AMERICAN UNIVERSITY OF ARMENIA
Center *for*
Responsible Mining

Results of Soil and Drinking-Water Testing in Kindergartens and Schools of Alaverdi City, Lori Marz, Republic of Armenia

Prepared by

AUA Center for Responsible Mining

Funded by

OneArmenia's crowdfunding campaign
"Let's Protect Armenia from Toxic Pollution"

Equipment donated by

Organization for Cooperation and Security in Europe (OSCE) Yerevan
United Nations Development Program (UNDP) Armenia

June 2016

TABLE OF CONTENTS

ABBREVIATIONS 3

ACKNOWLEDGMENTS 3

OVERVIEW AND KEY FINDINGS 4

BACKGROUND ON ALAVERDI COMMUNITY 9

BIBLIOGRAPHY 13

ANNEXES 15

Annex 1. Population of Alaverdi city by age and sex 16
Annex 2. Methodology on Soil Sampling and Testing 17
Annex 3. Methodology on Water Sampling and Testing 19
Annex 4. Soil Independent Monitoring Data 20
Annex 5. Drinking Water Monitoring Data 22
Annex 6. Determination of Background Levels of Metals in Soil of Alaverdi City 23
Annex 7. Inter-laboratory Comparison Tests Results 24
Annex 8. Measurements Exceeding the Armenian and International Soil Standard (SS) 25
Annex 9. Soil Test Results for Each Kindergarten and School 27
Annex 10. Complete Test Results of Soil Samples 36

ABBREVIATIONS

1A	OneArmenia
AUA	American University of Armenia
BL	Background level
CRM	Center for Responsible Mining
MAC	Maximum allowable concentration
OSCE	Organization for Security and Cooperation in Europe
SS	Soil Standard

ACKNOWLEDGMENTS

The AUA Center for Responsible Mining wishes to thank RA Ministry of Nature Protection, Lori Marz, Alaverdi Municipality, and individual kindergarten and school directors for their assistance and permissions to conduct soil and water testing in subject areas.

In addition, our work was greatly enhanced by the invaluable contribution of our Technical Advisory Board members, Dr. Robert Kurkjian (USA), Dr. Natella Mirzoyan (Armenia), and Dr. Gagik Melikyan (USA). Detail information on our Technical Advisory Board is available at the AUA Center for Responsible Mining webpage dedicated to environmental monitoring of mining communities in Armenia (http://crm.aua.am/independent_monitoring).

This report—fourth in a series of reports dedicated to 8 communities near mining or mineral processing facilities[1]—is funded by OneArmenia's crowdfunding campaign "Let's Protect Armenia from Toxic Pollution." Additional financial contributions were made by the UK Embassy Yerevan and a number of private donors.

The equipment used to prepare this report was donated by the Organization for Security and Cooperation in Europe (OSCE) and United Nations Development Program (UNDP) as a matching contribution in the same crowdfunding campaign.[2] We reiterate our gratitude to all our donors.

[1] Other communities included in the soil monitoring series include Ararat in the Ararat Marz, Armanis and Akhtala in the Lori Marz, as well as Kapan, Kajaran, Agarak and Syunik Village in the Syunik Marz.

[2] The OneArmenia crowdfunding closed in November 2014. OSCE and UNDP donated equipment arrived May 2015.

OVERVIEW AND KEY FINDINGS

This report provides the results of independent soil and drinking water[3] monitoring for heavy-metal pollution in the kindergartens and schools of the City of Alaverdi (Lori Marz, Republic of Armenia) performed by the American University of Armenia (AUA) Center for Responsible Mining (CRM). Alaverdi is one of the largest industrial centers of Armenia.

The soil monitoring in the City of Alaverdi was performed for 5 kindergartens and 4 secondary schools.[4] A total of 1277 children studies in the kindergartens and schools. Permissions were obtained from authorized bodies to conduct the sampling and testing. This included permissions from the municipality of Alaverdi for kindergartens and the Marz government for the schools.

The soil and water sampling and testing were conducted and documented according to protocols developed by the AUA Center for Responsible Mining based on international standards and guidance.[5] Total of 37 soil samples were collected from the playgrounds and exterior common spaces of Alaverdi's kindergartens and schools. The representative water sample was collected from the water taps in the Kindergarten №1 and in the School №12. The samples were brought to the AUA Center for Responsible Mining's laboratory. In soil samples the concentrations of total arsenic, copper, cadmium, mercury and lead were tested using Trace2o, Metalyser HM2000 Deluxe, Soils (see Annex 2 for Methodology of Soil Sampling and Testing). In water samples, the concentrations of total arsenic, arsenic (III), cadmium, copper, lead, mercury, zinc, manganese, aluminum, boron, chromium (VI), iron and nickel were tested using the portable heavy metals analysis system, with a combination of electrochemical and photometric instruments (Metalyser Deluxe HM2000 and Metalometer) from Trace2o Company (see Annex 3 for Methodology of Water Sampling and Testing).

The determination of background level (BL)[6] for each metal is given in Annex 6. Quality control of the results was carried out by conducting inter-laboratory comparisons (Annex 7). The comparison tests were conducted for 5 soil samples and 2 reference samples in the qualified laboratories of the RA Ministry of Nature Protection's Environmental Impact Monitoring Center SNCO and the RA Ministry of Health's National Center for Disease Control and Prevention SNCO. The comparison of soil test results with International Soil Standards is shown in Annex 8. Results for each individual kindergarten and school are presented in Annex 9.

Key Findings

With respect to drinking water, high levels of heavy metals in drinking water were not detected (Annex 5). The drinking water for the Alaverdi community, same as for the Akhtala, is supplied from the Lori-Berd major water pipeline with intake structure consisting of 19 groundwater catchments located near Lori Berd village and 32km far from mineral processing or other industrial activities.

[3] Surface water, such as the Debed river, which is used for irrigation, was not investigated due to the scope of the study was limited to the school, agricultural soil and water will have to be studied separately.

[4] No samples were taken from one kindergarten, one primary school and 5 secondary schools as the sites were covered by asphalt. The soil monitoring was not conducted for two high schools (№5 high school after St. Shahumyan and №8 high school after Sayat-Nova) in Alaverdi city as it was deemed that high-school students are less vulnerable to exposure to contaminated soil because of their height and less frequent outdoor playtime.

[5] Protocols used are available at http://crm.aua.am.

[6] The BLs for metals were determined based on preliminary study data that is not sufficient for establishing the exact BLs for each metal in soil of Alaverdi community. The determination of BL needs further deep investigation.

Also, reportedly, the pipes distributing water were replaced with new pipes in 2013 and do not contain lead.[7]

With respect to soil, our key finding for each of our 5 test metals is summarized in Figure 1 and described in the text below.

Figure 1. Heavy metals concentrations in soil samples from Alaverdi's kindergartens and schools, % out of exceeding Armenian SS, statistical summary, and international comparatives.

