements are presented in Table 3.2. When the analyzer could not detect the analyte of interest, calculated LOD was provided which is determined by multiplying the error of each measurement's statistics by three times. Results illustrated that the calculated LOD differed for each measurement. Table 3.2 presents the undetected measurements of soil samples for which the calculated LOD was above MAC. Results of table 3.2 show that Arsenic was not detected in 6.8% of total samples, however, lead was detected in all samples. Chromium was not detected in 5.8% samples and Cadmium was not detected in 98.1% of samples. Calculated LOD of non-detected measurements exceeded MAC for Arsenic in 2.9% of samples, Chromium in 1.9% of samples and Cadmium in 98.1% of samples.

Table 3.2. Armanis Community: Undetected Measurements

Heavy Metals	MAC mg/kg	% of undetected measurements out of total n/N Range of LOD's mg/kg	% out of total above MAC n/N Range of LOD's above MAC mg/kg
	Residential/ Agricultural		
As	12	6.8% 7/103 10-18	2.9% 3/103 17-18
Pb	400	0% 0/103 -	0.0% 0/103 -
Cr	64	5.8% 6/103 45-107	1.9% 2/103 69-107
Cd	14/1.4	98.1% 101/103 17-33	98.1% 101/103 17-33

All undetected measurements were excluded from further analysis. Table 3.3 presents the percentage of all samples exceeding the three reference levels - MAC, HBL (depth 10cm, 20 cm), CL as well as the GM and the range of all detected measurements. According to the results, 82.3% of Arsenic samples, 5.8% of Lead samples, 100% of Chromium and Cadmium samples exceeded the MAC. Out of all samples, 1.0% exceeded Cl for Arsenic and 5.8% for Lead. Out of all samples, 7.3% of Arsenic, 25.2% of Lead and 6.2% of Chromium samples exceeded HBL.

Table 3.3. Armanis Community: Comparison of Results to MAC, HBL (depth 10cm, 20 cm) and CL

Heavy Metals	MAC mg/kg Residential/ Agricultural	% above MAC out of detected n/N GM and Range of all detected mg/kg	CL mg/kg	% above CL level out of detected n/N GM and Range of all detected mg/kg	HBL (depth 10cm, 20 cm)	% above HBL out of detected n/N GM and Range of all detected mg/kg
As	12	82.3% 79/96 17.5 8-169	100	1.0% 1/96 17.5 8-169	31	7.3% 7/96 17.5 8-169
Pb	400	5.8% 6/103 93.8 19-3353	400	5.8% 6/103 93.8 19-3353	140	25.2% 26/103 93.8 19-3353
Cr	64	100.0% 97/97 183.2 67-1201	---*	---	391	6.2% 6/97 183.2 67-1201
Cd	14/1.4	100.0% 2/2 39.6 32-49	---*	---	Not Detected	---

* Not identified

Table 3.4 presents the results exceeding MAC by sample type, GM and the range of all detected measurements. Results show that yard soil samples exceeded MAC by 82.2% for Arsenic, 9.8% for Lead, 100.0% for Chromium and 100.0% for Cadmium. In garden soil samples, measurements exceeded MAC for Arsenic in 84.0% of samples, for Lead in 3.8% of samples and for Chromium in 100.0% of samples. In school and kindergartens measurements, results exceeded MAC for Arsenic in 80.0% of samples and for Chormium in 100.0% of samples. Cadmium was not detected in garden, school and kindergarten soil measurements. Samples from schools and kindergartens did not exceed MAC for Lead.

Table 3.4. Armanis Community: Results above MAC by Sample Type

Heavy metals	MAC Mg/kg	Soil Sample Type							
		Yard		Garden		School & Kindergarten		Background	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	82.2%	17.1	84.0%	16.7	80.0%	19.7	83.3%	17.2
		37/45	8-169	21/25	10-32	16/20	10-72	5/6	9-31
Pb	400	9.8%	135.6	3.8%	51.4	0.0%	79.5	0.0%	95.4
		5/51	35-3353	1/26	19-676	0/20	24-283	0/6	68-140
Cr	64	100.0%	191	100.0%	174.6	100.0%	178.6	100.0%	175.9
		47/47	67-1201	26/26	101-377	18/18	79-548	6/6	98-391
Cd	14/1.4	100.0%	39.6	-	-	-	-	-	-
		2/2	32-49	-	-	-	-	-	-

4. Metz Ayrum Community

Agricultural and residential soil samples were collected and tested from the Metz Ayrum Community during the field work for the thorough risk assessment in September of 2013.A total 106 soil samples (60 from yards, 30 from gardens, 10 from a school and a kindergarten and 6 for background measurements at surface 10cm and 20cm depth inside and outside of the community) were collected from the entire community, prepared in the laboratory and tested via XRF Spectrometer. The testing process took place in January of 2014 using 90 seconds as the testing time. Samples with below LOD were retested again with a testing time of 240 seconds in March (or April) or 2014. The testing results were compared with three reference levels: Maximum Allowable Concentrations (MAC), Clean up Levels (CL) and Highest Background Level (HBL) of 10cm, 20 cm depth (see Table 4.1).

Table 4.0 Metz Ayrum community: Range of background measurements

Heavy metals	**Range (mg/kg)**
As	24-56
Pb	29-88
Cr	98-203
Cd	-

Table 4.1. Metz Ayrum Community: Reference Levels for Comparison

Heavy Metals	MAC mg/kg	CL mg/kg	HBL (10cm, 20 cm depth) mg/kg
	Residential/ Agricultural		
As	12	100	56
Pb	400	400	75
Cr	64	-*	203
Cd	14/1.4	-*	Not detected

* Not identified

Some measurements of the soil samples were below LOD of the XRF analyzer. The results of undetected measurements are presented in Table 4.2. If the analyzer could not detect the analyte of interest, it provided the calculated LOD which is determined by multiplying three times the error of counting statistics of each measurement. The calculated LOD differed for each measurement. Table 4.2 presents the undetected measurements for which the calculated LOD was above MAC. Results of table 4.2 show that for Arsenic, Lead and Chromium, only in a few samples the analyte of interest was not detected and the calculated LOD was below the MAC for all measurements. However, the results for Cadmium are completely different: all measurements were below the LOD of the instrument and calculated LOD of all those measurements exceeded MAC.

Table 4.2. Metz Ayrum Community: Undetected Measurements

Heavy Metals	MAC mg/kg	% of undetected measurements out of total n/N Range of LOD's mg/kg	% out of total above MAC n/N Range of LOD's above MAC mg/kg
	Residential/ Agricultural		
As	12	2.8% 3/106 10-12	0.0% 0/106 -
Pb	400	0% 0/106 -	0.0% 0/106 -
Cr	64	3.8% 4/106 37-51	0.0% 0/106 -
Cd	14/1.4	100.0% 106/106 15-33	100.0% 106/106 15-33

All undetected measurements were excluded from further analysis. Table 4.3 presents the percentage of samples out of the total samples that exceeded the three reference levels -MAC, HBL (depth of 10cm, 20 cm), CL in addition to the GM and the range of all detected measurements. According to the results, 99% of all samples tested exceeded MAC for Arsenic and 100% for Chromium. None of the samples exceeding MAC for Lead and there is no detected measurement for Cadmium. None of the measurements exceeded CL for Arsenic and Lead. The results exceeded HBL measurements in 1.9% cases for Arsenic, 19.8% cases for Lead, and 6.9% cases for Chromium.

Table 4.3. Metz Ayrum Community: Comparison of Results to MAC, HBL (depth 10cm, 20 cm) and CL

Heavy Metals	MAC mg/kg	% above MAC out of detected	CL mg/kg	% above CL level out of detected	HBL (depth	% above HBL out of detected

	Residential/ Agricultural	n/N GM and Range of all detected mg/kg		n/N GM and Range of all detected mg/kg	10cm, 20 cm)	n/N GM and Range of all detected mg/kg
As	12	99.0% 102/103 24.4 9-64	100	0.0% 0/103 24.4 9-64	56	1.9% 2/103 24.4 9-64
Pb	400	0.0% 0/106 54.9 19-359	400	0.0% 0/106 54.9 19-359	75	19.8% 21/106 54.9 19-359
Cr	64	100.0% 102/102 127 75-312	---*	---	203	6.9% 7/102 127 75-312
Cd	14/1.4	-	---*	---	Not Detected	---

* Not identified

Table 4.4 presents the results exceeding MAC by sample type, GM and range of all detected measurements. Results show that Arsenic is above MAC in all garden, school and kindergarten samples and in 98.2% of yard soil samples. In all yard, garden school and kindergarten samples, Chromium levels exceed MAC. None of the samples were above MAC for Lead.

Table 4.4. Metz Ayrum Community: Results above MAC by Sample Type

Heavy metals	MAC Mg/kg	Soil Sample Type					
		Yard		Garden		School & Kindergarten	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	98.2% 56/57	23.1 9-64	100.0% 30/30	27.4 18-61	100.0% 10/10	20.8 13-37
Pb	400	0.0% 0/60	60.2 19-359	0.0% 0/30	48.1 19-118	0.0% 0/10	48.7 29-113

Cr	64	100.0%	134.3	100.0%	132.2	100.0%	131.6
		56/56	75-312	30/30	81-181	10/10	91-268
Cd	14/1.4	-	-	-	-	-	-
		-	-	-	-	-	-

5. Chochkan Community

The field work for the thorough risk assessment in Chochkan Community was completed in September of 2013. A total of 166 soil samples were collected throughout the community from the residential and agricultural soil. The samples were prepared in the laboratory and tested via XRF Spectrometer. Out of the 163 soil samples, 100 were from the yards, 50 from gardens, 10 from a school and a kindergarten and 6 for background measurements at surface,10 and 20cm depth inside and outside of the community (range of background measurements presented in the Table 5.0). The testing process took place in December of 2013. The duration of testing time was 90 seconds. Samples having test results below the LOD were retested again with the testing time of 240 seconds in March (or April) of 2014. The testing results were compared with three reference levels: Maximum Allowable Concentrations (MAC), Clean up Levels (CL) and Highest Background Level (HBL) of 10cm, 20 cm depth (see Table 5.1).

Table 5.0 Chochkan community: Range of background measurements

Heavy metals	**Range (mg/kg)**
As	24-83
Pb	38-111
Cr	109-203
Cd	-

Table 5.1. Chochkan Community: Reference Levels for Comparison

Heavy Metals	**MAC mg/kg**	**CL mg/kg**	**HBL (10cm, 20 cm depth) mg/kg**
	Residential/ Agricultural		
As	12	100	83
Pb	400	400	94
Cr	64	-*	203
Cd	14/1.4	-*	Not detected

* Not identified

Some measurements of the community soil samples were below LOD of the XRF analyzer. The results of undetected measurements are presented in Table 5.2. If the analyzer could not detect the analyte of interest, it provided determined LOD which is calculated by multiplying three times the error of the counting statistics of each measurement. Calculated LOD differed for each measurement. Table 5.2 presents the undetected measurements for which the calculated LOD was above MAC. Results of table 5.2 shows that for Arsenic, Lead and Cromium there are very few samples with the not detected analyte of interest and the calculated LOD was below the MAC for all Lead and Chromium measurements and above only in 0.6% for Arsenic, however the results for Cadmium are completely different: all measurements were below the limit of detection of the instrument and calculated LOD of all those measurements exceeded MAC.

Table 5.2. Chochkan community: Undetected Measurements

Heavy Metals	**MAC mg/kg**	**% of undetected measurements out of total** **n/N** **Range of LOD's mg/kg**	**% out of total above MAC** **n/N** **Range of LOD's above MAC mg/kg**
	Residential/ Agricultural		
As	12	2.4% 4/166 7-16	0.6% 1/166 16
Pb	400	0.6% 1/166 9	0.0% 0/166 -
Cr	64	2.4% 4/136 54-61	0.0% 0/166 -
Cd	14/1.4	100.0% 166/166 18-39	100.0% 166/166 18-39

All undetected measurements were excluded from further analysis. Table 5.3 presents the percentage of samples out of the total samples that exceeded the three reference levels -MAC, HBL (depth 10cm, 20 cm), CL as well as the GM and the range of all detected measurements. According to the results 91.4% of all testing exceeded MAC for Arsenic, 1.2% for Lead and 96.9% for Chromium. There is no detected measurement for Cadmium. In 0.6% testing results exceeded Cl for arsenic and in 1.2% for Lead. The results exceeded highest background measurements for Arsenic only in 0.6% testing, for Lead in 12.1% and for Chromium in 7.4% testing.

Table 5.3. Chochkan community: Comparison of Results to MAC, HBL (depth 10cm, 20 cm) and CL

Heavy Metals	MAC mg/kg Residential/ Agricultural	% above MAC out of detected n/N GM and Range of all detected mg/kg	CL mg/kg	% above CL level out of detected n/N GM and Range of all detected mg/kg	HBL (depth 10cm, 20 cm)	% above HBL out of detected n/N GM and Range of all detected mg/kg
As	12	91.4% 148/162 20.8 7-115	100	0.6% 1/162 20.8 7-115	83	0.6% 1/162 20.8 7-115
Pb	400	1.2% 2/165 51.7 17-621	400	1.2% 2/165 51.7 17-621	94	12.1% 20/165 51.7 17-621
Cr	64	96.9% 157/162 126.2 55-571	---*	---	203	7.4% 12/162 126.2 55-571
Cd	14/1.4	-	---*	---	Not Detected	---

* Not identified

Table 5.4 presents the results exceeding MAC by sample type, GM and range of all detected measurements. Results show that in yard soil samples 93.8% exceeded MAC for Arsenic, in 1.0% for Lead and in 98.0% for Chromium. In 84.0% and 93.8% of garden soil testing results

exceeded MAC for Arsenic and Chromium respectively. In school and kindergarten testing 100.0% exceeded MAC for Arsenic, 10.0% for Lead and 100.0% for Chromium. There is no measurements exceeding MAC for Lead in garden soil tests. The instrument was not able to detect Cadmium in any of measurements.

Table 5.4. Chochkan community: Results above MAC by Sample Type

Heavy metals	MAC Mg/kg	Soil Sample Type							
		Yard		Garden		School & Kindergarten		Background	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	93.8%	19.3	84.0%	19.6	100.0%	34.2	100.0%	51.2
		90/96	10-54	42/50	7-115	10/10	18-82	6/6	24-83
Pb	400	1.0%	55.7	0.0%	42.0	10.0%	57.2	0.0%	70.5
		1/99	17-581	0/50	20-226	1/10	24-621	0/6	38-111
Cr	64	98.0%	128.1	93.8%	115.9	100.0%	163.7	100.0%	136.2
		98/100	58-326	45/48	55-356	8/8	101-571	6/6	109-203
Cd	14/1.4	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-

II. Syunik region communities

6. Agarak community

The field work for the thorough risk assessment in Agarak Community was conducted in August of 2013. The entire town was divided into four sectors (see Picture 3.) and a total of 185 soil samples were collected from the residential and agricultural areas of the community. The samples were prepared in the laboratory and tested via XRF Spectrometer. Out of 185 soil samples, 91 were collected from yards, 75 from gardens, 10 from a school and a kindergarten and 9 for background measurements at surface, 10 and 20cm depth inside and outside of the community (range of background measurements presented in the Table 6.0). The testing process took place in January of 2014. The duration of testing time was 90 seconds. Samples with test

results below the LOD were retested again using 240 seconds as the testing time. The results were compared with three reference levels: Maximum Allowable Concentrations (MAC), Clean up Levels (CL) and Highest Background Level (HBL) of 10cm, 20 cm depth (see Table 6.1).

Table 6.0 Agarak community: Range of background measurements

Heavy metals	**Range (mg/kg)**
As	9-27
Pb	22-178
Cr	60-217
Cd	-

Table 6.1. Agarak Community: Reference Levels for Comparison

Heavy Metals	**MAC mg/kg**	**CL mg/kg**	**HBL (10cm, 20 cm depth) mg/kg**
	Residential/ Agricultural		
As	12	100	17
Pb	400	400	178
Cr	64	-*	215
Cd	14/1.4	-*	Not detected

* Not identified

Some community soil sample test results (e.g., yard, gardens, schools and kindergartens) were below the LOD of the XRF analyzer. The results of the undetected measurements are presented in Table 6.2. According to the results, Arsenic was not detected in 14.6% of samples and calculated LOD was above MAC in 1.1% of samples, Furthermore, Lead was not detected in 2.4% of samples and the calculated LOD was below the MAC. Even though, Chromium was detected in all samples, Cadmium was not detected in all the samples where the LOD was above MAC.

Table 6.2. Agarak Community: Undetected Measurements

Heavy Metals	MAC mg/kg	% of undetected measurements out of total n/N Range of LOD's mg/kg	% out of total above MAC n/N Range of LOD's above MAC mg/kg
	Residential/ Agricultural		
As	12	14.6% 27/185 5-14	1.1% 2/185 13-14
Pb	400	2.4% 2/185 7-8	0.0% 0/185 -
Cr	64	0.0% 0/185 -	0.0% 0/185 -
Cd	14/1.4	100.0% 185/185 15-36	100.0% 185/185 15-36

All undetected measurements were excluded from further analysis. Table 6.3 presents the percentage of samples out of the total samples that exceeded the three reference levels - MAC, HBL (depth 10cm, 20 cm), CL as well as the GM and the range of all detected measurements. According to the results, 31.0% of the detected samples exceeded MAC for Arsenic, 0.5% for Lead, and 96.2% for Chromium. GM for Chromium exceeds the MAC 2.1 times. Clean-up level exceeds only for Lead in 0.5% samples.

For Arsenic, Lead and Chromium results exceeded HBL by 5.1%, 3.8% and 7.0% accordingly while Cadmium was not detected in the soil. These numbers are less than the percentages exceeding MAC, which could suggest that the natural background concentration of heavy metals in the community is high. There were also some samples that exceed even the high background concentrations.

Table 6.3. Agarak Community: Results Compared to MAC, HBL (depth 10cm, 20 cm) and CL

Heavy Metals	MAC mg/kg Residential/ Agricultural	% above MAC out of detected n/N GM and Range of all detected mg/kg	CL mg/kg	% above CL level out of detected n/N GM and Range of all detected mg/kg	HBL (depth 10cm, 20 cm)	% above HBL out of detected n/N GM and Range of all detected mg/kg
As	12	31.0% 49/158 11.1 5-27	100	0.0% 0/158 11.1 5-27	17	5.1% 8/158 11.1 5-27
Pb	400	0.5% 1/183 48.6 13-552	400	0.5% 1/183 48.6 13-552	178	3.8% 7/183 48.6 13-552
Cr	64	96.2% 178/185 135.4 50-671	---*	---	215	7.0% 13/185 135.4 50-671
Cd	14/1.4	-	---*	---	Not Detected	---

* Not identified

Table 6.4 presents the results exceeding MAC by sample type, GM and range of all detected measurements. The results show that in yard soil samples 23.3% exceeded MAC for Arsenic, in 1.1% for Lead and 96.7% in Chromium. In 36.2% and 97.3% of garden soil testing results exceeded MAC for Arsenic and Chromium respectively. In school and kindergarten testing 40.0% exceeded MAC for Arsenic and 90.0% for Chromium. There weren't any samples that exceeded the MAC for Lead among the garden, school and kindergarten soil samples. Furthermore, the instrument was not able to detect Cadmium in any of the samples.

Table 6.4. Agarak Community: Results above MAC by Sample Type

Heavy metals	MAC Mg/kg	Soil Sample Type					
		Yard		Garden		School & Kindergarten	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	23.3% 17/73	10.5 5-20	36.2% 25/69	11.5 7-22	40.0% 4/10	11.4 9-16
Pb	400	1.1% 1/91	64.8 16-552	0.0% 0/73	34.7 13-236	0.0% 0/10	40.4 18-88
Cr	64	96.7% 88/91	132.3 61-488	97.3% 73/75	139.8 50-671	90.0% 9/10	139.5 64-492
Cd	14/1.4	- -	- -	- -	- -	- -	- -

Table 6.5 presents the results that are above MAC and they are introduced according to sections. Results show that the highest GM for Arsenic (12.4mg/kg) and the highest percentage of samples exceeding MAC (47.2%) can be found in Section 4. In Section 2, Lead exceeded MAC (2.4%) in one sample only. Chromium was distributed evenly in the community and 92.7 to 97.4% of samples across all sections exceeded MAC. Table 6.6 shows the results that were above MAC by CL. Only one yard soil sample exceeded CL for Lead and none for Arsenic. Table 6.7 summarizes the results of soil samples collected from the designated four sections that exceeded the CL. The sample that needs clean-up for Lead was collected from Section 2.

Picture 3. Agarak Community: Map with highlighted sectors.

Table 6.5. Agarak Community: Results above MAC by Sections

Heavy metals	MAC mg/kg	Sections							
		1		2		3		4	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	16.1% 5/31	10.7 6-19	18.2% 6/33	9.9 7-15	32.7% 18/55	11.1 5-20	47.2% 17/36	12.4 7-22
Pb	400	0.0% 0/39	53.0 19-330	2.4% 1/41	53.9 16-552	0.0% 0/63	56.4 18-249	0.0% 0/35	30.3 13-236
Cr	64	97.4% 38/39	137.9 61-283	92.7% 38/41	117.9 58-290	96.8% 61/63	138.2 62-492	97.3% 36/37	143.6 50-671
Cd	14/1.4	-	-	-	-	-	-	-	-

Table 6.6. Agarak Community: Results above CL by Sample Type

Heavy Metals	CL mg|kg	Sample Type					
		Yard		Garden		School & Kindergarten	
		% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg
As	100	0.0% 0/73	10.5 5-20	0.0% 0/69	11.5 7-22	0.0% 0/10	11.4 9-16
Pb	400	1.1% 1/91	64.8 16-552	0.0% 0/73	34.7 13-236	0.0% 0/10	40.4 18-88

Table 6.7. Agarak Community: Results above CL by Sections

Heavy Metals	CL mg|kg	Sections							
		1		2		3		4	
		% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg
As	100	0.0% 0/31	10.7 6-19	0.0% 0/33	9.9 7-15	0.0% 0/55	11.1 5-20	0.0% 0/36	12.4 7-22
Pb	400	0.0% 0/39	53.0 19-330	2.4% 1/41	53.9 16-552	0.0% 0/63	56.4 18-249	0.0% 0/35	30.3 13-236

7. Artsvanik Community

The field work for the thorough risk assessment in Artsvanik Community was performed in September of 2013. A total of 113 soil samples were collected from the residential and agricultural areas of the community, prepared in the laboratory and tested via XRF Spectrometer. Out of the 113 soil samples, 66 were yards, 30 from gardens, 10 from a school and a kindergarten in addition to 6 soil samples collected for background measurements at surface, 10 and 20cm depth inside and outside of the community (range of background measurements presented in the Table 7.0). The testing process took place in January of 2014. The duration of testing time was 90 seconds. Samples having test results below the LOD were retested again with the testing time of 240 seconds in March (or April) of 2014. The results were compared with three reference levels: Maximum Allowable Concentrations (MAC), Clean up Levels (CL) and Highest Background Level (HBL) of 10cm, 20 cm depth (see Table 7.1).

Table 7.0 Artsvanik community: Range of background measurements

Heavy metals	**Range (mg/kg)**
As	7-12
Pb	8-11
Cr	62-123
Cd	-

Table 7.1. Artsvanik Community: Reference Levels for Comparison

Heavy Metals	**MAC mg/kg**	**CL mg/kg**	**HBL (10cm, 20 cm depth) mg/kg**
	Residential/ Agricultural		
As	12	100	10
Pb	400	400	11
Cr	64	-*	123
Cd	14/1.4	-*	Not detected

* Not identified

Some measurements of the community soil samples were below the LOD of the XRF analyzer. The results of these undetected measurements are presented in Table 7.2. If the analyzer could not detect the analyte of interest, it provided the calculated LOD which is determined by multiplying the error of counting statistics of each measurement by three times. Calculated LOD differed for each measurement. Table 7.2 presents the undetected measurements of the samples for which the calculated LOD was above MAC. Table 7.2 results show that in 8.0% of the

samples Arsenic was not detected and 2.7% of the samples were above the MAC. The instrument was able to detect Lead in all the samples. Chromium was not detected in 6.2% of the samples only and all the calculated LOD was below the MAC. For all the samples, Cadmium was not detected and the calculated LOD were above the MAC. Failure to detect an analyte of interest is not a sign of low concentration but the physical matrix of the soil could disrupt the detection ability of the instrument. The analyzer was actually able to detect Chromium in all the samples.

Table 7.2. Artsvanik Community: Undetected Measurements

Heavy Metals		**% of undetected measurements out of total**	**% out of total above MAC**
	MAC mg/kg	**n/N**	**n/N**
		Range of LOD's mg/kg	**Range of LOD's above MAC mg/kg**
	Residential/ Agricultural		
As	12	8.0%	2.7%
		9/113	3/133
		4-16	16
Pb	400	0.0%	0.0%
		0/113	0/113
		-	-
Cr	64	6.2%	0.0%
		7/113	0/113
		50-64	-
Cd	14/1.4	100.0%	100.0%
		113/113	113/113
		17-34	17-34

All undetected measurements were excluded from further analysis. Table 7.3 presents data on the percentage of the samples out of the total that exceeded the three reference levels - MAC, HBL (depth 10cm, 20 cm), CL as well as the GM and the range of all detected measurements. According to the results, 51.0% of all detected measurements exceeded MAC for Arsenic, 0.9% for Lead (however 91.2% of samples exceeded HBL for Lead), 96.2% for Chromium. GM of detected measurements for Chromium exceeded MAC by 1.8 times. For Lead, 0.9% of soil

samples need clean-up. CL for Chromium and Cadmium were not identified during the literature review and standards were substantially different across countries. Results show that, 76.9% of Arsenic, 91.2% of Lead and 47.2% of Chromium exceeded the highest background measurements (Cadmium was not detected in the soil). This indicates that the surface level exposure is much higher even in comparison with the highest background measurement thus suggesting external pollution.

Table 7.3. Artsvanik Community: Results Compared to MAC, HBL (depth 10cm, 20 cm) and CL

Heavy Metals	MAC mg/kg Residential/ Agricultural	% above MAC out of detected n/N GM and Range of all detected mg/kg	CL mg/kg	% above CL level out of detected n/N GM and Range of all detected mg/kg	HBL (depth 10cm, 20 cm)	% above HBL out of detected n/N GM and Range of all detected mg/kg
As	12	51.0% 53/104 12.9 5-28	100	0.0% 0/104 12.9 5-28	10	76.9% 80/104 12.9 5-28
Pb	400	0.9% 1/113 32.3 7-672	400	0.9% 1/113 32.3 7-672	11	91.2% 103/113 32.3 7-672
Cr	64	96.2% 102/106 117.9 58-203	---*	---	123	47.2% 50/106 117.9 58-203
Cd	14/1.4	-	---*	---	Not Detected	---

* Not identified

Table 7.4 presents the results exceeding the MAC by sample type, GM and range of all detected measurements. Results show that 58.1% of yard soil samples exceeded the MAC for Arsenic, 1.5% for Lead, 95.2% for Chromium. In garden soil samples, the results exceeded the MAC for Arsenic in 44.8% of the samples and for Chromium in 100.0% of the samples. School and kindergarten sample results exceeded the MAC for Arsenic in 50.0% of the samples and Chromium in 100.0% of the samples. School and kindergarten soil samples have the highest GM for both Arsenic and Chromium in comparison to the yard and garden soil samples of the

community. Cadmium was not detected in any of the samples. The samples collected from the school and kindergarten areas did not exceed the MAC for Lead.

Table 7.4. Artsvanik Community: Results above MAC by Sample Type

Heavy metals	MAC Mg/kg	Soil Sample Type					
		Yard		Garden		School & Kindergarten	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	58.1% 36/62	13.6 5-28	44.8% 13/29	12 6-20	50.0% 4/8	14.1 10-14
Pb	400	1.5% 1/66	33.4 10-672	0.0% 0/30	25.7 7-172	0.0% 0/10	89.9 26-278
Cr	64	95.2% 59/62	117.8 58-199	100.0% 29/29	118.4 65-201	100.0% 10/10	125.4 70-203
Cd	14/1.4	- -	-	-	-	-	-

8. Kajaran Community

The Thorough Risk Assessment field work in Kapan community took place in August-September of 2013. The town was divided into three sectors (see Picture 4). The investigators collected 279 soil samples: 250 from yards, 20 from schools and kindergartens, 9 for background purposes at surface, 10 and 20cm depth inside and outside of the community (range of background measurements presented in the Table 8.0).

Soil samples were prepared in the laboratory following the protocol developed based on review of international guidelines. The preparation process for soil samples took place in December of 2013 and it included drying, homogenization and sieving. The prepared soil samples were tested by the XRF analyzer (INNOV-X α-2000) based on the protocol developed for soil testing. The testing process took place in December of 2013 using 90 seconds as the duration of testing time. Samples displaying test results below the LOD and above the MAC

were retested again in March-April of 2014 using 240 seconds as the testing time. The results were compared with three reference levels: Maximum Allowable Concentrations (MAC), Clean up Levels (CL) and Highest Background Level (HBL) of 10cm, 20 cm depth (see Table 8.1).

Table 8.0 Kajaran community: Range of background measurements

Heavy metals	**Range (mg/kg)**
As	8-35
Pb	35-129
Cr	74-296
Cd	-

Table 8.1. Kajaran Community: Reference Levels for Comparison

Heavy Metals	**MAC** **mg/kg**	**CL** **mg/kg**	**HBL (10cm, 20 cm depth)** **mg/kg**
	Residential/ Agricultural		
As	12	100	35
Pb	400	400	129
Cr	64	-*	238
Cd	14/1.4	-*	Not Detected

* Not identified

Some measurements of the community soil samples (in yards, schools and kindergartens) were below the LOD of the XRF analyzer. The results of undetected measurements are presented in Table 8.2. When the analyzer could not detect the analyte of interest, calculated LOD was provided which is counted as three times the error of counting statistics of each measurement. Interestingly, calculated LOD differed for each measurement. Table 8.2 presents undetected measurements for which the calculated LOD was above MAC. Results of Table 8.2 show that in 1.8% of the samples Arsenic was not detected and 1.7% of the samples were above the MAC. The instrument was unable to detect any Lead in one sample only, but that sample was below the MAC. In 9.6% of the samples, Cadmium was not detected and the calculated LOD for all these samples were above the MAC. This indicates that failure to detect an analyte of interest is not a sign of low concentration of that analyte but the physical characteristics of the soil could

influence the detection ability of the instrument. However, the analyzer was able to detect Chromium in all the samples.

Table 8.2. Kajaran Community: Undetected Measurements

Heavy Metals	MAC mg/kg	% of undetected measurements out of total n/N Range of LOD's mg/kg	% out of total above MAC n/N Range of LOD's above MAC mg/kg
	Residential/ Agricultural		
As	12	1.8%	1.7%
		5/279	4-279
		10-304	20-304
Pb	400	0.4%	0.0%
		1/279	0/279
		8	-
Cr	64	0.0%	0.0%
		0/279	0/279
		-	-
Cd	14/1.4	99.6%	99.6%
		278/279	278/279
		19-50	19-50

All undetected measurements were excluded from further analysis. Table 8.3 presents the percentage of all samples that exceeded the three reference levels: MAC, HBL (depth 10cm, 20 cm), CL as well as the GM and the range of all detected measurements. According to the results, 97.4% of all detected measurements exceeded MAC for Arsenic, 3.2% for Lead, 100.0% for Chromium and 100.0% for Cadmium. GM of detected measurements for Arsenic exceeded MAC by 2.4 times, for Chromium by 3.4 times. For Arsenic, 0.7% of soil samples need clean-up and 3.2% for Lead. CL for Chromium and Cadmium were not identified during the literature review and standards were substantially different across countries.

According to the test results, 30.3% of Arsenic, 20.5% of Lead and 39.8% of Chromium exceeded the highest background measurements (Cadmium was not detected in the soil). This

indicates that the surface level exposure was higher even in comparison with the highest background measurement thus suggesting external pollution.

Table 8.3. Kajaran Community: Comparison of Results to MAC, HBL (depth 10 cm, 20 9cm) and CL

Heavy Metals	MAC mg/kg Residential/ Agricultural	% above MAC out of detected n/N GM and Range of all detected mg/kg	Clean-up level (CL) mg/kg	% above CL level out of detected n/N GM and Range of all detected mg/kg	Highest background level (HBL) (depth 10, 20 cm)	% above HBL out of detected n/N GM and Range of all detected mg/kg
As	12	97.4% 267/274 28.9 7-129	100	0.7% 2/274 28.9 7-129	35	30.3% 83/274 28.9 7-129
Pb	400	3.2% 9/278 84.0 15-76052	400	3.2% 9/278 84.0 15-76052	129	20.5% 57/278 84.0 15-76052
Cr	64	100.0% 279/279 215.6 74-733	---*	---	238	39.8% 111/279 215.6 74-733
Cd	14/1.4	100% 1/1 39 39	---*	---	Not Detected	---

* Not identified

Table 8.4 presents the results exceeding MAC by sample type, GM and the range of all detected measurements. The results shows that Arsenic concentration is very high in yard soil samples (98.0% exceeded MAC) and in schools/kindergartens testing (95.0% exceeded MAC). In 3.6% of yard testing lead exceeded MAC. In 100.0% of yard, schools and kindergartens testing Chromium exceeded MAC and Cadmium exceeded MAC in a detected measurement which was from the yard.