		Arsenic		Cadmium		Copper		Lead		Mercury	
Armenian Soil Standard *(mg/kg)*		***2***		*******		***3***		***32***		***2.1***	
Kindergarten/ School	**No. of samples**	GM** mg/kg	*% of total*	GM mg/kg	*% of total*	GM mg/kg	*% of total*	GM mg/kg	*% of total*	GM mg/kg	*% of total*
Kindergarten №1	3	41.96	100%	0.86	-	555.96	100%	57.91	100%	<0.1	0%
Kindergarten №2	5	45.53	100%	1.62	-	723.00	100%	85.36	100%	<0.1	0%
Kindergarten №4	3	55.32	100%	1.86	-	628.64	100%	65.91	100%	<0.1	0%
Kindergarten №5	5	22.40	100%	0.91	-	163.88	100%	37.35	100%	<0.1	0%
Kindergarten №6	4	10.91	100%	0.54	-	94.60	100%	34.07	66.7%	<0.1	0%
School №1	4	104.90	100%	6.99	-	2970.58	100%	184.51	100%	<0.1	0%
School №4	3	14.75	100%	0.51	-	147.52	100%	30.28	33.3%	0.11	0%
School №7	5	28.49	100%	0.73	-	150.74	100%	28.22	0%	<0.1	0%
School №12	5	24.70	100%	0.73	-	183.95	100%	31.08	40%	0.23	0%
Total GM	***37***	***31.79***	***100%***	***1.12***	***-***	***327.32***	***100%***	***49.75***	***69.4%***	<0.1	***0%***
Standard deviation	-	***27.06***	***-***	***1.98***	***-***	***873.86***	***-***	***48.74***	***-***	***0.09***	***-***
Minimum	-	***10.32***	***-***	***0.47***	***-***	***87.77***	***-***	***20.87***	***-***	***<0.10***	***-***
Maximum	-	***107.60***	***-***	***7.83***	***-***	***2987.00***	***-***	***192.50***	***-***	***0.23***	***-***
Background level***	***10***	***18.3***		***0.22***		***227.2***		***146.3***		***1.14***	
International maximum allowable concentrations (mg/kg)*****											
Russia		*2*		*-*		*3*		*30*		*2.1*	
Belgium		*110*		*6*		*400*		*700*		*15*	
Netherlands		*55*		*12*		*190*		*530*		*10*	
Germany		*50*		*20*		*-*		*400*		*20*	
France		*37*		*20*		*190*		*400*		*7*	
Sweden		*15*		*0.4*		*100*		*80*		*1*	
Norway		*2*		*3*		*100*		*60*		*1*	
Canada		*12*		*14*		*63*		*140*		*6.6*	
China		*30*		*0.3*		*50*		*250*		*0.3*	
US EPA screening level		*22*		*85*		*250*		*400*		*-*	

Notes:
(*) Armenian SS has not established a MAC for cadmium.
(**) Geometric mean (GM) is a type of average, which indicates the typical value of a set of numbers by using the product of their values (as opposed to the arithmetic mean which uses their sum).
(***) See Annex 6 for methodology for calculating background levels (BL).
(****) See Annex 8 for percentage of soil samples exceeding international standards.

- **Arsenic** concentrations in our soil samples ranged from 10.32 to 107.60 mg/kg. The geometric means (GMs) of all samples exceeded the Armenian Soil Standard (SS)[8] by 15.9 times.

[7] The pipes distributing water in Alaverdi city were replaced in the frame of Water Supply and Sewerage Sector Project sponsored by Asian Development Bank, 2013. The report is available at http://armwater.am/files/adb/armenian/IEE/III.%20Lori_IEE-arm/III.%20Lori%20IEE%20armenian.pdf

[8] The Armenian Soil Standards are specified in Order #01, issued by the Minister of Health of RA on 25.01.2010 on "Hygienic requirements N 2.1.7.003-10 establishing sanitary norms and rules for soil quality." It should be noted that there

Armenian SS for arsenic, at 2 mg/kg of soil, is among the most stringent in the world (Figure 1). It matches that of Norway and Russia, the latter being the basis of the Armenian SS. However, the majority of soil samples exceeded the standards set by the countries listed in Figure 1. Annex 8 details the percentage of soil samples exceeding these international standards.

The soil test data were also compared with the background level of arsenic, that is, in areas that are either distant from sources of pollution and/or are deep enough underground to make it unlikely to have been impacted by industrial/mining activity in Alaverdi city. Our reference area study (Annex 6) shows that the BL for arsenic in the soil of Alaverdi is 18.3 mg/kg. The GM of all soil samples exceeded the BL by 1.7 times. Based on our current level of BL analysis, it is not possible for us to link the level of arsenic in soil to industrial and mineral processing activities in the city. Further analysis would have to be done to find or exclude causal link.

Our findings, however, compel us to conclude that arsenic is a heavy metal of high concern in the Alaverdi community. Arsenic exceeded the almost all international comparatives in Annex 8. Our recommendation is that the playgrounds in kindergartens and schools should be covered by surface materials (asphalt, concrete, rubber, etc.) that are "washable" (by rain or hosing down) and would minimize children's exposure to arsenic in soil.

In addition, we are compelled to raise the question about the currency and relevance of Armenian SS. There is a need for a national discussion to update the country's soil standard for arsenic.

- **Cadmium** concentrations in soil samples ranged from 0.47 to 7.83 mg/kg. As the Armenian SS does not specify allowable concentrations for cadmium, it is not possible to draw conclusions based on Armenian law.

  Many of our soil samples, however, had cadmium at levels exceeding standards set by China (0.3 mg/kg) and Sweden (0.4 mg/kg), countries with the most stringent standards internationally (Figure 1). In addition, cadmium in the samples collected from the School N1 exceeds the standards set by Norway (3 mg/kg) and Belgium (6 mg/kg). Other comparatives we've studied have significantly higher allowable concentrations: Netherlands 12 mg/kg, Germany 20 mg/kg, and US EPA 85 mg/kg, to name a few. None of our samples had cadmium levels that exceeded the allowable limits set by these standards.

  Background level analysis for cadmium shows an average of 0.22 mg/kg (Annex 6), lower than international comparatives in Annex 8.

  These findings compel us to conclude that: a) Armenian SS for cadmium are in need of updating and b) if Armenia concludes that the Swedish and Chinese standards or even more stringent ones are the relevant ones for Armenia, then the solution for arsenic specified above—viz., covering playgrounds with materials that reduce children's exposure to soil and dust with metals of concern—will also minimize exposure risk to cadmium.

is yet another soil standard RA Government Decision # 92-N, 25.01.2005 on "Establishment of the assessment procedure of the economic activities impact on soil resources" but this regulation is neither implemented by the RA Ministry of Health nor RA Ministry of Nature Protection.

- **Copper** concentrations ranged from 87.77 to 2987.00 mg/kg. The Armenian SS for copper is 3 mg/kg. Hence, all soil samples exceeded Armenian SS for copper, with the mean for all samples being 109.1 times of the Armenian SS.

  Armenia, along with Russia (on which Armenian standards are based), has the most stringent standards with respect to copper from our international comparatives (Figure 1). However, copper in the most soil samples, especially in the samples collected from the School №1, exceeded all international standards in Annex 8. Our comparative countries have soil standards ranging from 50 mg/kg in China to 400 mg/kg in Belgium.

  Our analysis shows a background level of 227.2 mg/kg for copper in Alaverdi, about 76 times higher than Armenian SS.

  Our findings, however, compel us to conclude that copper is a heavy metal of concern in the Alaverdi community. While it may be reasonably argued that soil cannot be expected to be cleaner than the background level, our recommendation is that kindergarten and school soil has to be kept to a higher standard. We recommend the same solution as for arsenic specified above—viz., covering playgrounds with materials that reduce children's exposure to soil and dust containing metals of concern.

- **Lead** levels in soil samples ranged from 20.87 to 192.50 mg/kg. The Armenian SS for lead is 32 mg/kg. This is among the most stringent standards (along with Russia) among international comparatives presented in Figure 1.

  Notwithstanding, the part of our soil samples exceeded the standards set by Norway (60 mg/kg), Sweden (80 mg/kg), as well as some of the soil samples exceeded the standards set by Canada (140 mg/kg) (Annex 8).

  It should be noted that our analysis shows a background level for lead in Alaverdi is 146.3 mg/kg, about 4.6 times higher than the Armenian SS.

  These findings compel us to conclude that lead is a heavy metal of concern in the Alaverdi city. Based on knowledge of international research on lead contamination in soil and background levels, the amounts detected in Alaverdi raise immediate alarm for children's health risk insofar due to the lead toxicity. So, our recommendation is that the playgrounds should be covered by surface materials that reduce children's exposure to soil and dust with metals of concern and minimize exposure risk to lead.

- **Mercury** levels in the most soil samples were not detected. The detected measures range from 0.10 to 0.30 mg/kg. Our analysis shows that the background level of mercury is 1.14 mg/kg, which is 2 times less than mercury allowable level set by Armenian SS (2.1 mg/kg).

  The detected amounts of mercury didn't exceed the Armenian SS, as well as the international standards in Figure 1. Our comparative countries have soil standards ranging from 6.6 mg/kg in Canada to 20 mg/kg in Germany (Figure 1). US EPA has not established an allowable level for mercury.

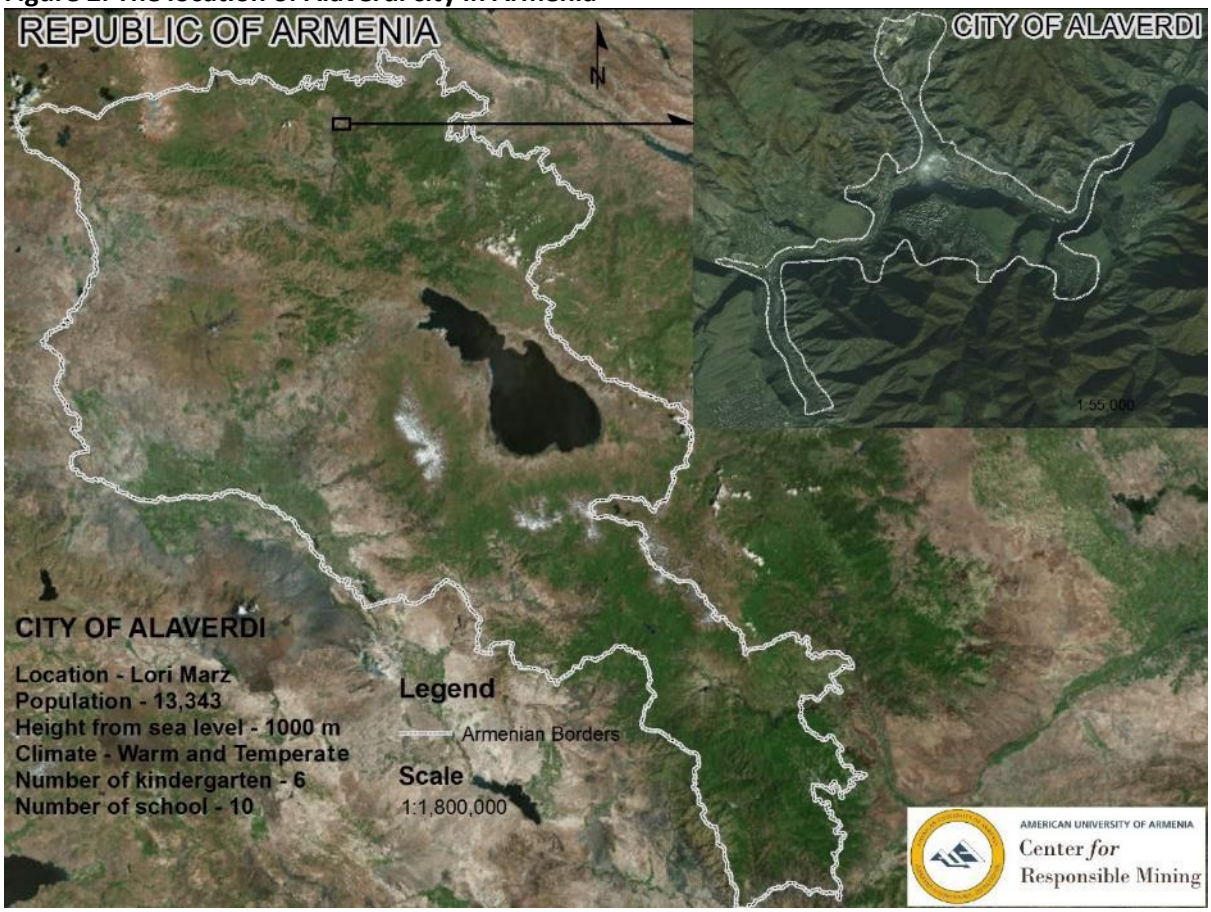
Recommendations

- Discuss findings with community leaders as well as school and kindergarten heads to determine effective action needed.
- Investigate the Debed river pollution by heavy metals due to mining activity in the Alaverdi city.
- Apply this study method for other parts of Alaverdi city (park, yard, public place, playfield), whenever possible increasing the list of investigated metals, such as chromium, zinc, nickel, manganese, etc.
- Implement continuing soil monitoring every couple of years in Alaverdi community to monitor changes in soil contamination by heavy metals due to mining and other industrial activities.
- Check the source and quality of a new soil to be brought to the playground of kindergartens and schools.
- Establish a soil-quality database using this first study as a baseline.
- Initiate discussion at the national level to review and revise Armenia's soil standards, including the methodologies for determining these standards. Armenia should utilize global best-practice approaches when revising its standards.

BACKGROUND ON ALAVERDI COMMUNITY

The city of Alaverdi is located in the sub-region of the Small Caucasian mountain gorge, at a height of 1000m above sea level, on slopes, occupying the Valley of Debed River and Sanahin lowland. The height of Debed Valley is almost 350m, with Gugarats Mountains on the left and Virahayots highlands on the right (Figure 2). Debed river flows through the center of the town dividing it into 2 parts. The older northern half of Alaverdi is located in the Debed canyon, while the newer southern half of the town is located in the Sanahin plateau. It is surrounded by large villages including Sanahin at the southeast, Haghpat at the east, Akori at the west, and Odzun at the southwest. The Somkheti Mountains dominate over the town from the north and the northwest while the Pambak Mountains dominate from the south and the southwest. The Lalvar peak with a height of 2544 meters is located in the northwest of the town.