Table 8.4. Kajaran Community: Results above MAC by Sample Type

Heavy metals	MAC Mg/kg	Soil sample type			
		Yard		Schools & Kindergartens	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	98.0%	29.1	95.0%	30.9
		240/245	7-129	19/20	12-60
Pb	400	3.6%	86	0.0%	66.3
		9/249	15-76052	0/20	29-163
Cr	64	100.0%	218.7	100.0%	204.2
		250/250	75-733	20/20	206-531
Cd	14/1.4	100.0%	39	-	-
		1/1	39	-	-

Table 8 shows the percentage of the samples exceeding the MAC by community sections. Among all the sections, all the samples exceeded the MAC for Chromium but only in Section 1 and 2 the samples exceeded the MAC for Arsenic. The concentration of Arsenic in Section 3 is also high and exceeded the MAC in 94.5% of the samples. The highest concentration of Lead was found in Section 1, where 6.7% of the samples exceeded the MAC and in one of the samples the concentration was extremely high (76,052 mg/kg). In Section 2, 2.3% of the samples and in Section 3 1.8% of the samples exceeded the MAC. Cadmium was detected in one sample only in Section 1 and that sample was above MAC.

Table 8.5. Kajaran Community: Results above MAC by Sections

Heavy metals	MAC mg/kg	Sections					
		1		2		3	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	100.0%	28.5	100.0%	34.6	94.5%	26

		72/72	13-85	88/88	17-85	104/110	7-129
Pb	400	6.7%	94.2	2.3%	90.6	1.8%	75.3
		5/75	15-76052	2/88	29-1006	2/111	20-819
Cr	64	100.0%	210.6	100.0%	257	100.0%	194.5
		75/75	78-733	89/89	93-724	111/111	75-482
Cd	14/1.4	100.0%	39	-	-	-	-
		1/1	39	-	-	-	-

Table 8.6 and 8.7 illustrate the results above CL by sample type and sections. In all the detected yard samples, 0.8% needed clean-up for Arsenic and 3.6% for Lead. According to Table 8.7, 1.8% of the samples in Section 3 exceeded CL for Arsenic. Moreover, in Sections 1, 2 and 3, 6.7%, 2.3% and 1.8% of the samples respectively exceeded CL for Lead.

Table 8.6. Kajaran Community: Results above CL by Sample Type

Heavy Metals	CL mg|kg	Sample type			
		Yard		School & Kindergarten	
		% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg
As	100	0.8% 2/245	29.1 7-129	0.0% 0/20	30.9 12-60
Pb	400	3.6% 9/249	86 15-76052	0.0% 0/20	66.3 29-163

Table 8.7. Kajaran Community: Results above CL by Sections

Heavy Metals	CL mg|kg	Sections					
		1		2		3	
		% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg
As	100	0.0% 0/72	28.5 13-85	0.0% 0/88	34.6 17-85	1.8% 2/110	26 7-129
Pb	400	6.7% 5/75	94.2 15-76052	2.3% 2/88	90.6 29-1006	1.8% 2/111	75.3 20-819

After accurate testing of 279 residential soil samples in the Kajaran Community, the results indicate that 97.4% of all detected measurements exceeded the MAC for Arsenic, 3.2% for Lead, 100.0% for Chromium and 100.0% for Cadmium. According to the results, soil

samples that need cleanup for Arsenic were observed in 0.7% of the samples (2 yard soil samples) and 3.2% for Lead (9 yard soil samples). Extremely high concentrations (76,052mg/kg) of Lead was found in one yard soil sample in Section 1, which exceeded MAC by 190.1 times.

Picture 4. Kajaran Community: Map with highlighted sectors.

9. Kapan Community

The thorough risk assessment field work in Kapan Community took place in September of 2013. The town was divided into five sectors (see Picture 5). The investigators collected 281 soil samples: 251 from yards, 21 from schools and kindergartens, 9 for background purposes at surface-level, as well as 10cm and 20cm depth samples from inside and outside of the community (range of background measurements presented in the Table 9.0). Soil samples were prepared in the laboratory following the protocol developed based on a review of international guidelines. The preparation process for soil samples took place in December of 2013 and it included drying, homogenization and sieving. The prepared soil samples were tested by the XRF analyzer (INNOV-X α-2000) based on the protocol developed for soil testing. The testing process took place in January of 2013 using 90 seconds as the duration of testing time. Samples displaying test results below the LOD and above the MAC were retested again in March-April of 2014 using 240 seconds as the testing time. The results were compared with three reference levels: Maximum Allowable Concentrations (MAC), Clean up Levels (CL) and Highest Background Level (HBL) of 10cm, 20 cm depth (see Table 9.1).

Table 9.0 Kapan community: Range of background measurements

Heavy metals	**Range (mg/kg)**
As	12-39
Pb	13-157
Cr	90-181
Cd	-

Table 9.1. Kapan Community: Reference Levels for Comparison

Heavy Metals	MAC mg/kg	CL mg/kg	HBL (10cm, 20 cm depth) mg/kg
	Residential/ Agricultural		
As	12	100	39
Pb	400	400	157
Cr	64	-*	177
Cd	14/1.4	-*	Not Detected

* Not identified

Some measurements of the community soil samples (e.g., from yards, schools and kindergartens) were below the LOD of the XRF analyzer. The results of undetected measurements are presented in Table 9.2. When the analyzer could not detect the analyte of interest, calculated LOD was provided which is counted as three times the error of counting statistics of each measurement. Interestingly, calculated LOD differed for each measurement. Table 9.2 presents undetected measurements for which the calculated LOD was above MAC. Results of Table 9.2 show that 1.8% of samples out of the total samples did not detect Arsenic and all undetected measurements were above MAC. In all of the samples, the analyzer was able to detect Lead. Chromium was not detected in 3.9% of the samples, however, only in one sample (0.4%) was the calculated LOD above MAC. In 97.9% of samples, Cadmium was not detected and the calculated LOD for all those samples were above MAC. This indicates that undetected measurement is not a sign of low concentration of the analyte of interest and the physical matrix of soil could influence the detection ability of the instrument.

Table 9.2. Kapan Community: Undetected Measurements

Heavy Metals	MAC mg/kg	% of undetected measurements out of total n/N Range of LOD's mg/kg	% out of total above MAC n/N Range of LOD's above MAC mg/kg
	Residential/ Agricultural		
As	12	1.8% 5/281 15-24	1.8% 5/281 15-24
Pb	400	0.0% 0/281 -	0.0% 0/281 -
Cr	64	3.9% 11/281 40-79	0.4% 1/281 79
Cd	14/1.4	97.9% 275/281 15-39	97.9% 275/281 15-39

All undetected measurements were excluded from further analysis. Table 9.3 presents the percentage of all samples that exceeded the three reference levels: MAC, HBL (depth 10cm and 20 cm), CL as well as the GM and the range of all detected measurements. According to the results, 96.7% of all detected measurements exceeded MAC for Arsenic, 4.3% for Lead, 99.6% for Chromium and 100% for Cadmium. GM of detected measurements for Arsenic exceeded MAC by 2.1 times, Chromium by 2.2 times and Cadmium by 3.8 times. For Arsenic, 2.9% of soil samples need clean-up and 4.3% for Lead. CL for Chromium and Cadmium were not identified during the literature review and standards differed substantially across countries. According to the test results, 11.2% of Arsenic, 19.6% of Lead and 21.1% of Chromium exceeded the highest background measurements (Cadmium was not detected in the soil). This indicates that the surface level exposure was higher even in comparison with the highest background measurement thus suggesting external pollution.

Table 9.3. Kapan Community: Comparison of Results to MAC, HBL (depth 10 cm, 20 cm) and CL

Heavy Metals	MAC mg/kg Residential/ Agricultural	% above MAC out of detected n/N GM and Range of all detected mg/kg	CL mg/kg	% above CL level out of detected n/N GM and Range of all detected mg/kg	HBL (depth 10cm, 20 cm)	% above HBL out of detected n/N GM and Range of all detected mg/kg
As	12	96.7% 267/276 24.8 7-400	100	2.9% 8/276 24.8 7-400	39	11.2% 31/276 24.8 7-400
Pb	400	4.3% 12/281 93.8 13-19,499	400	4.3% 12/281 93.8 13-19,499	157	19.6% 55/281 93.8 13-19,499
Cr	64	99.6% 269/270 143.4 63-645	---*	---	177	21.1% 57/270 143.4 63-645
Cd	14/1.4	100% 6/6 53.2 22-227	---*	---	Not Detected	---

* Not identified

Table 9.4 presents the results exceeding MAC by sample type, GM and the range of all detected measurements. The results show that Arsenic concentration is very high in yard soil (97.2%) as well as school and kindergarten samples (95.2%). In 4.4% of yard and 4.8% of school samples, Lead exceeded MAC. Furthermore, in one of the yard sample, the amount of Lead exceeded MAC by 48.7 times (19,499 mg/kg). In 99.6% of yard and 100.0% of school as well as kindergarten samples, Chromium exceeded MAC. Cadmium exceeded MAC in all detected samples which were collected from yards.

Table 9.5 presents the results exceeding CL level by sample type. The results show that 3.3% of the yard soil in the community exceeded CL for Arsenic and 4.4% for Lead. Moreover, 4.8% of school and kindergarten soil samples exceeded CL for Lead.

Table 9.4. Kapan Community: Results above MAC by Sample Type

Heavy metals	MAC Mg/kg	Soil Sample Type			
		Yard		Schools & Kindergartens	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	97.2%	25	95.2%	24.1
		239/246	7-400	20/21	10-48
Pb	400	4.4%	97.2	4.8%	89.8
		11/251	14-19499	1/21	30-487
Cr	64	99.6%	144.1	100.0%	135.8
		239/240	63-645	21/21	112-180
Cd	14/1.4	100.0%	53.2	-	-
		6/6	22-227	-	-

Table 9.5. Kapan Community: Results above CL by Sample Type

Heavy Metals	CL mg|kg	Sample Type			
		Yard		School & Kindergarten	
		% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg
As	100	3.3% 8/246	25 7-400	0.0% 0/21	24.1 10-48
Pb	400	4.4% 11/251	97.2 14-19499	4.8% 1/21	89.8 30-487

Table 9.6 shows the results exceeding the MAC according to the community sections. The results show that the percentage of the samples exceeding the MAC for Arsenic in all sections is high (in 92.5-100% of the samples). Chromium concentration is also very high across the sections and exceeded the MAC in 97.9-100% of samples. Lead concentration is comparably low and exceeded the MAC in 7.4% of the samples in Section 1, 3.8% of the samples in Section 2, 1.7% of the samples in Section 3, 5.6% of the samples in Section 4 and 2.6% of the samples in Section 5. Cadmium was detected in two sections (only in 2 samples) and the results exceeded the MAC.

Table 9.7 shows the percentages of the samples exceeding the CL according to the sections of the community. Comparably, the more affected sections are Section 2 (9.6% of samples exceeded the CL for Arsenic and 3.8% of the samples exceeded the CL for Lead) and Section 4 (1.1% of the samples exceeded the CL for Arsenic and 5.6% of the samples exceeded the CL for Lead).

Table 9.6. Kapan Community: Results above MAC by Sections

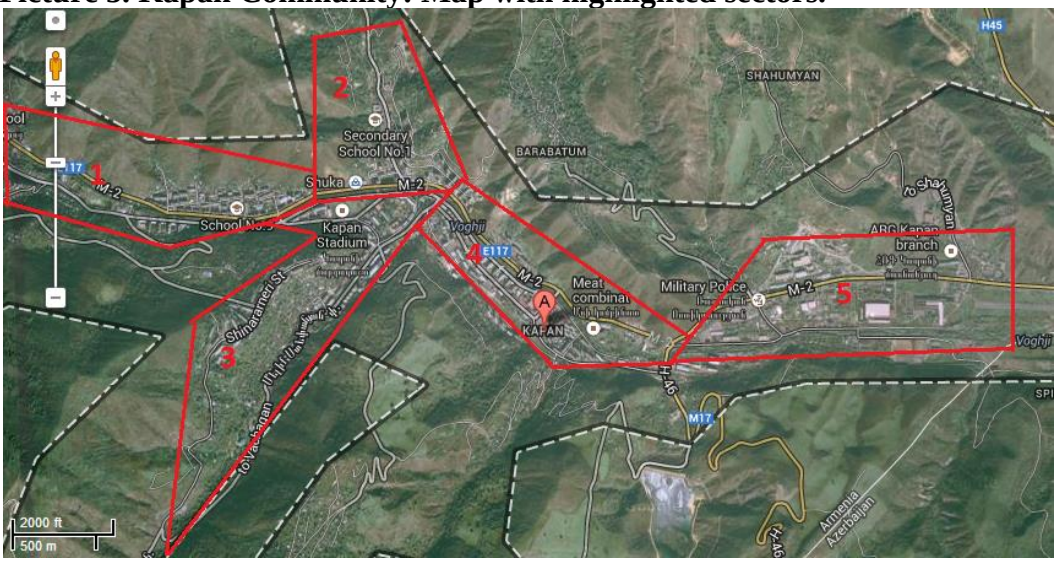
Heavy metals	MAC mg/kg	Sections									
		1		2		3		4		5	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	92.5% 49/53	20.1 7-79	100.0% 52/52	38.3 13-400	93.0% 53/57	20.6 10-58	98.6% 68/69	22.7 11-173	100.0% 38/38	28.5 13-192
Pb	400	7.4% 4/54	97.6 24-499	3.8% 2/52	86.1 19-19499	1.7% 1/58	75.4 20-508	5.6% 4/71	112.8 14-738	2.6% 1/39	110.2 21-1492
Cr	64	100.0% 53/53	145.4 68-292	97.9% 47/48	126.3 63-497	100.0% 58/58	156.3 83-645	100.0% 69/69	145.4 81-451	100.0% 35/35	141.2 65-281
Cd	14/1.4	100.0% 1/1	227 227	100.0% 1/1	36 36	-	-	100.0% 1/1	34 34	100.0% 3/3	43.3 22-74

Table 9.7. Kapan Community: Results above CL by Sections

Heavy Metals	CL mg|kg	Sections									
		1		2		3		4		5	
		% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg	% ↑ CL n/N	GM and Range of all detected mg/kg
As	100	0.0% 0/53	20.1 7-79	9.6% 5/52	38.3 13-400	0.0% 0/57	20.6 10-58	1.1% 1/69	22.7 11-173	5.3% 2/38	28.5 13-192
Pb	400	7.4% 4/54	97.6 24-499	3.8% 2/52	86.1 19-19499	1.7% 1/58	75.4 20-508	5.6% 4/71	112.8 14-738	2.6% 1/39	110.2 21-1492

After testing of 281 residential soil samples in the Kapan Community, the results indicate that 96.7% of all detected measurements exceeded MAC for Arsenic, 4.3% for Lead, 99.6% for Chromium and 100% for Cadmium. According to the results, soil samples that need cleanup for Arsenic were observed in 2.9% of samples (8 yard soil samples) and for Lead in 4.3% o samples (11 yard soil samples and a sample from school/kindergarten).

Picture 5. Kapan Community: Map with highlighted sectors.



10. Lernadzor community

The field work for the thorough risk assessment in Lernadzor Community was conducted in August of 2013. A total 116 soil samples were collected from the residential and agricultural areas of the community, prepared in the laboratory and tested via XRF Analyzer. Out of the 116 soil samples, 63 were from yards, 37 from gardens, 10 from a school and a kindergarten in addition to 6 samples for background measurements at surface,10 and 20cm depth inside and outside of the community (range of background measurements presented in the Table 10.0). The testing process took place in January of 2014. The duration of testing time was 90 seconds. Samples having test results below the LOD were retested again with the testing time of 240 seconds in March-April of 2014.. The results were compared with three reference levels: Maximum Allowable Concentrations (MAC), Clean up Levels (CL) and Highest Background Level (HBL) of 10cm, 20 cm depth (see Table 10.1).

Table 10.0 Lernadzor community: Range of background measurements

Heavy metals	**Range (mg/kg)**
As	15-61
Pb	13-60
Cr	112-221
Cd	-

Table 10.1. Lernadzor Community: Reference Levels for Comparison

Heavy Metals	**MAC mg/kg**	**CL mg/kg**	**HBL (10cm, 20 cm depth) mg/kg**
	Residential/ Agricultural		
As	12	100	61
Pb	400	400	60
Cr	64	-*	221
Cd	14/1.4	-*	Not detected

* Not identified

Some measurements of the community soil samples were below LOD of the XRF analyzer. The results of undetected measurements are presented in Table 10.2. If the analyzer could not detect the analyte of interest, it provided calculated LOD which is determined by multiplying the error of counting statistics of each measurement by three times. Calculated LOD differed for each measurement. Table 10.2 presents the undetected measurements for which the calculated LOD was above MAC. Results of Table 10.2 show that there are no undetected measurements for Arsenic and Lead. Chromium was not detected in 3.4% of the samples and the calculated LOD for these samples exceeded MAC only in 1.7% of the samples. Cadmium was not detected in any samples and the calculated LOD for all undetected measurements was above MAC.

Table 10.2. Lernadzor Community: Undetected Measurements

Heavy Metals	MAC mg/kg	% of undetected measurements out of total n/N Range of LOD's mg/kg	% out of total above MAC n/N Range of LOD's above MAC mg/kg
	Residential/ Agricultural		
As	12	0.0% 0/116 -	0.0% 0/116 -
Pb	400	0.0% 0/116 -	0.0% 0/116 -
Cr	64	3.4% 4/116 51-71	1.7% 2/116 65-71
Cd	14/1.4	100.0% 116/116 17-35	100.0% 116/116 17-35

All undetected measurements were excluded from further analysis. Table 10.3 presents the percentage of samples out of the total samples tested that exceed the three reference levels - MAC, HBL(depth 10cm,20 cm), CL as well as the GM and the range of all detected measurements. According to the results, for Arsenic 92.2% of samples exceed MAC, but none exceeded HBL. Furthermore, for Lead, 0.9% of the samples exceeded MAC while 32.8% exceeded HBL. For Chromium, 99.1% of the samples exceeded MAC, but only 15.2% of the samples for HBL. Cadmium was not detected in any of the samples. None of the samples exceeded the CL for Arsenic but for Lead one sample (0.9%) was above CL. GM exceeded the MAC by 1.7 times for Arsenic and 2.4 times for Chromium.

Table 10.3. Lernadzor Community: Results Compared to MAC, HBL (depth 10cm, 20 cm) and CL

Heavy Metals	MAC mg/kg Residential/ Agricultural	% above MAC out of detected n/N GM and Range of all detected mg/kg	CL mg/kg	% above CL level out of detected n/N GM and Range of all detected mg/kg	HBL (depth 10cm, 20 cm)	% above HBL out of detected n/N GM and Range of all detected mg/kg
As	12	92.2% 107/116 20.2 7-61	100	0.0% 0/116 20.2 7-61	61	0.0% 0/116 20.2 7-61
Pb	400	0.9% 1/116 55.8 13-498	400	0.9% 1/116 55.8 13-498	60	32.8% 38/116 55.8 13-498
Cr	64	99.1% 111/112 156.5 62-440	---*	---	221	15.2% 17/112 156.5 62-440
Cd	14/1.4	-	---*	---	Not Detected	---

* Not identified

Table 10.4 presents the results exceeding MAC by sample type, GM and the range of all detected measurements. Results show that MAC exceeded in 93.7% of yard soil samples for Arsenic, 1.6% for Lead and 100.0% for Chromium. Among garden soil samples, MAC exceeded in 86.5% of samples for Arsenic, 0.0% for Lead and 97.1% for Chromium. In school and kindergarten samples, 100% of the samples exceeded MAC for Arsenic and Chromium. Cadmium was not detected in any of soil samples. Among gardens, school, and kindergarten samples, none of them exceeded MAC for Lead.

Table 10.4. Lernadzor Community: Results above MAC by Sample Type

Heavy metals	MAC Mg/kg Residential/ Agricultura –	Soil Sample Type					
		Yard		Garden		School & Kindergarten	
		% ↑ MAC	GM and Range	% ↑ MAC	GM and Range	% ↑ MAC	GM and Range

		n/N	of all detected mg/kg	n/N	of all detected mg/kg	n/N	of all detected mg/kg
As	12	93.7%	21.5	86.5%	16.7	100.0%	22.1
		59/63	7-44	32/37	9-27	10/10	15-43
Pb	400	1.6%	58.8	0.0%	51.3	0.0%	78.2
		1/63	20-498	0/37	26-335	0/10	35-218
Cr	64	100.0%	164.4	97.1%	138.5	100.0%	170.5
		61/61	67-440	34/35	62-307	10/10	104-301
Cd	14/1.4	-	-	-	-	-	-
		-	-	-	-	-	-

11. Syunik Village Community

The field work for the thorough risk assessment in Syunik Village Community was performed in September of 2013. A total 90 soil samples were collected from residential and agricultural areas of the community, prepared in the laboratory and tested via XRF Analyzer. Out of the 90 soil samples, 51 were from yards, 23 from gardens, 10 from a school and a kindergarten in addition to 6 samples for background measurements at surface,10 and 20cm depth inside and outside of the community (range of background measurements presented in the Table 11.0). The testing process took place in January of 2014. The duration of testing time was 90 seconds. Samples having test results below the LOD were retested again in March –April of 2014 with a testing time of 240 seconds. The results were compared with three reference levels: Maximum Allowable Concentrations (MAC), Clean up Levels (CL) and Highest Background Level (HBL) of 10cm, 20 cm depth (see Table 11.1).

Table 11.0 Syunik village community: Range of background measurements

Heavy metals	**Range (mg/kg)**
As	12-55
Pb	9-67
Cr	96-147
Cd	-

Table 11.1. Syunik Village: Reference Levels for Comparison

Heavy Metals	**MAC mg/kg**	**CL mg/kg**	**HBL (10cm, 20 cm depth) mg/kg**
	Residential/ Agricultural		
As	12	100	55
Pb	400	400	26
Cr	64	-*	147

Cd	14/1.4	-*	Not detected

* Not identified

Some measurements of the community soil samples were below the LOD of the XRF analyzer. The results of undetected measurements are presented in Table 11.2. If the analyzer could not detect the analyte of interest, it provided the calculated LOD which is determined by multiplying the error of counting statistics of each measurement by three times. Calculated LOD differed for each measurement. Table 11.2 presents the undetected measurements for which the calculated LOD was above MAC. Results of Table 11.2 show that the analyzer failed to detect Arsenic and Chromium only in a few samples and the calculated LOD of the undetected samples was below the MAC. Moreover, Lead is detected in all measurements. Therefore, the undetected samples for those three heavy metals are not a major concern for Syunik Village. However, Cadmium was not detected in 98.9% of the samples and for all the undetected samples, the LOD was above MAC. Therefore, undetected samples do not necessarily indicate that Cadmium concentrations are below MAC.

Table 11.2. Syunik Village: Undetected Measurements

Heavy Metals	**MAC mg/kg**	**% of undetected measurements out of total n/N Range of LOD's mg/kg**	**% out of total above MAC n/N Range of LOD's above MAC mg/kg**
	Residential/ Agricultural		
As	12	1.1% 1/90 7	0.0% 0/90 -
Pb	400	0.0% 0/90 -	0.0% 0/90 -
Cr	64	1.1% 1/90 55	0.0% 0/90 -
Cd	14/1.4	98.9% 89/90 17-34	98.9% 89/90 17-34

All undetected measurements were excluded from further analysis. Table 11.3 presents the percentage of samples out of the total samples that exceeded the three reference levels - MAC, HBL (depth of 10cm and 20 cm), CL as well as the GM and the range of all detected measurements. According to the results, for Arsenic 83.1% of the samples exceeded MAC, but only 2.2% exceeded HBL. For Lead, none of the samples exceeded MAC but 74.4% exceeded the HBL. For Chromium, 97.8% of the samples exceeded MAC, but only 23.6% exceeded the HBL. Cadmium was detected in one measurement result was above MAC. For Arsenic and Lead, none of the samples exceeded the CL. GM for Arsenic exceeded the MAC by 1.4 times and for Chromium by 1.9 times.

Table 11.3. Syunik Village: Results Compared to MAC, HBL (depth 10cm, 20 cm) and CL

Heavy Metals	MAC mg/kg Residential/ Agricultural	% above MAC out of detected n/N GM and Range of all detected mg/kg	Clean-up level (CL) mg/kg	% above CL level out of detected n/N GM and Range of all detected mg/kg	Highest background level (HBL) (depth 10cm, 20 cm)	% above HBL out of detected n/N GM and Range of all detected mg/kg
As	12	83.1% 74/89 17.8 10-77	100	0.0% 0/89 17.8 10-77	55	2.2% 2/89 17.8 10-77
Pb	400	0.0% 0/90 44.7 9-272	400	0.0% 0/90 44.7 9-272	26	74.4% 67/90 44.7 9-272
Cr	64	97.8% 87/89 122.8 49-270	---*	---	147	23.6% 21/89 122.8 49-270
Cd	14/1.4	100.0% 1/1 35 35	---*	---	Not Detected	---

* Not identified

Table 11.4 presents the results exceeding MAC by sample type, GM, and the range of all detected measurements. Results indicate that among yard soil samples, Arsenic, Chromium and Cadmium exceeded MAC in 96.1%, 100.0% and 100.0% of the samples respectively. In garden soil samples,

Arsenic and Chromium exceeded MAC in 60.9% and 95.7% of samples. Among school and kindergarten soil samples, Arsenic and Chromium exceeded MAC in 66.7% and 88.9% of samples.

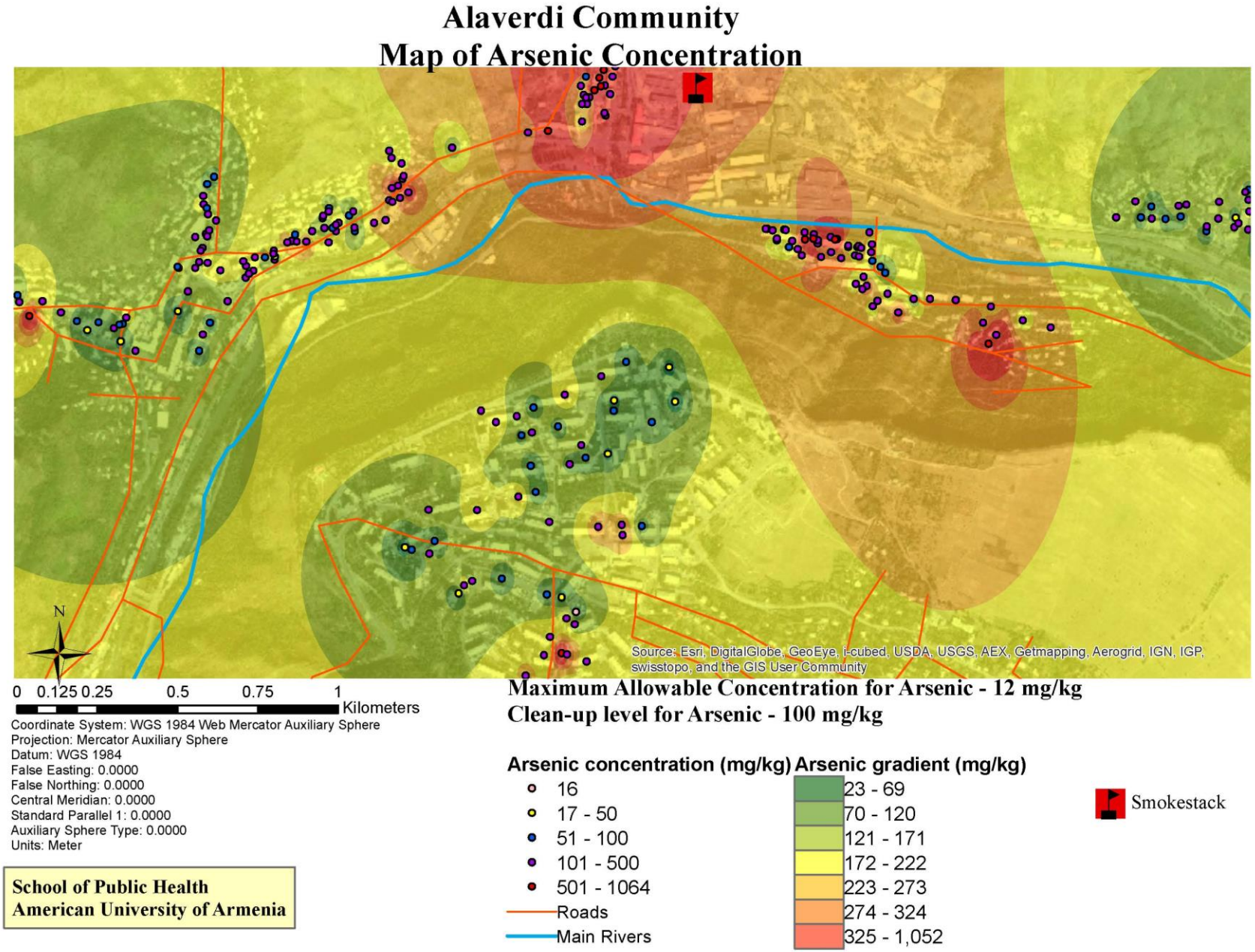
Table 11.4. Syunik Village: Results above MAC by Sample Type

Heavy metals	MAC Mg/kg	Soil Sample Type					
		Yard		Garden		School & Kindergarten	
	Residential/ Agricultural	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg	% ↑ MAC n/N	GM and Range of all detected mg/kg
As	12	96.1% 49/51	20.3 10-77	60.9% 14/23	13.4 10-21	66.7% 6/9	14.1 10-24
Pb	400	0.0% 0/51	59.7 18-272	0.0% 0/23	27.5 14-105	0.0% 0/10	50.5 10-137
Cr	64	100.0% 51/51	128.6 70-270	95.7% 22/23	117.8 63-206	88.9% 8/9	106.5 49-152
Cd	14/1.4	100.0 1/1	35 35	- -	- -	- -	- -

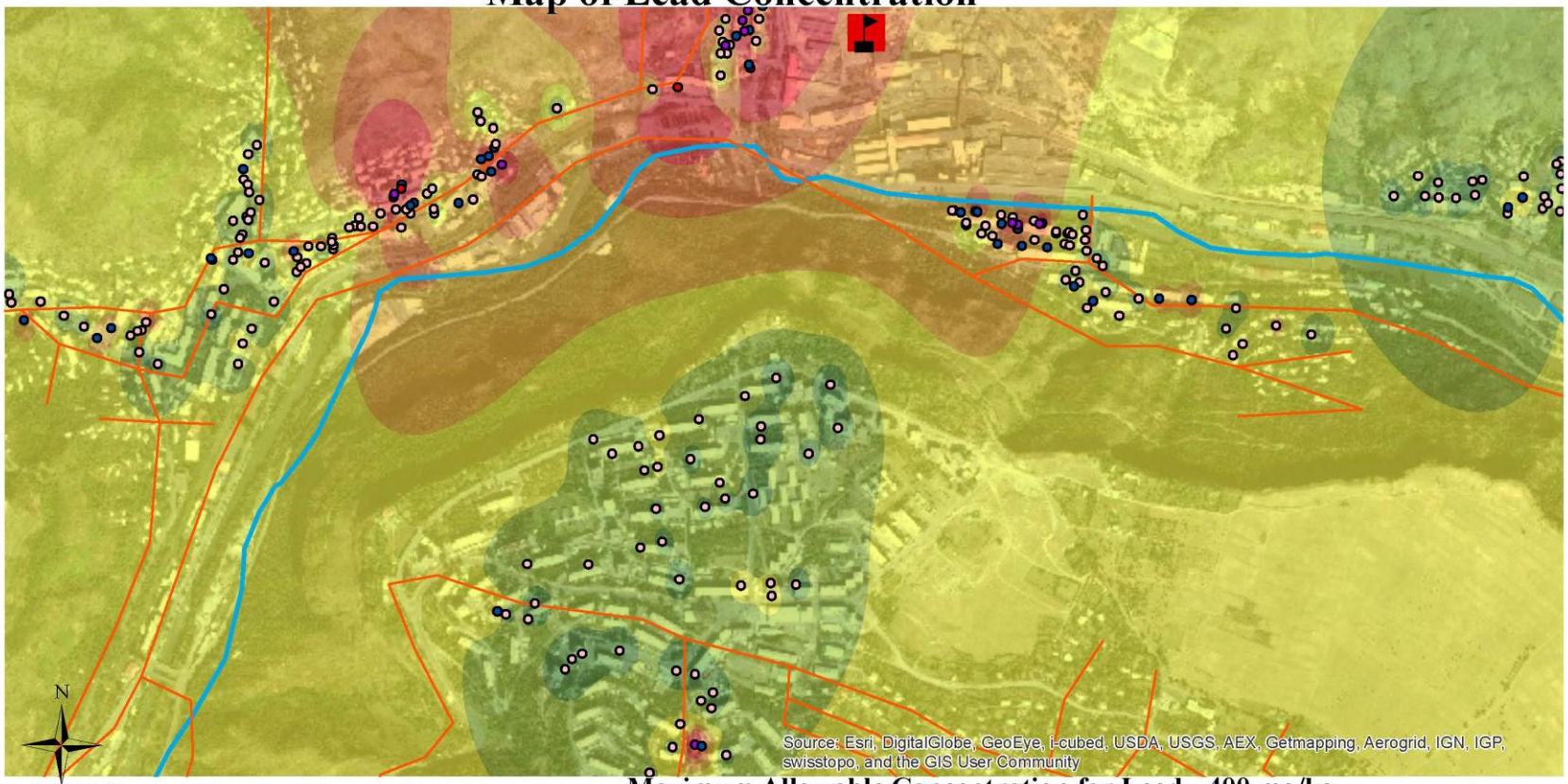
REFERENCE:

1. *Method 6200.Field Portable X-Ray Fluorescence Spectometry for the Determination of Elemental Concentrations in Soil and Sediment.* US Environmental Protection Agency 2007. http://www.epa.gov/osw/hazard/testmethods/sw846/pdfs/6200.pdf
2. *Instruction Manual. Innov-X Systems Alpha Series, X-Ray Fluorescence Spectrometers* 2005.