Figure 2. The location of Alaverdi city in Armenia



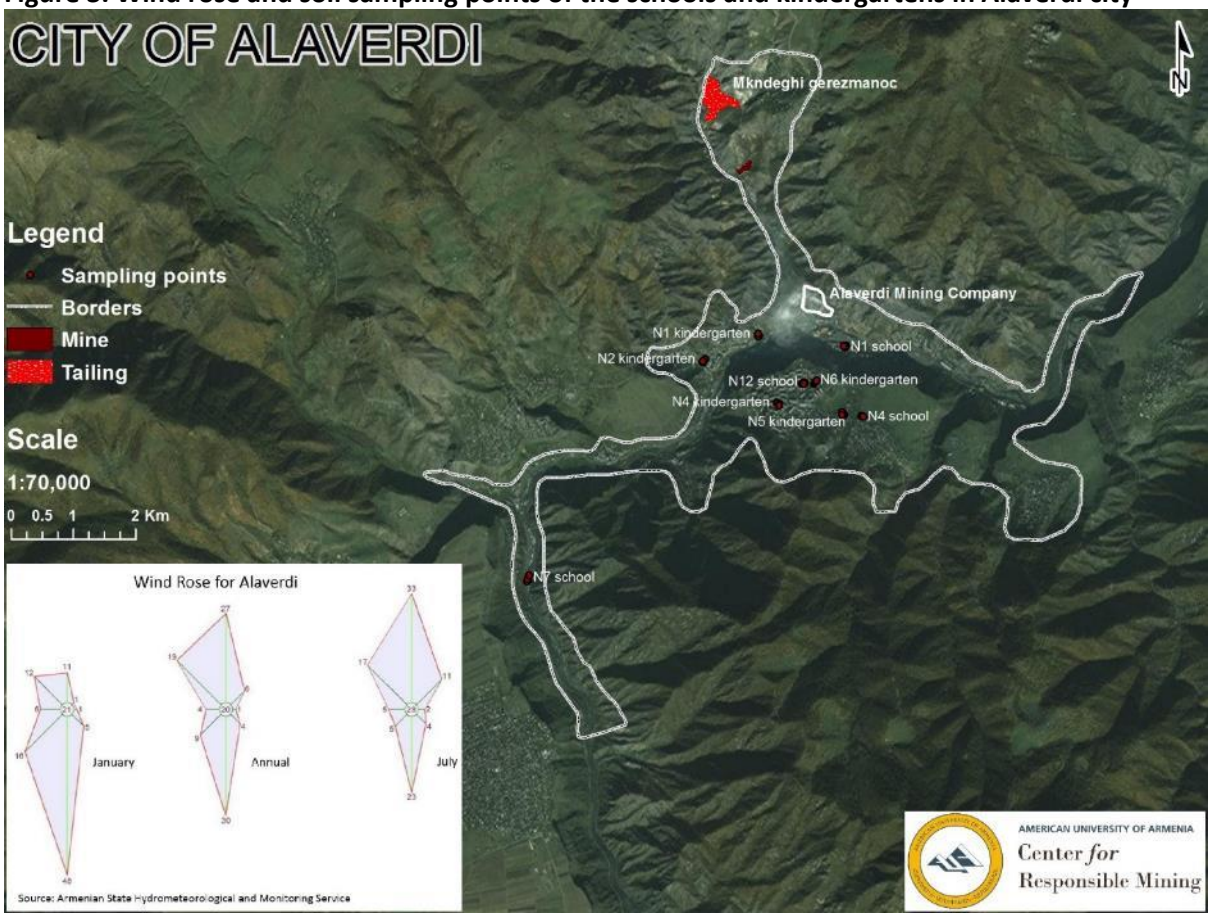
The region of modern-day Alaverdi was most probably settled during the 1st half of the 2nd millennium BC. The village located in the region was named “Manes”. In 1912 that village, as well as the upper residence thereof (by Alaverdi and the factory “Piritis”) became the city of Alaverdi with a permanent population of 3235 people, except the workers of the plant. In 1918 the city became a part of the newly-formed the Republic of Armenia. Between 1959 and 1962 the borders of Alaverdi city were expanded while the southern half of the city was built in the Sanahin plateau on the right

bank of Debed river. Nowadays, Alaverdi city is divided into two main districts-- Alaverdi with Piruzyan, Shahumyan, Engels and Jravazan sub-districts and Sarahart with Sanahit sub-district.

Climate and landscapes. Alaverdi has a hot climate with mild winters of regular snow. The highest temperature was recorded in July by 30 to 35°C, and the lowest in January and February by -17°C. In average, the winter starts in the second 10-day period of December and ends at the beginning of March. The winter weather is unstable. Frosts, as well as sunny warm days are often. The spring is long-lasting, with regular humidity. The spring late frosts end in the second half of April. The summer is hot and humid. The relative humidity is rarely below 60%. The annual atmospheric precipitation reaches up to 551mm.

Alaverdi landscape (basically in Debed Valley) consists of sloped ridges, except for Sanahin lowland. The left bank slopes descent to the river abruptly, whereas the right bank slopes gradually. The area is rich with copper-sulfur volcanic rock, gypsum and stone reserves. Due to the exploitation of copper mine, the mountainous forest landscape was significantly changed in the area (Figure 3).

Figure 3. Wind rose and soil sampling points of the schools and kindergartens in Alaverdi city



Population. As of the 2011 census, the permanent population of the city is 13,343 with 6,144 male and 7,199 female. The population in the age group 0-19 is 3,298 (Annex 1).

Wind patterns. The RA Ministry of Emergency Situations' Armenian State Hydrometeorological and Monitoring SNCO prepares the wind rose for Alaverdi city based on long-term meteorological data. The wind rose indicates that the 48% of winds are in the north to south direction during winter and the 33% of winds are in the south to north during summer (Figure 3).

Industry. Copper smelting and mining facilities in the city of Alaverdi have a history of over 245 years. The first small mining factory was constructed by French in the 19th century, when the exploitation of copper mine was started-- new mine pits opened, new stokeholds, heaters, workshops, ancillary buildings were built. As a result, Alaverdi was developing as a center of the mining industry. Armenia produced 1/5 of the overall cooper of Russia, the 67% of which was from Alaverdi and its surroundings. In the 18th and 19th centuries Alaverdi copper smelter was able to produce from 60 to 200 tons of copper per year. At the beginning of the 20th century, when the Soviet power was established in Alaverdi, the production capacity was at about 2,000 tons of copper per year. The peak of production was achieved in 1980s-90s, when nearly 55,000 tons of refined copper was produced annually.[9]

Photograph 1. Mining industry in Alaverdi city, Lori Marz

Source: https://www.emaze.com/@AIFOOTIR/Presentation-Name

In 1988 the earthquake and the transit to a new socio-economic reality had its impacts on the industries of Alaverdi. The operation of the copper plant was stopped. After the closure of the mining plant in 1988-1989 years, the territory thereof was used by various industrial facilities, with regularly changing profiles and capacities. The mining plant, reopened in 1997 by "Manes and Vallex" CJSC, then in 2002 company gained its current name "Armenian Copper Programme". Today comprises the largest portion of the GDP for the Alaverdi Community and the whole Marz of Lori.[10]