FIGURES (MAPS PREPARED BY KRISTINA AKOPYAN, MD, MPH)



Alaverdi Community
Map of Lead Concentration



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Kilometers

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Auxiliary Sphere Type: 0.0000
Units: Meter

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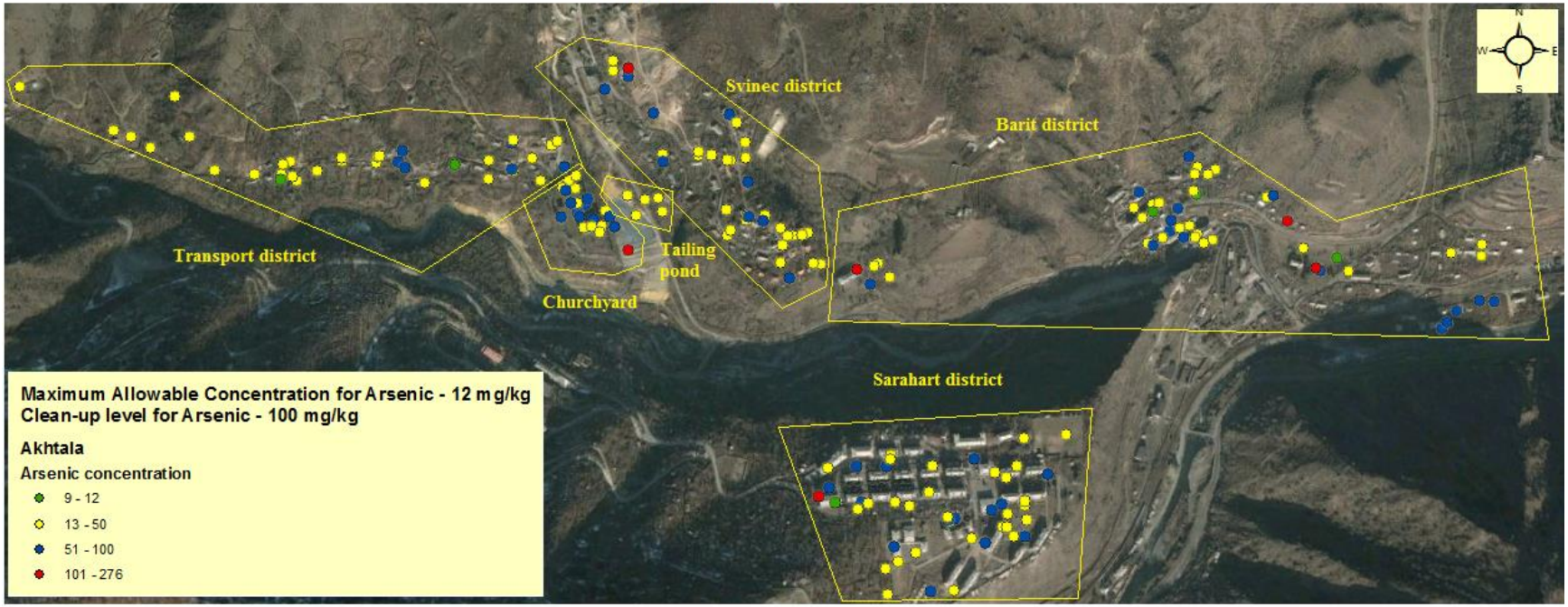
American University of Armenia

Maximum Allowable Concentration for Lead - 400 mg/kg
Clean-up level for Lead - 400 mg/kg

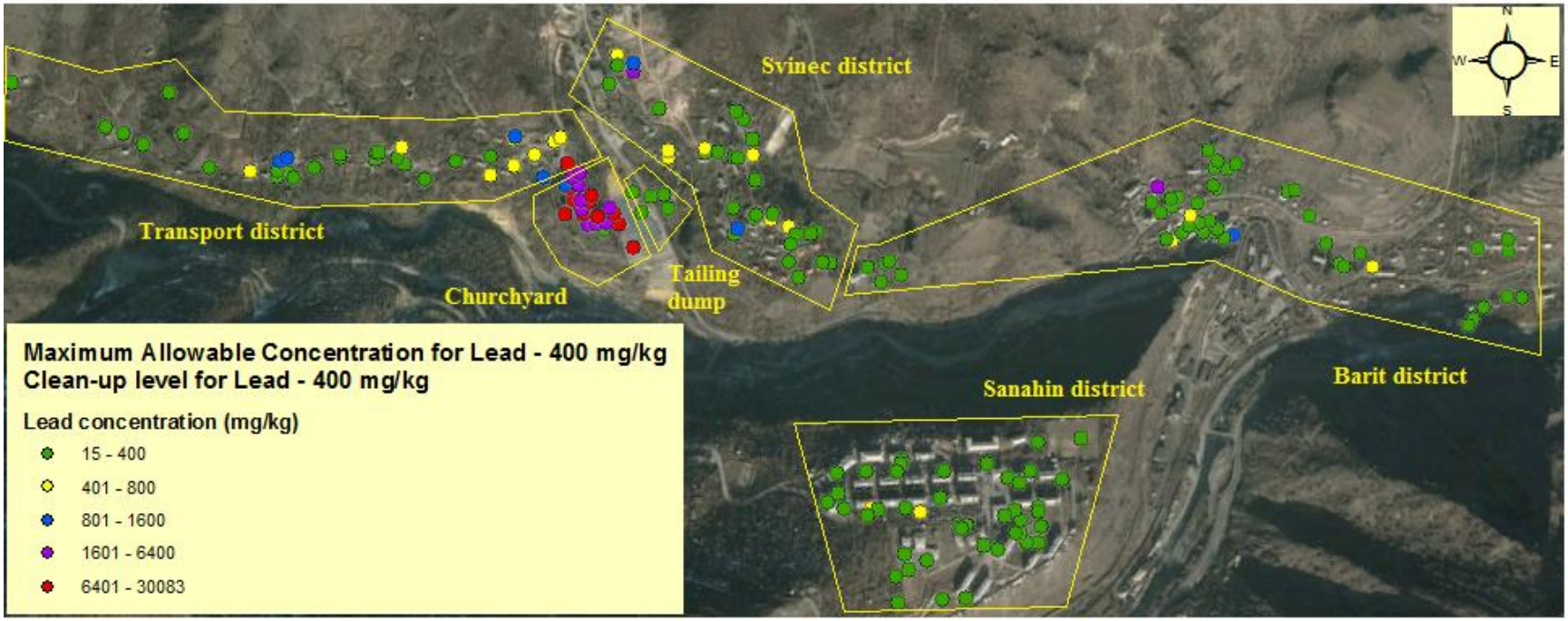
Lead concentration (mg/kg)	Lead gradient (mg/kg)
13 - 399	17 - 81
400	82 - 170
401 - 800	171 - 272
801 - 1600	273 - 361
1601 - 3703	362 - 451
Roads	452 - 540
Main Rivers	541 - 3,268

Smokestack

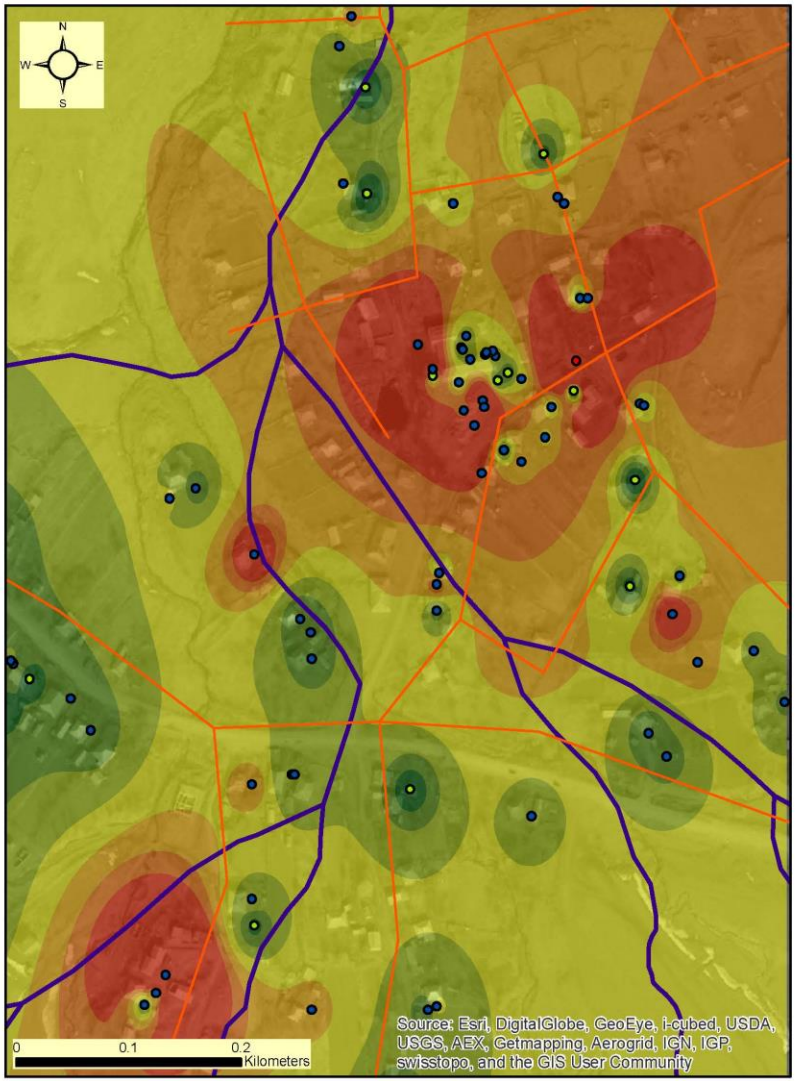
Akhtala Community
Map of Arsenic Concentration



Akhtala Community
Map of Lead Concentration



Armanis Community
Map of Arsenic Concentration



Maximum Allowable Concentration for Arsenic - 12 mg/kg
Clean-up Level for Arsenic - 100 mg/kg

Armanis

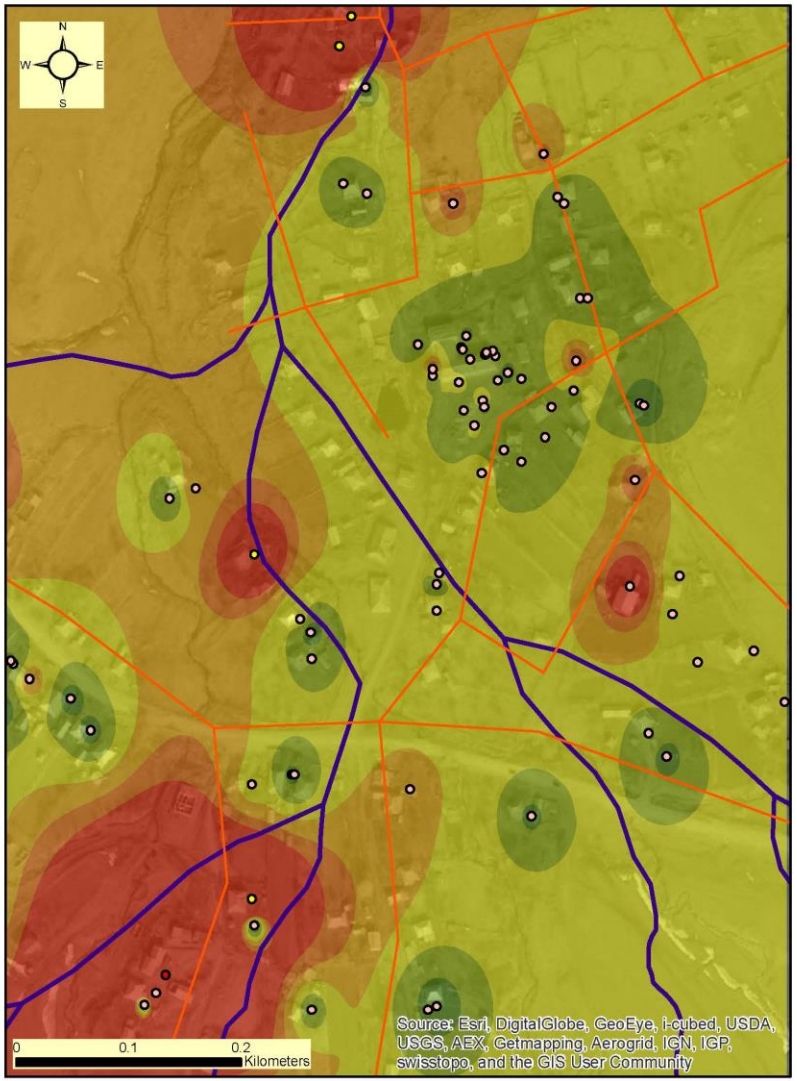
Arsenic concentration (mg/kg)

- 8 - 12
- 13 - 100
- 101 - 169
- Roads
- Rivers

Arsenic gradient (mg/kg)

- 8 - 13
- 14 - 15
- 16 - 18
- 19 - 20
- 21 - 23
- 24 - 25
- 26 - 164

Armanis Community
Map of Lead Concentration



Maximum Allowable Concentration for Lead - 400 mg/kg
Clean-up Level for Lead - 400 mg/kg

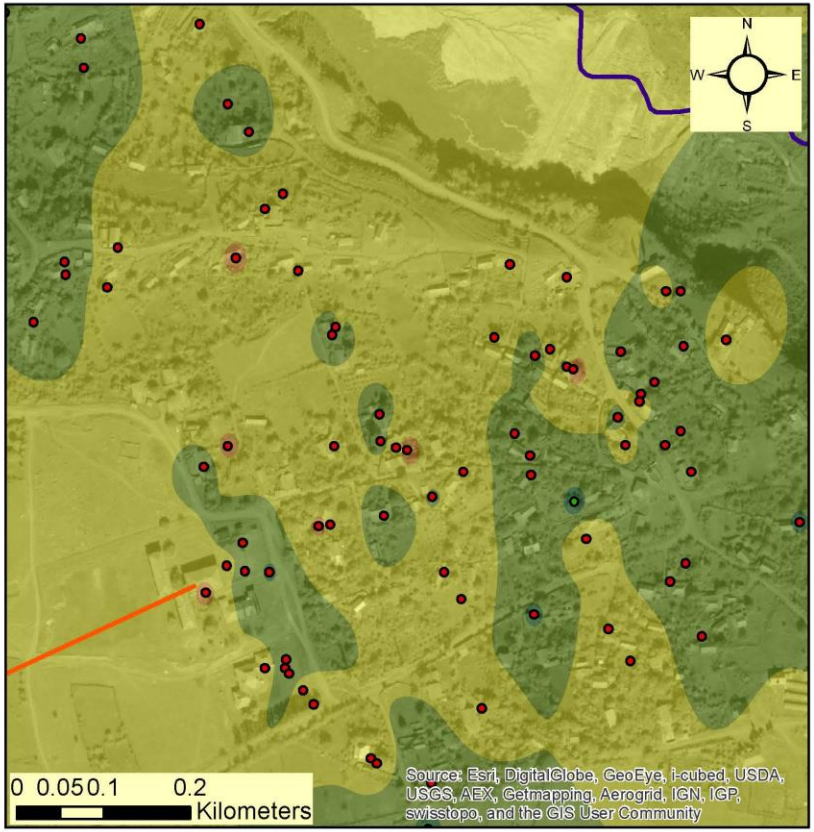
Lead concentration (mg/kg)

- 19 - 400
- 401 - 800
- 801 - 3353
- Roads
- Rivers

Lead gradient (mg/kg)

- 22 - 29
- 30 - 70
- 71 - 111
- 112 - 152
- 153 - 192
- 193 - 233
- 234 - 3,271

Metz Ayrum Community
Map of Arsenic Concentration



Maximum Allowable Concentration for Arsenic - 12 mg/kg
Clean-up level for Arsenic - 100 mg/kg

Metz Ayrum

Arsenic concentration (mg/kg)

- 9 - 12
- 13 - 64
- Rivers
- Roads

Arsenic gradient (mg/kg)

- 9.113815308 - 15.05650164
- 15.05650165 - 24.4481383
- 24.44813831 - 33.83977497
- 33.83977498 - 43.23141163
- 43.23141164 - 64

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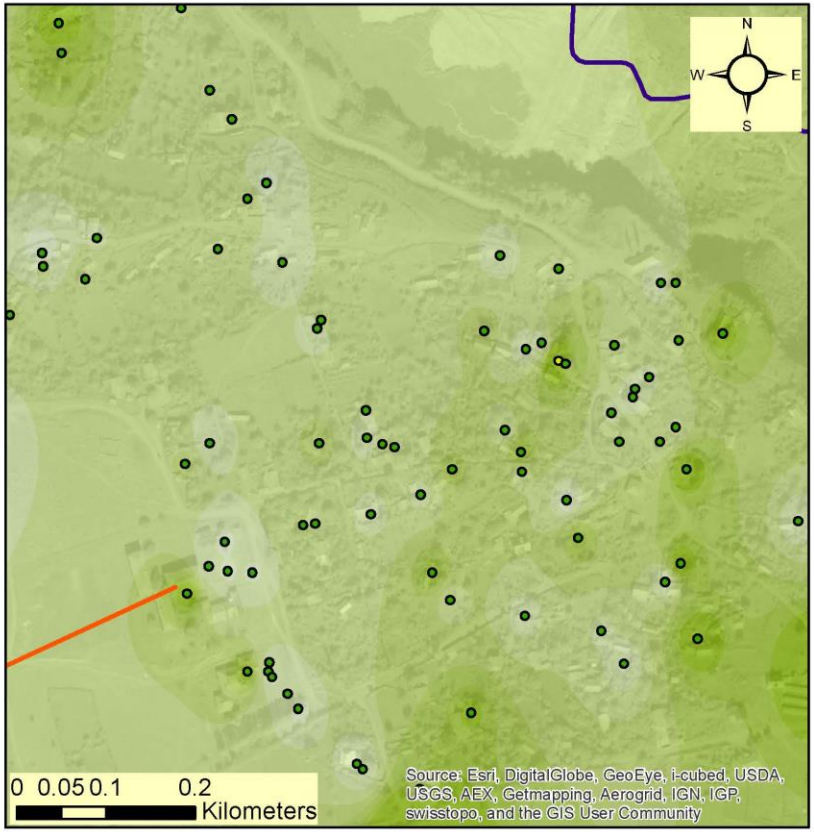
Metz Ayrum Community
Map of Lead Concentration



Maximum Allowable Concentration for Lead - 400mg/kg

Lead concentration (mg/kg)

- 19 - 200
- 201 - 359
- Rivers
- Roads

Lead gradient (mg/kg)

- 19.07323265 - 39.46141149
- 39.4614115 - 50.93513276
- 50.93513277 - 62.40885402
- 62.40885403 - 73.88257528
- 73.88257529 - 85.35629655
- 85.35629656 - 96.83001781
- 96.83001782 - 358.1965027

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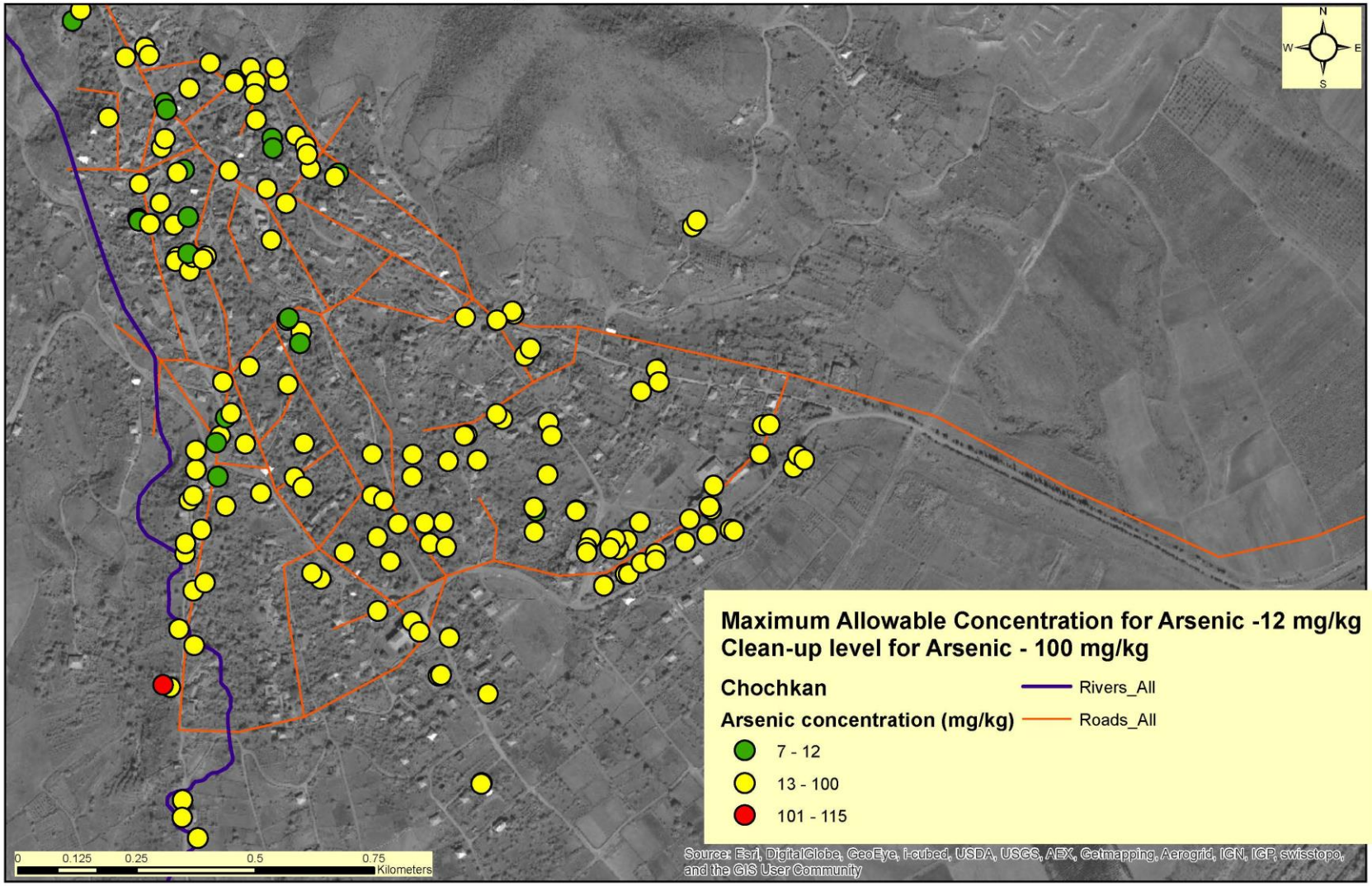
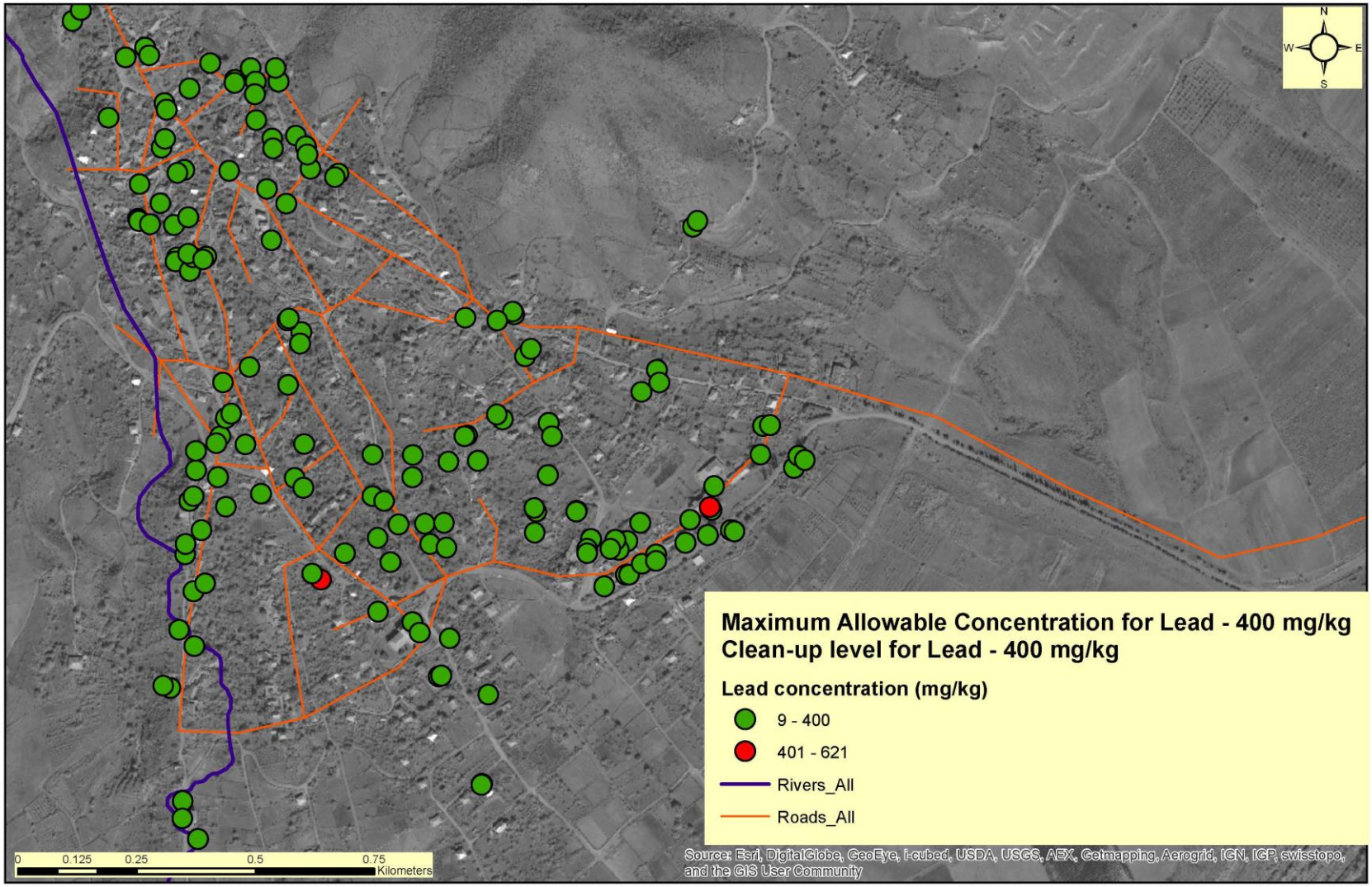
Units: Meter

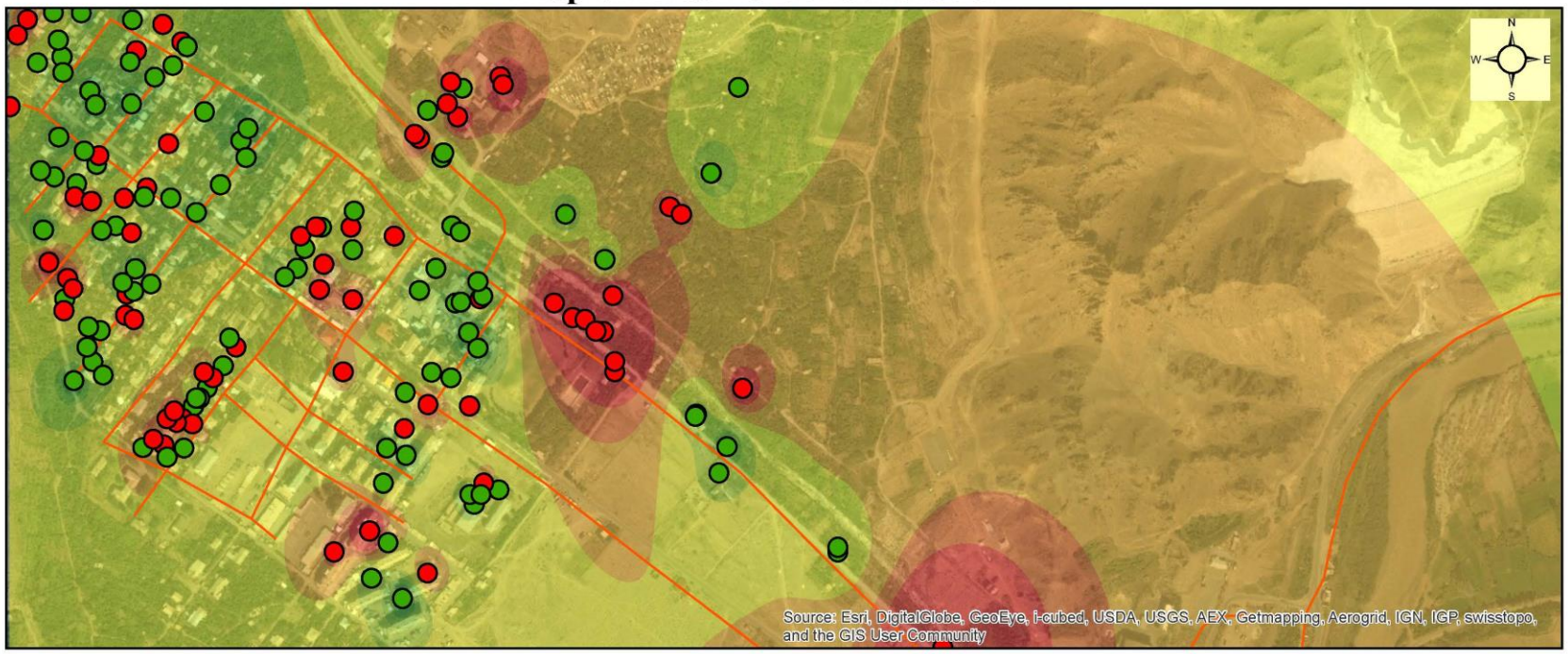
Chochkan Community
Map of Arsenic Concentration



Chochkan Community
Map of Lead Concentration



Agarak Community
Map of Arsenic Concentration



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Kilometers

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Auxiliary Sphere Type: 0.0000
Units: Meter

School of Public Health
American University of Armenia

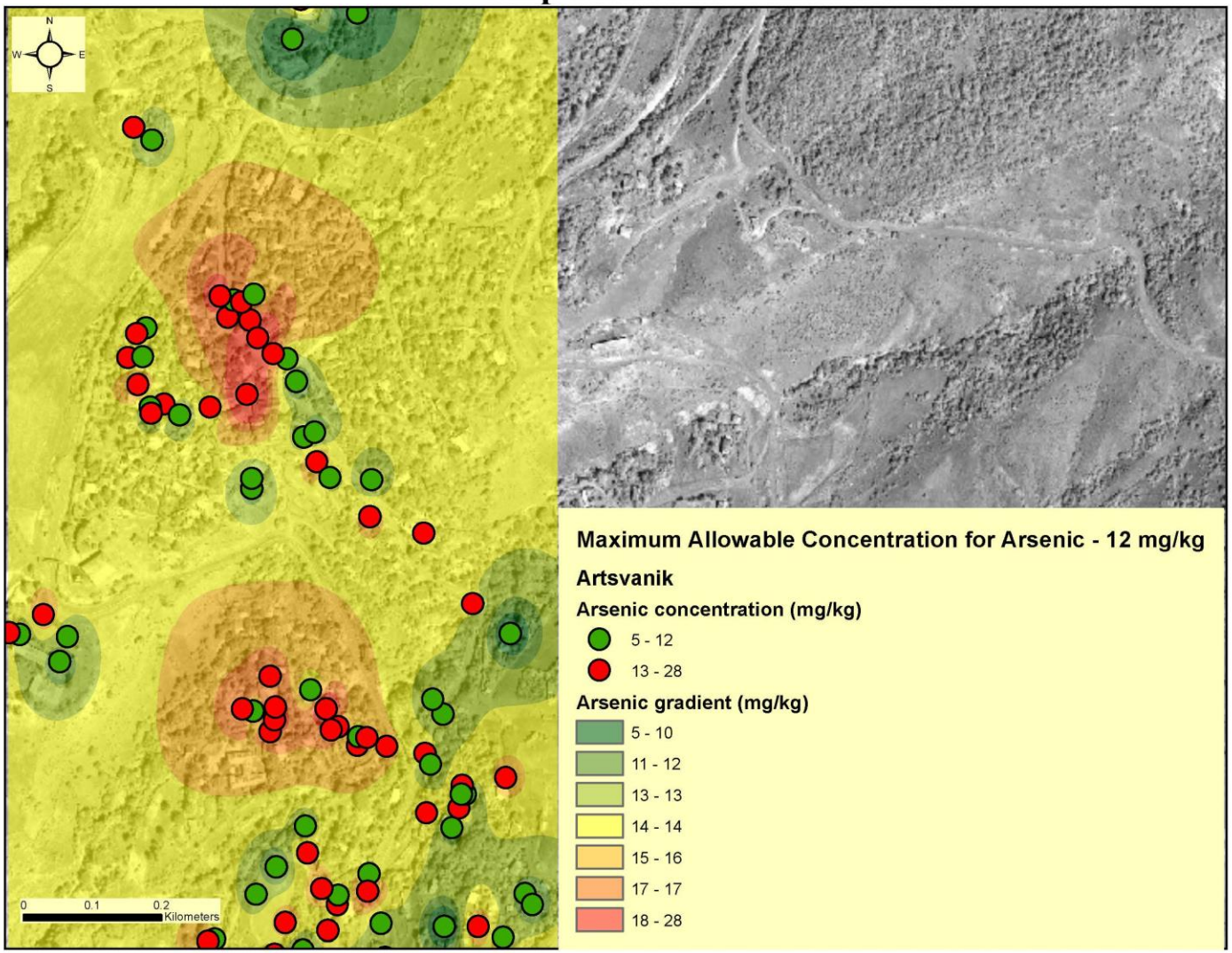
Maximum Allowable Concentration for Arsenic - 12 mg/kg
Clean-up level for for Arsenic - 100 mg/kg