The company operates the Alaverdi copper mine that is located in 3km north Alaverdi city. The approved mine reserves are around 158.69ha, with the following average metal content: 5.16% of

[9] The data is available at http://www.alaverdi.am/en/history/general-information.html

[10] The information is provided by the UNEP, OSCE Global Environmental Outlook for Cities Program's "GEO Alaverdi. Environment and Urban Development" study and available at http://www.grida.no/files/publications/GEO%20Alaverdy%20FINAL%20ENG.pdf

copper, 0.12g/t of gold, 5.76g/t of silver.[11] The productive capacity of the company allows production of two types of blister copper - Class A, with higher content of gold and silver, and Class B, with relatively low content of gold and silver. The main input for production of the Class A blister copper is copper concentrate. The product used for producing Class B blister copper (re-smelted secondary copper) is basically copper scrap, which is purchased domestically. Copper content in Class B blister copper is minimum 98.5 %, while silver and gold content could be up to 140 gr/t and 4 gr/t respectively.[12]

In the 1980s, a repository site, called "the arsenic grave", for toxic metals containing substances from Alaverdi Copper Smelting Company was built in the north of Alaverdi city. In present, the arsenic repository site abandoned and the isolation walls are almost destroyed with huge piles of toxic chemicals and disgusting smell being exposed to erosion.[13]

Environmental issues of the community. Alaverdi city faces several environmental issues. Based on the monthly and annual reports[14] of RA Ministry of Nature Protection's Environmental Impact Monitoring Center SNCO, the air of Alaverdi city the Armenian Air Standard are exceeded by 1.9-2.4 times for sulfur dioxide (58 cases of exceeding the air standard in 2015), as well as the maximum concentrations of the nitrogen dioxide and dust exceeded the air standards by 2.2-4.4 and 1.9-12.0 times, accordingly.

The final report[15] of the EU Project: Trans-Boundary River Management Phase II for the Kura River basin – Armenia, Georgia, Azerbaijan is indicated that the Debed rivers' water quality correspond to poor (IV) class and the aquatic ecosystem has suffered due to high level of water contamination by heavy metals, such as copper, zinc and iron. Based on the Final report of "Thorough Risk Assessment of 11 Communities in Armenia" prepared by AUA School of Public Health partnered with the Blacksmith Institute,[16] the soil in Alaverdi community is contaminated by toxic metals, such as arsenic, chromium and lead. In addition, the report on "Assessing a risk of toxic elements discharge from an arsenic-containing substance repository site in the city of Alaverdi" prepared by National Academy of Sciences' the Center for Ecological-Noosphere Studies[17] revealed that the high level of arsenic in the soil, sediments and rainwater was detected in the area near "the As grave" in Alaverdi city.

In addition, a number of NGOs, including the Alaverdi Aarhus Center[18] when interviewed for during our site visit, as well as scientific researches expressed their concerns about air, soil, water and food pollution in Alaverdi city, believing that such pollution damages the environment and has led to the increased health risks.[19]

---

[11] The data is provided by the RA Ministry of Emergency Situation and the RA Ministry of Energy and Natural Resources in a letter response to inquiry by the Transparency International Anticorruption Center. October 2014.
[12] The data is available at http://acp.vallexgroup.am/en/About-Us-History
[13] The data is vailable at http://www.ecolur.org/en/news/waste/vghostv-of-arsenic-burial-site-in-alaverdi/1495/
[14] The reports are available at http://www.armmonitoring.am/
[15] The report is available at http://www.kura-aras.org/
[16] The report is available at http://chsr.aua.am/files/2015/01/TRA-report-_ENG-webpage-June_2015.pdf
[17]The reports are available at
http://aarhus.am/CASE/i-report-2010-english1.pdf
[18]The reports are available at
http://aarhus.am/?s=Alaverdi&lang=en
http://www.arminfo.info/index.cfm?objectid=A3AB8CC0-1916-11E2-AC8DF6327207157C
http://www.armeniapedia.org/wiki/Alaverdi_Birth_Defects
[19]The reports are available at
http://aua.am/chsr/UserFiles/File/new/Thesis%202013/Grboyan%20Siran_%202014.pdf

BIBLIOGRAPHY

Agency for Toxic Substances and Disease Registry. (2013). Cadmium Toxicity: What Are the U.S. Standards for Cadmium Exposure? Retrieved from http://www.atsdr.cdc.gov/csem/csem.asp?csem=6&po=7

Environmental Protection Agency. (2010). Cleanup of Lead, Arsenic Began This Month. Retrieved August 25, 2015, from http://www.epa.gov/region05/cleanup/bautsch/pdfs/bgm_fs_201009.pdf

Environmental Protection Agency. (2013c). Lead in Soil: Why is it a Problem?. Retrieved from http://www.epa.gov/region1/leadsafe/pdf/chapter3.pdf

Environmental Protection Agency. (2015). Regional Screening Levels – Generic Tables, Retrieved from https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2015

European Commission. (2002). Towards a Thematic Strategy on Soil Protection. Retrieved from http://ec.europa.eu/environment/soil/three_en.htm

Federal Soil Protection Ordinance (BBodSchV) in Germany. (1999). Retrieved from http://www.gesetze-im-internet.de/bbodschv/BJNR155400999.html#BJNR155400999BJNG000300305

Health Canada (2013). Final Human Health State of the Science Report on Lead. Retrieved from http://www.hc-sc.gc.ca/ewh-semt/alt_formats/pdf/pubs/contaminants/dhhssrl-rpecscepsh/dhhssrl-rpecscepsh-eng.pdf

Health Canada (2013). Mercury. Your Health and the Enivronment. Retrieved from http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/mercur/index-eng.php#q-53

Jeroen Provoost , Christa Cornelis, Frank Swartjes (2006). Comparison of Soil Standards for Trace Elements Between Countries. *Journal of Soils and Sediments, Volume 6, Issue 3, pp 173-181* http://link.springer.com/article/10.1065%2Fjss2006.07.169

Norwegian Pollution Control Authority. (1999). Guidelines on risk assessment of contaminated sites, report 99:06.

Order # 01, issued by the Minister of Health of RA on 25.01.2010 on “Hygienic requirements N 2.1.7.003-10 establishing sanitary norms and rules for soil quality”.

Order # 53, issued by the Minister of Health of Russian Federation on 17.04.2003 on “Hygienic-epidemiological requirements for soil”. http://www.vashdom.ru/sanpin/2171287-03/#sub_1000

Order # 876, issued by the Minister of Health of RA on 25.12.2002 on “Drinking Water: Hygienic requirements for water quality supplied by centralized systems and establishing sanitary norms and rules for water quality control N 2-III-A 2-1”.

Otto Simonett (Editor) (2012) Mining in Armenia. Zoï Environment Network REPORT 3/2012 http://www.envsec.org/publications/mining_in_armenia.pdf

Protocol for Determining Background Levels of Heavy Metals in Soil of Mining Communities (2016). AUA Center for Responsible Mining

Protocols and Forms for Soil and Water Monitoring in Mining Communities (2015). AUA Center for Responsible Mining

Quality Assurance and Quality Control for Testing Environmental Samples (2016). AUA Center for Responsible Mining

RA Lori Marz, Alaverdi Regional Administration. (2015) Retrieved from http://lori.mtaes.am/about-communities/

RA Ministry of Territorial Administration and Emergency Situation (2013). The types and the indicators of tailing dams of the ore processing plants of RA.

RA National Statistical Service (2015). Population Census 2011. Retrieved from http://publicdata.am/schools/2012/%D4%B1%D6%80%D5%A1%D6%80%D5%A1%D5%BF

RA Government Decision # 92-N, 25.01.2005 on "Establishment of the assessment procedure of the economic activities impact on soil resources"

Soil Environmental Standards/Screening Values in China. (1995). Ministry of Environmental Protection of China (GB 15618-1995). Retrieved from http://www.iccl.ch/download/durban_2013/

Swedish Environmental Protection Agency. (1996). Development of generic guideline values. Model and data used for generic guideline values for contaminated soils in Sweden.

Swiss Agency for the Environmental Forests and Landscape. (1998). Derivation of trigger and clean-up values for inorganic pollutants in the soil. Environmental documentation no.83.

Trace2o, Metalyser HM2000 Deluxe (Soils), Technical Characterization of the device is available on http://www.trace2o.com/products/metalyser-deluxe-hm2000/overview~22.html

ANNEXES

Annex 1. Population of Alaverdi city by age and sex

Age	Total	Male	Female
0-4	927	486	441
5-9	834	469	365
10-14	730	385	345
15-19	807	408	399
20-24	1059	530	529
25-29	1070	509	561
30-34	946	445	501
35-39	728	359	369
40-44	734	321	413
45-49	906	413	493
50-54	1201	523	678
55-59	1003	380	623
60-64	751	314	437
65-69	306	130	176
70-74	581	234	347
75-79	354	133	221
80-84	276	84	192
85+	130	21	109
Total	***13343***	***6144***	***7199***

Source: Population Census 2011 for Armenia, National Statistic Service of the Republic of Armenia, http://armstat.am/file/doc/99482563.pdf

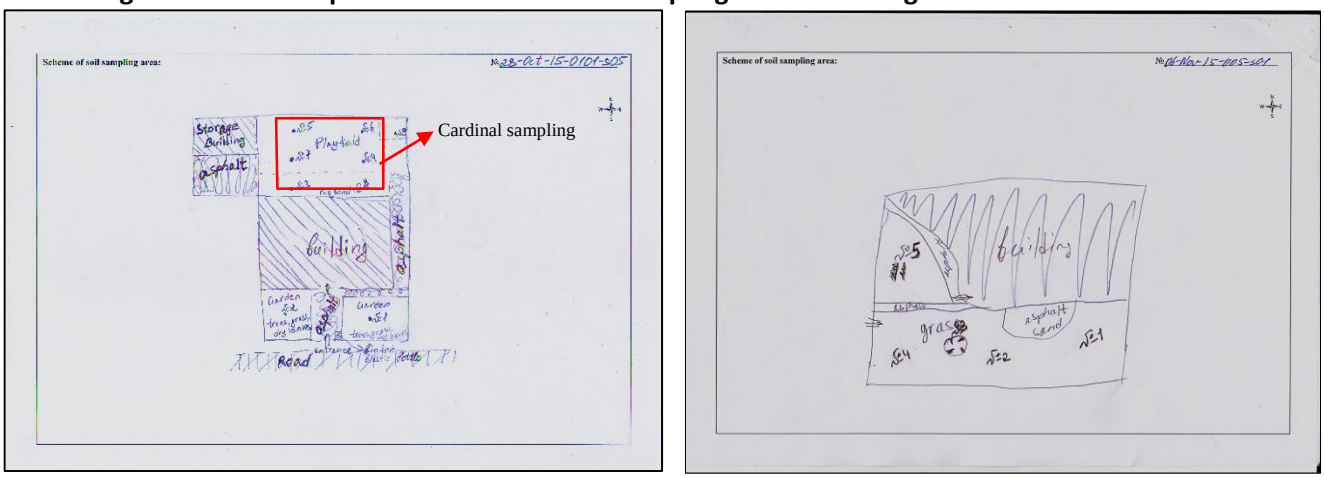
Annex 2. Methodology on Soil Sampling and Testing

The methodology on soil sampling and testing for Alaverdi city based on the appropriate standard protocols and forms developed by the AUA Center for Responsible Mining based on international standards and guidance[20], in particular, ISO 17025, ISO 5667, ISO 10381, EPA IWRG 701-2009, EPA 540-R-01-00.

Soil sampling. The soil monitoring in the City of Alaverdi was implemented during November 2015. A total of 52 soil samples were collected from 5 kindergartens and 4 schools and 5 reference sampling points (5 cm, 10 cm, 20 cm) for determination of metals' Background Levels in Armanis, Alaverdi and Akhtala communities. The soil sampling was done according to ISO 10381 and the requirements of the developed protocols and forms.

The number of soil samples, collected from each school/kindergarten, was determined by the size of sampling site: the minimum 2 samples and average 5 samples for each school/kindergarten. Prior to starting the fieldwork, a baseline location of sites to be used for the collection of soil samples was established. The leaves, grasses, branches, garbage or other items were removed from sampling point before taking the sample from 5 cm depth. The scheme of sampling site and locations of sampling points was drawn in the appropriate protocol/form (Figure 4). The sampling for BLs determination is given in Annex 6.

Figure 4. The examples of schemes for soil sampling area in kindergartens and schools



The cardinal sampling layout was used for collecting the soil samples from large sampling sites, such as playfields and gardens of the kindergartens/schools. These sampling locations were spaced approximately 5-10m apart. The soil temperature was measured for each sampling point *in situ*.

All collected soil samples were labeled and transported to the laboratory in the special cooler box (under the <6°C condition) for the further test. In the laboratory, the soil samples were stored in the refrigerator, for no more than six months.

[20]Protocols used are available at http://crm.aua.am.

Soil testing. The concentrations of arsenic, cadmium, copper, lead and mercury in the soil samples were measured with the Metalyser Deluxe HM2000 portable heavy metal analyzer from Trace2o Company, based on Anodic Stripping Voltammetry method, in the AUA Center for Responsible Mining's laboratory. Before starting the measurements, the soil sample was dried in the oven at 100°C, for an hour. Then, the soil sample was dissolved in the deionized water for digestion. After 5 min, required for efficient extraction of metals from soil to water, the liquid fraction was filtered. From the filtrate 3.5ml was mixed with the appropriate buffer solution and diluted by 60ml deionized water, and analyzed for heavy metal concentration.

Low concentration measurements. The Metalyser Deluxe HM2000 device that was used for soil tests has a limitation for detecting low concentrations of metals. The Limit of Detection (LOD) for each metals given in the Figure 5 below.

Figure 5. The LOD's range for each metal.