Agarak

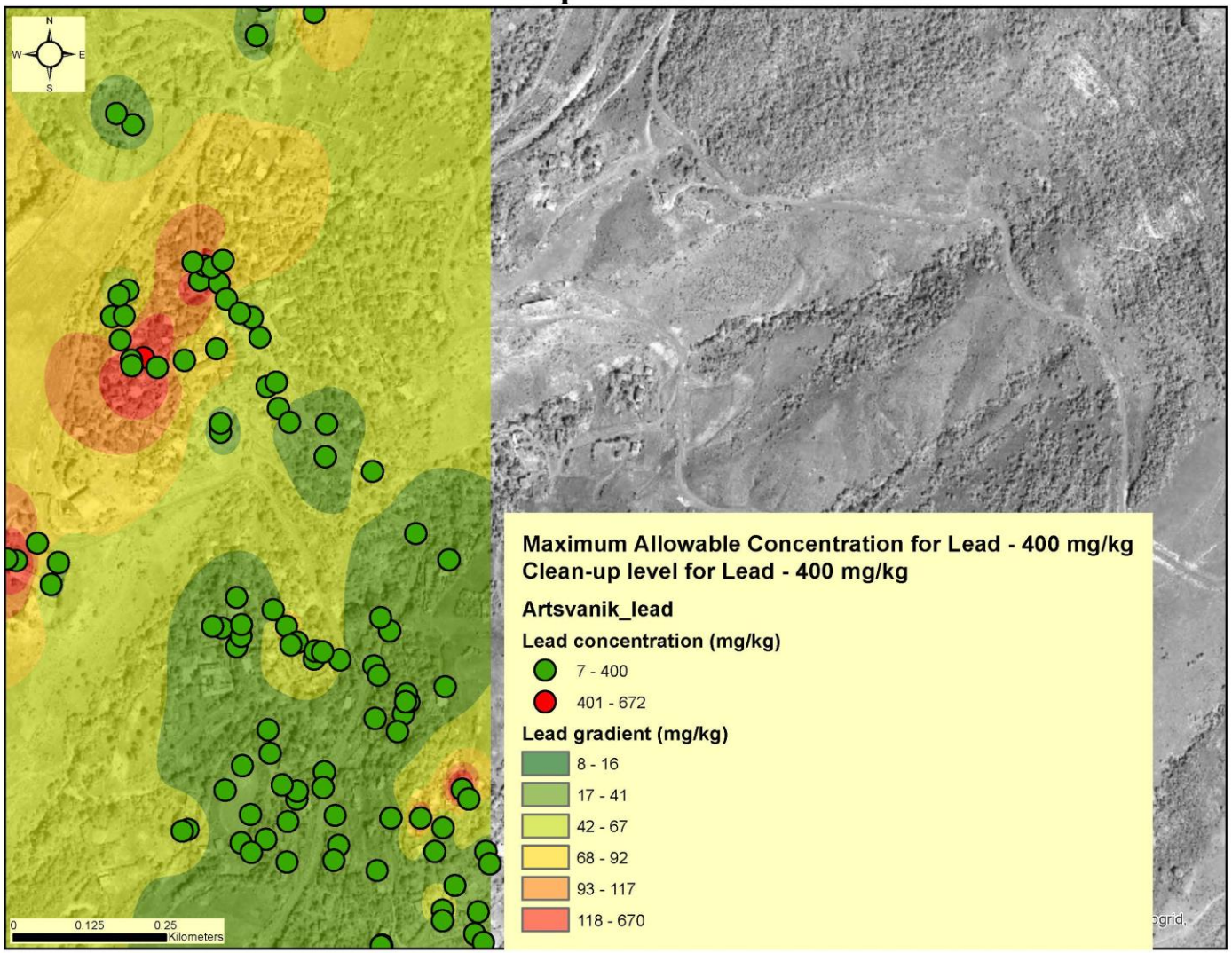
Arsenic concentration (mg/kg)
- 5 - 11
- 12 - 22
- Roads

Arsenic gradient (mg/kg)
- 5 - 9
- 10 - 9
- 10 - 10
- 11 - 11
- 12 - 12
- 13 - 13
- 14 - 22

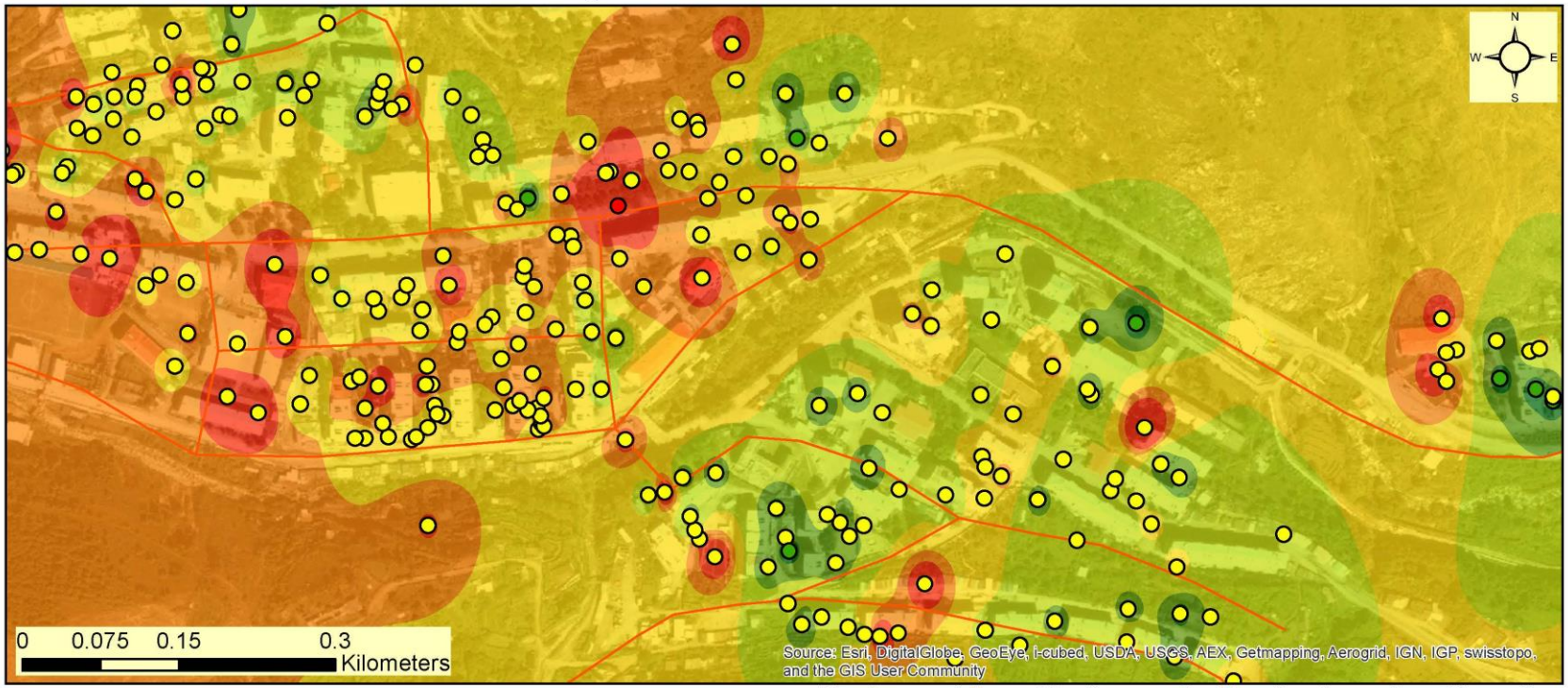
Artsvanik Community
Map of Arsenic Concentration



Artsvanik Community
Map of Lead Concentration



Kajaran Community
Map of Arsenic Concentration



Maximum Allowable Concentration for Arsenic - 12 mg/kg
Clean-up level for Arsenic - 100 mg/kg

Kajaran

Arsenic concentration (mg/kg)

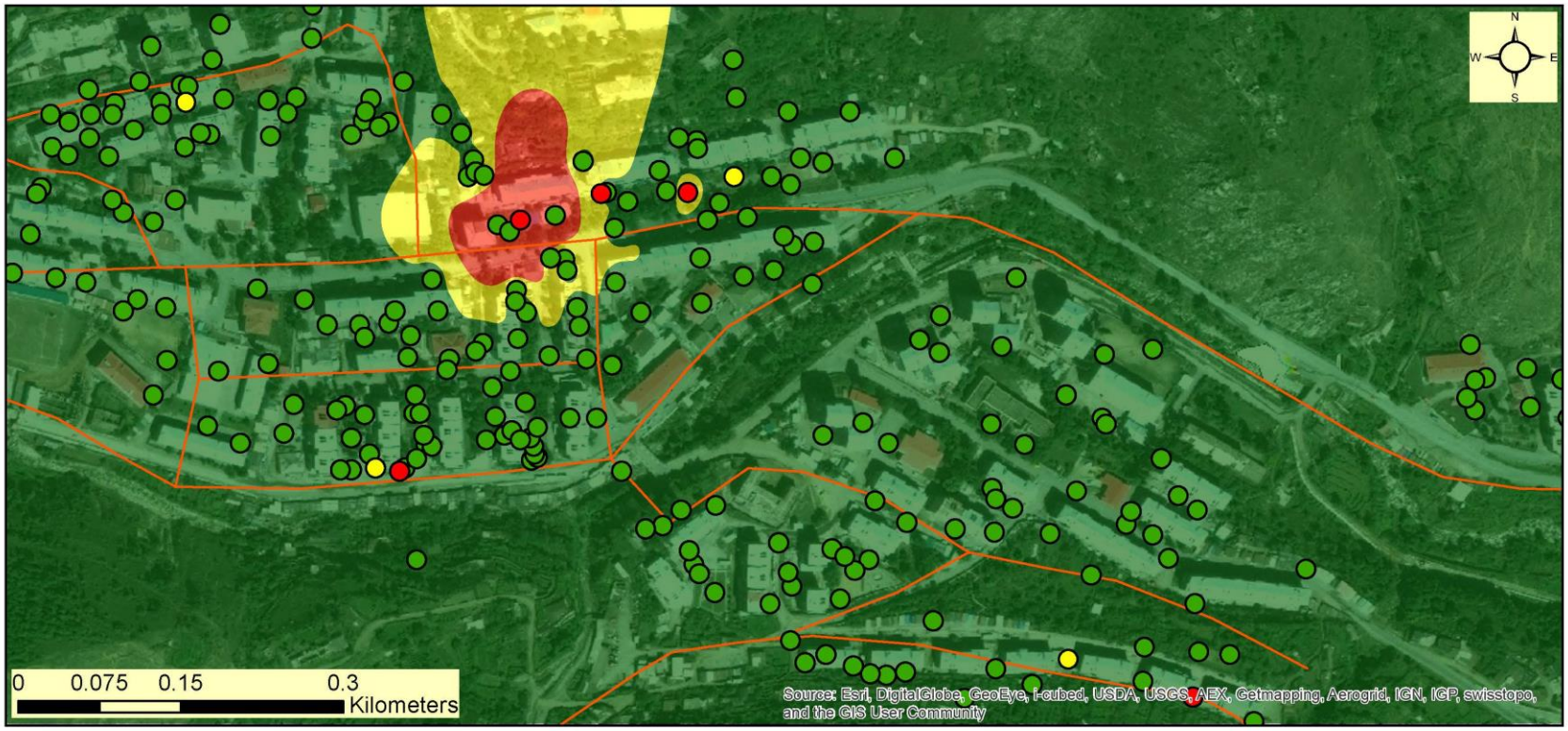
- 0 - 12
- 13 - 100
- 101 - 129
- Roads

Arsenic gradient (mg/kg)

- 0 - 17
- 18 - 23
- 24 - 28
- 29 - 34
- 35 - 39
- 40 - 128

Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Projection: Mercator Auxiliary Sphere
Datum: WGS 1984
False Easting: 0.0000
False Northing: 0.0000
Central Meridian: 0.0000
Standard Parallel 1: 0.0000
Auxiliary Sphere Type: 0.0000
Units: Meter

Kajaran Community
Map of Lead Concentration

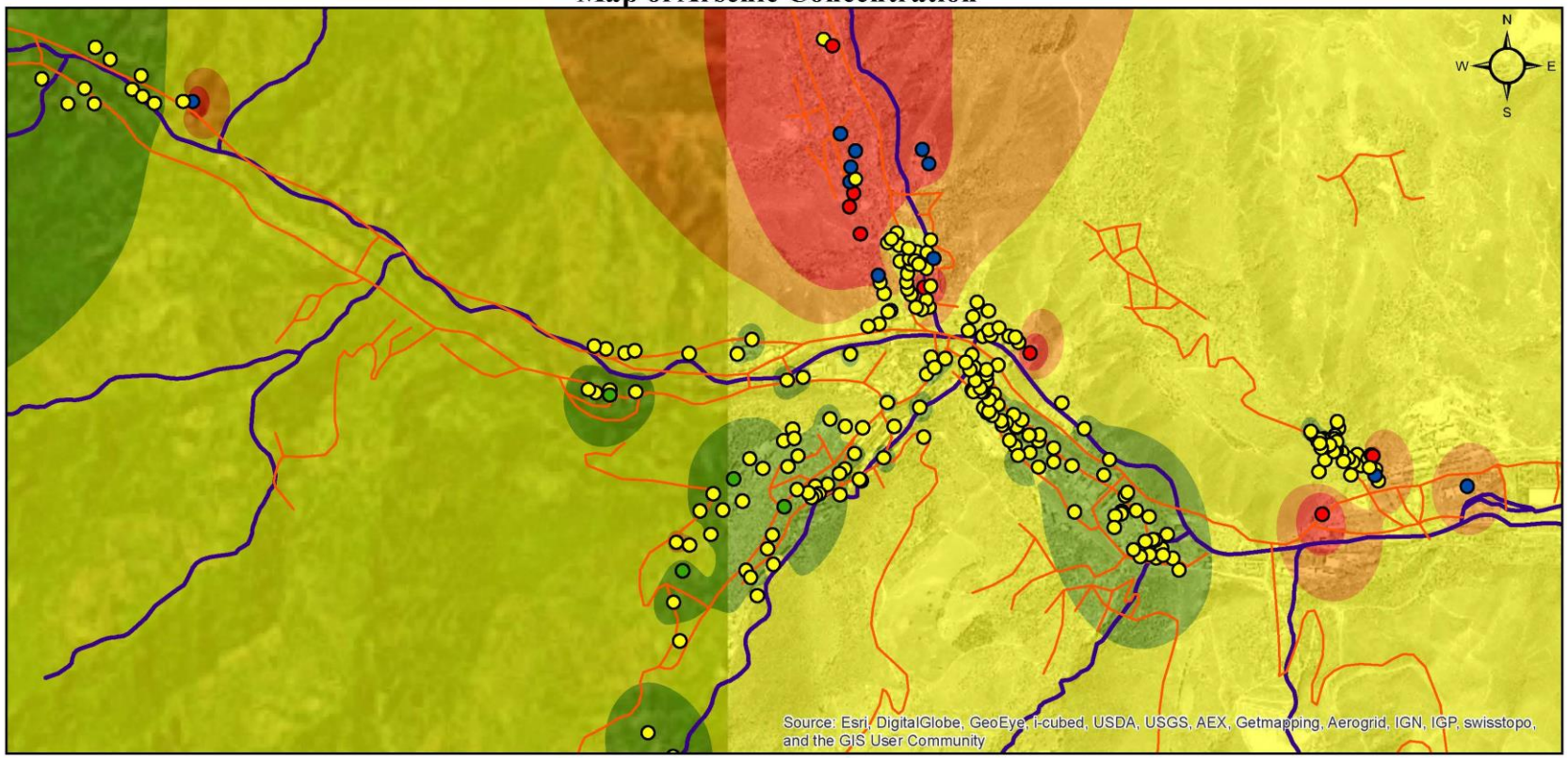


Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Projection: Mercator Auxiliary Sphere
Datum: WGS 1984
False Easting: 0.0000
False Northing: 0.0000
Central Meridian: 0.0000
Standard Parallel 1: 0.0000
Auxiliary Sphere Type: 0.0000
Units: Meter

Maximum Allowable Concentration for Lead - 400 mg/kg
Clean-up level for Lead - 400 mg/kg

Lead concentration (mg/kg)	Lead gradient (mg/kg)
8 - 400	13 - 703
401 - 800	704 - 1,772
801 - 76052	1,773 - 75,982
Roads	

Kapan Community
Map of Arsenic Concentration



0 0.3 0.6 1.2 1.8 2.4 Kilometers

Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Projection: Mercator Auxiliary Sphere
Datum: WGS 1984
False Easting: 0.0000
False Northing: 0.0000
Central Meridian: 0.0000
Standard Parallel 1: 0.0000
Auxiliary Sphere Type: 0.0000
Units: Meter

Maximum Allowable Concentration for Arsenic - 12 mg/kg
Clean-up level for Arsenic - 100 mg/kg

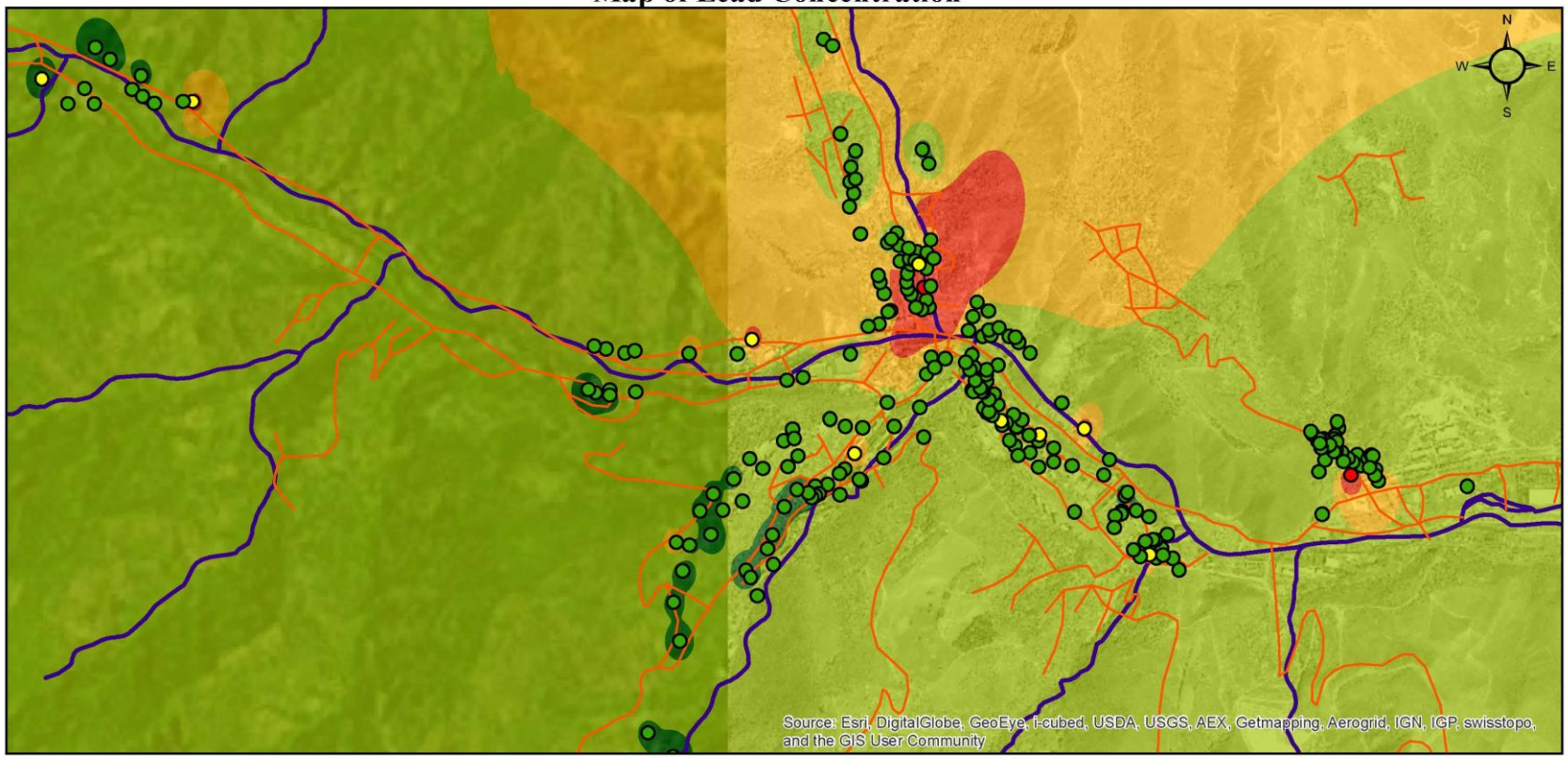
Kapan

Arsenic concentration (mg/kg)
- 7 - 12
- 13 - 50
- 51 - 100
- 101 - 400

Arsenic gradient (mg/kg)
- 8 - 12
- 13 - 25
- 26 - 38
- 39 - 51
- 52 - 395

Roads
Rivers

Kapan Community
Map of Lead Concentration



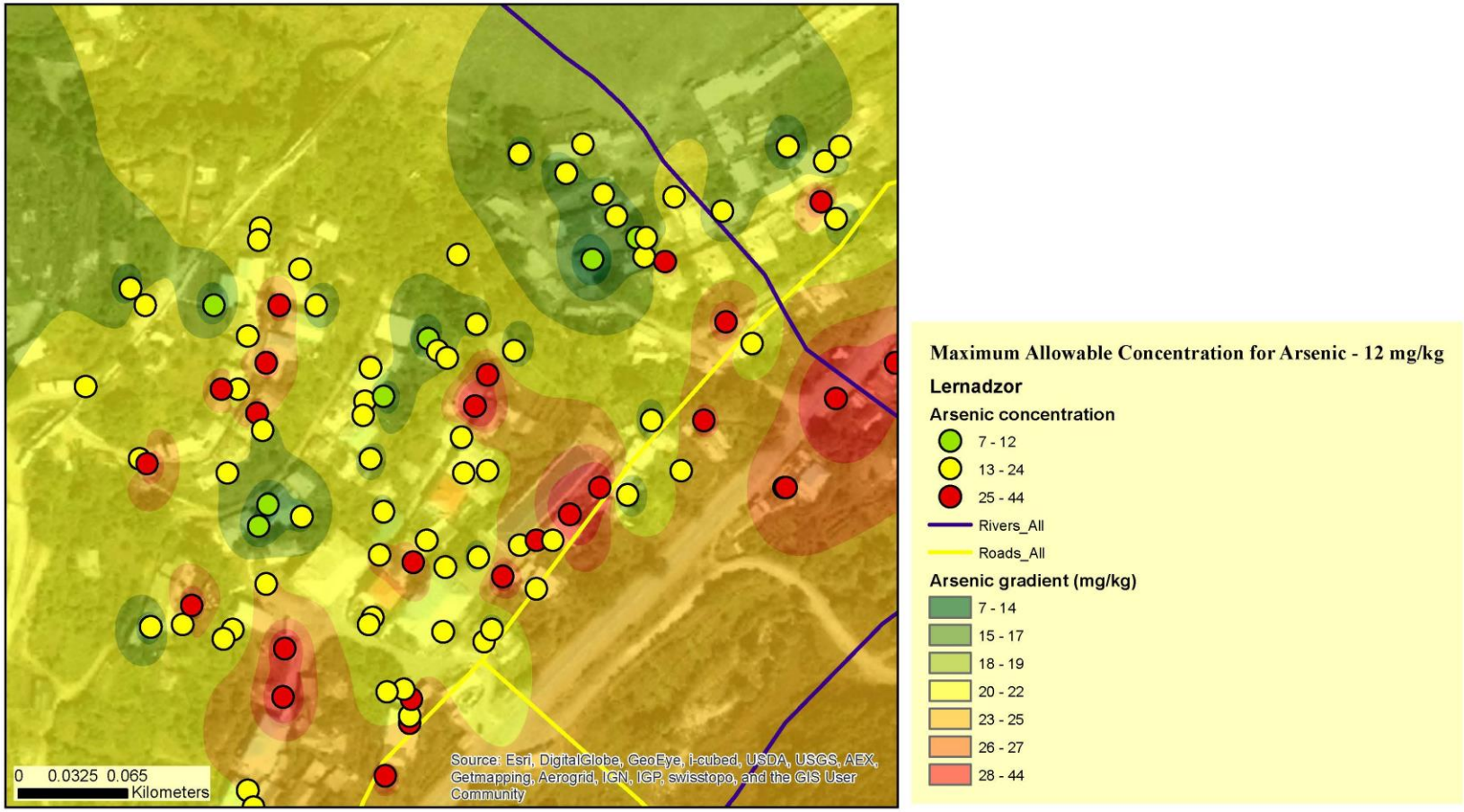
0 0.3 0.6 1.2 1.8 2.4
Kilometers

Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Projection: Mercator Auxiliary Sphere
Datum: WGS 1984
False Easting: 0.0000
False Northing: 0.0000
Central Meridian: 0.0000
Standard Parallel 1: 0.0000
Auxiliary Sphere Type: 0.0000
Units: Meter

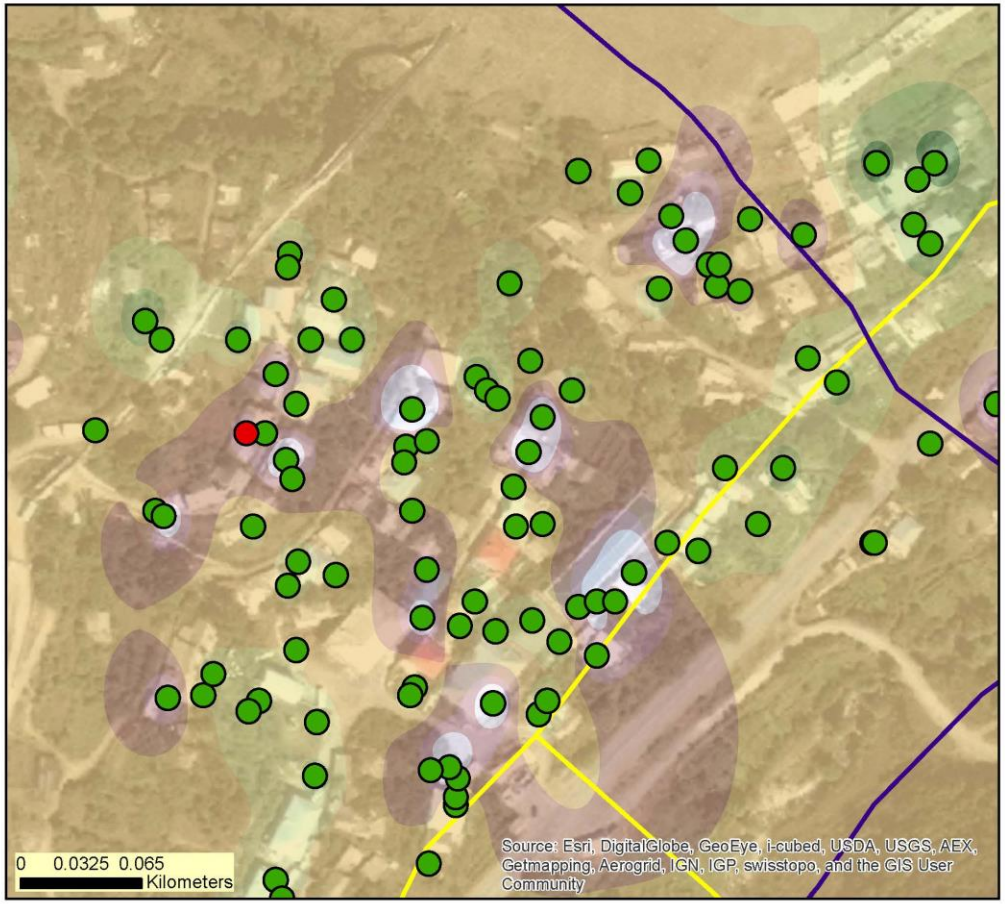
Maximum Allowable Concentration for Lead - 400 mg/kg
Clean-up level for Lead - 400 mg/kg

Lead concentration (mg/kg)	Lead gradient (mg/lg)	
14 - 400	18 - 96	329 - 19,216
401 - 800	97 - 212	Roads
801 - 19499	213 - 328	Rivers

Lernadzor Community
Map of Arsenic Concentration



Lernadzor Community
Map of Lead Concentration



Maximum Allowable Concentration for Lead - 400 mg/kg
Clean-up level for Lead - 400 mg/kg

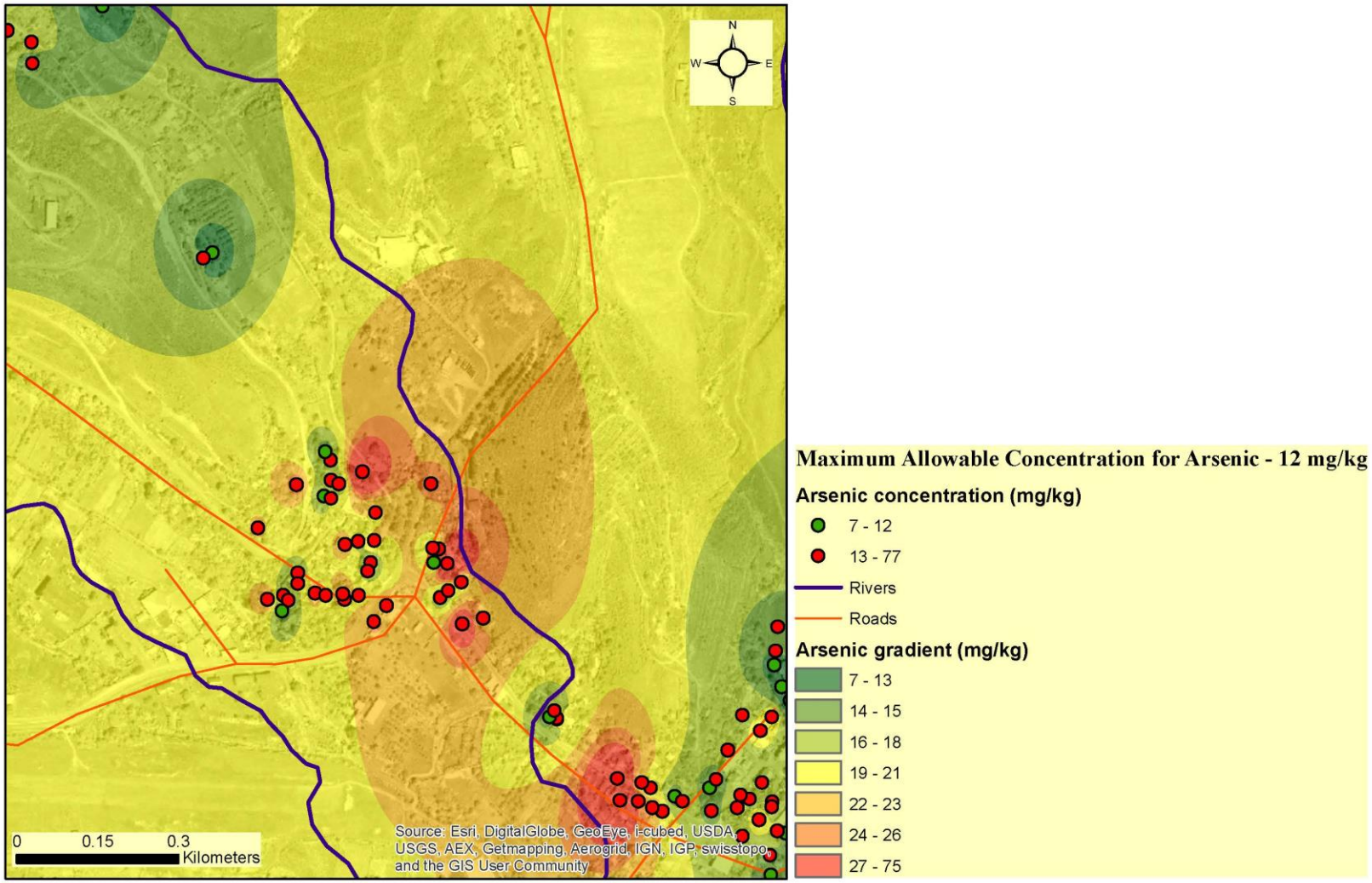
Lead concentration (mg/kg)

- 20 - 400
- 401 - 498
- Rivers_All
- Roads_All

Lead gradient (mg/kg)

- 20 - 35
- 36 - 47
- 48 - 58
- 59 - 70
- 71 - 82
- 83 - 94
- 95 - 330

Syunik village
Map of Arsenic Concentration



Syunik village
Map of Lead Concentration