Metal	LOD's range (mg/kg)
Arsenic	10-500
Cadmium	5-500
Lead	5-500
Copper	10-500
Mercury	5-500

The measurements were performed using the single-point standard addition method. A problem with LOD was resolved by manual calculation (eq. 1), where sample and standard peak heights were obtained from "Metaware" software.

$$Cu = \frac{IuVsCs}{IsVs+(Is-Iu)Vu} \qquad \text{(eq. 1)}$$

Iu = sample peak height,
Is = standard addition peak height,
Vs = volume of standard solution added,
Vu = volume of original sample,
Cs= concentration of standard solution,
Cu= concentration of original sample.

Annex 3. Methodology on Water Sampling and Testing

The methodology for drinking water sampling and testing is based on the appropriate standard protocols and forms[21] developed by the AUA Center for Responsible Mining based on international standards and guidance, in particular, ISO 17025, ISO 5667, EPA IWRG 701-2009, EPA 540-R-01-00.

Sampling. The drinking water samples in the City of Alaverdi were collected in November 2015. The representative water samples were collected from the water tap in the Kindergarten №1 and School №12 in Alaverdi city. The water sampling points represented the content of supplied water for the whole city. The water sampling was done according to ISO 5667 and the requirements of the developed protocols and forms.

The collected water samples were labeled and transported to the laboratory in the special cooler box (under the <6oC) for the further test. In the laboratory, the water samples were stored in the refrigerator for no more than a day.

Testing. The concentrations of total arsenic, arsenic (III), cadmium, copper, lead, mercury, zinc, manganese, aluminum, boron, chromium (VI), iron and nickel in the water samples were measured using the Metalyser Deluxe HM2000 and Metalometer portable heavy metal analyzer system from Trace2o Company, based on electrochemical and photometric methods, in the AUA Center for Responsible Mining's laboratory.

Total arsenic, arsenic (III), cadmium, lead, mercury and zinc were not detected by Anodic Stripping Voltammetry method due to high interferences in the water samples during the measurement. Copper, manganese, aluminum, boron, chromium (VI), iron and nickel in the water sample were detected only by Photometric method. Water sample preparation for the photometric test was performed with the appropriate buffers and reagents.

[21] Protocols used are available at http://crm.aua.am.

Annex 4. Soil Independent Monitoring Data

Kindergarten №1

Sampling point №	Arsenic, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Mercury, mg/kg
05-Nov-15-0603-s01-01	43.81	0.84	555.73	48.95	<0.1
05-Nov-15-0603-s01-02	40.52	0.80	551.97	49.20	<0.1
05-Nov-15-0603-s01-03	41.62	0.95	560.21	80.65	<0.1
Geometric mean	**41.96**	**0.86**	**555.96**	**57.91**	**<0.1**

Kindergarten №2

Sampling point №	Arsenic, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Mercury, mg/kg
05-Nov-15-0603-s02-01	42.22	1.52	732.24	79.17	<0.1
05-Nov-15-0603-s02-02	41.24	1.57	729.13	86.03	<0.1
05-Nov-15-0603-s02-03	49.28	1.73	722.34	75.74	<0.1
05-Nov-15-0603-s02-04	45.92	1.62	719.57	91.28	<0.1
05-Nov-15-0603-s02-05	49.64	1.68	711.89	96.25	<0.1
Geometric mean	**45.53**	**1.62**	**723.00**	**85.36**	**<0.1**

Kindergarten №4

Sampling point №	Arsenic, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Mercury, mg/kg
06-Nov-15-0603-s03-01	55.80	1.91	621.70	66.86	<0.1
06-Nov-15-0603-s03-02	57.90	1.81	629.40	62.70	<0.1
06-Nov-15-0603-s03-03	52.40	1.86	634.90	68.30	<0.1
Geometric mean	**55.32**	**1.86**	**628.64**	**65.91**	**<0.1**

Kindergarten №5

Sampling point №	Arsenic, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Mercury, mg/kg
06-Nov-15-0603-s04-01	20.32	1.02	163.18	38.60	<0.1
06-Nov-15-0603-s04-02	22.15	0.94	155.90	36.90	<0.1
06-Nov-15-0603-s04-03	24.60	0.88	172.60	38.20	<0.1
06-Nov-15-0603-s04-04	21.76	0.82	167.50	37.40	<0.1
06-Nov-15-0603-s04-05	23.40	0.90	160.70	35.70	<0.1
Geometric mean	**22.40**	**0.91**	**163.88**	**37.35**	**<0.1**

Kindergarten №6

Sampling point №	Arsenic, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Mercury, mg/kg
06-Nov-15-0603-s05-01	12.46	0.55	108.31	40.60	<0.1
06-Nov-15-0603-s05-02	11.60	0.51	105.67	37.80	<0.1
06-Nov-15-0603-s05-03	10.84	0.54	91.28	33.14	<0.1
06-Nov-15-0603-s05-04	10.32	0.57	87.77	31.57	<0.1
Geometric mean	**11.28**	**0.54**	**97.86**	**35.60**	**<0.1**

School №1

Sampling point №	Arsenic, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Mercury, mg/kg
20-Nov-15-0603-s08-01	105.40	7.08	2958.40	186.70	<0.1
20-Nov-15-0603-s08-02	102.00	7.83	2973.00	192.50	<0.1
20-Nov-15-0603-s08-03	104.69	6.67	2964.00	181.80	<0.1
20-Nov-15-0603-s08-04	107.60	6.45	2987.00	177.40	<0.1
Geometric mean	**104.90**	**6.99**	**2970.58**	**184.51**	**<0.1**

School №4

Sampling point №	Arsenic, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Mercury, mg/kg
06-Nov-15-0603-s06-01	12.40	0.55	245.45	47.71	0.11
06-Nov-15-0603-s06-02	13.80	0.51	118.57	25.30	0.10
06-Nov-15-0603-s06-03	18.76	0.47	110.30	23.00	0.12
Geometric mean	**14.75**	**0.51**	**147.52**	**30.28**	**0.11**

School №7

Sampling point №	Arsenic, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Mercury, mg/kg
20-Nov-15-0603-s07-01	28.09	0.67	151.50	27.74	<0.1
20-Nov-15-0603-s07-02	28.93	0.64	146.95	26.91	<0.1
20-Nov-15-0603-s07-03	29.47	0.62	139.60	25.68	<0.1
20-Nov-15-0603-s07-04	28.42	0.88	155.86	30.10	<0.1
20-Nov-15-0603-s07-05	27.60	0.91	160.69	31.03	<0.1
Geometric mean	**28.49**	**0.73**	**150.74**	**28.22**	**<0.1**

School №12

Sampling point №	Arsenic, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Mercury, mg/kg
20-Nov-15-0603-s09-01	20.87	0.90	148.48	20.87	0.19
20-Nov-15-0603-s09-02	22.43	0.86	155.90	21.91	0.18
20-Nov-15-0603-s09-03	26.21	0.47	246.53	49.50	0.30
20-Nov-15-0603-s09-04	27.50	0.50	234.20	47.02	0.28
20-Nov-15-0603-s09-05	27.27	1.13	157.60	27.27	0.24
Geometric mean	**24.70**	**0.73**	**183.95**	**31.08**	**0.23**

Annex 5. Drinking Water Monitoring Data

Metals	Measurement results for, mg/l		Armenian Drinking Water Standard,[22] mg/l
	Sample number 20-Nov-15-0603-w01	Sample number 20-Nov-15-0603-w09	
Aluminum	<0.01	<0.01	0.5
Boron	<0.1	<0.1	0.5
Chromium (VI)	0.02	0.02	0.05
Iron	<0.02	<0.02	0.3
Nickel	<0.1	<0.1	0.1
Copper	<0.05	<0.05	1.0
Manganese	<0.1	<0.1	0.1

Note: Total arsenic, arsenic (III), cadmium, mercury, zinc and lead were not detected due to high interferences during the measurements.

[22]The Armenian Drinking Water Standards are specified in Order # 876, issued by the Minister of Health of RA on 25.12.2002 on "Drinking Water: Hygienic requirements for water quality supplied by centralized systems and establishing sanitary norms and rules for water quality control N 2-III-A 2-1".

Annex 6. Determination of Background Levels of Metals in Soil of Alaverdi City

The determination of background level for each metal in soil of Armanis, Akhtala and Alaverdi communities was conducted by horizontal and distance sampling, based on requirements of the Protocol for Determining Background Levels of Metals in Soil developed by the AUA Center for Responsible Mining based on international standards and guidance.[23] The background reference area was selected by horizontal sampling at depth 5 cm, 10 cm and 20 cm and distance sampling from about 1.9 km out of the city of Alaverdi.

Totally 15 reference samples from 5 cm, 10 cm and 20 cm depth were collected from the sites that were located near the Village of Odzun (distance is 500-600 m) and far from mining activities and industrial processing. The calculation of BLs for each metal are shown the Figure 6 below.

Figure 6. The calculation of metals' BLs in soil for Alaverdi city

Number of sampling point	Metals, mg/kg				
	Arsenic	Cadmium	Copper	Lead	Mercury
Armenian SS	***2***	***-***	***3***	***32***	***2.1***
06(01;03;07)-sRef-01 (10cm)	22.80	0.22	208.97	167.54	2.13
06(01;03;07)-sRef-02 (10cm)	19.90	0.24	192.93	176.55	1.92
06(01;03;07)-sRef-03 (10cm)	18.81	0.21	210.94	167.31	1.97
06(01;03;07)-sRef-04 (10cm)	20.60	0.23	189.14	175.30	2.00
06(01;03;07)-sRef-05 (10cm)	20.00	0.21	188.89	166.67	2.08
06(01;03;07)-sRef-01 (20cm)	14.51	0.21	233.00	123.82	0.21
06(01;03;07)-sRef-02 (20cm)	14.65	0.22	231.40	123.32	0.22
06(01;03;07)-sRef-03 (20cm)	14.79	0.23	229.82	117.81	0.27
06(01;03;07)-sRef-04 (20cm)	16.73	0.21	258.45	121.58	0.21
06(01;03;07)-sRef-05 (20cm)	16.28	0.22	276.84	120.96	0.24
Number of samples	10	10	10	10	10
Arithmetic mean	17.91	0.22	222.04	146.09	1.13
Median	17.77	0.22	220.38	145.24	1.10
Standard deviation	2.91	0.01	29.66	26.17	0.95
Minimum	14.51	0.21	188.89	117.81	0.21
Maximum	22.80	0.24	276.84	176.55	2.13
Lower band	16.8	0.22	211.9	136.0	0.8
Upper band	19.7	0.23	242.6	156.6	1.5
Background Level	***18.3***	***0.22***	***227.2***	***146.3***	***1.14***

The BL was selected for each metal based on the results of the non-parametric statistical analyses. The calculated BL is the concentration value against which site concentration data are compared to determine whether the data represent site contamination. Sample concentrations greater than the maximum BL are categorized as likely site contamination, whereas sample concentrations less than or equal to the maximum background levels are categorized as ambient conditions.

[23]Protocols used are available at http://crm.aua.am.

Annex 7. Inter-laboratory Comparison Tests Results

The inter-laboratory comparison tests were performed for assuring the quality of test and calibration results for the AUA Center for Responsible Mining's laboratory. The comparison tests were conducted for 7 soil samples in the qualified laboratories of RA Ministry of Nature Protection's Environmental Impact Monitoring Center (EIMC) SNCO and RA Ministry of Health's National Center for Disease Control and Prevention (NCDCP) SNCO.

The soil samples for comparison tests were selected according to following principles:

- One sample with low or high concentrations of the measured parameters,
- Arbitrary selection,
- One reference sample.

Determination of metals in the soil samples was performed by ICP-Mass Spectrometric Method (by Perkin Elmer MS device) in the EIMC's laboratory and by Atomic Adsorption Spectrometric Method (by Agilent AAS device) in the NCDC's laboratory. Determination of mercury in both laboratories was conducted by Mercury Atomic Adsorption Analyzer. The data is provided in the Figure 7 below.

Figure 7. The inter-laboratories tests results

Name of Laboratory	Arsenic, mg/kg	Cadmium, mg/kg	Lead, mg/kg	Copper, mg/kg	Mercury, mg/kg
Armenian SS	***2***	***-***	***32***	***3***	***2.1***
Background Level	***18.3***	***0.22***	***146.3***	***227.2***	***1.14***
	06(01;03;07)-sRef-05(20cm)				
AUA CRM	16.28	0.22	120.96	276.84	0.24
EIMC	17.98	0.70	38.60	102.32	0.0038
	06(01;03;07)-sRef-04(20cm)				
AUA CRM	16.73	0.21	121.58	258.45	0.21
NCDCP	12.0	n.d.	44.75	100.00	0.007
	Sampling point 05-Nov-15-0603-s01-01				
AUA CRM	43.81	0.84	48.95	555.73	<0.1
NCDCP	6.0	n.d.	28.8	146.1	0.078
	Sampling point 05-Nov-15-0603-s02-03				
AUA CRM	49.28	1.73	75.74	722.34	<0.1
EIMC	50.57	1.91	88.21	732.64	0.0043
	Sampling point 06-Nov-15-0603-s05-02				
AUA CRM	11.60	0.51	37.80	105.67	<0.1
NCDCP	7.0	n.d.	21.1	105.6	0.036
	Sampling point 06-Nov-15-0603-s06-03				
AUA CRM	18.76	0.47	23.00	110.30	0.12
NCDCP	6.5	n.d.	37.6	186.0	0.18
	Sampling point 20-Nov-15-0603-s08-02				
AUA CRM	102.00	7.83	192.50	2973.00	<0.1
EIMC	110.26	6.27	179.49	3034.93	0.0168

(*) n.d. stands for not detected

Annex 8. Measurements Exceeding the Armenian and International Soil Standard (SS)[24]

Figure 8. Arsenic Measurements

School/ kindergarten	Total number of tests	% of tests exceeding SS and US EPA screening level for As										
		Armenia	Russia	Belgium	Netherlands	Germany	France	Sweden	Norway	Canada	China	US EPA
Soil Standard (mg/kg)		***2***	***2***	***110***	***55***	***50***	***37***	***15***	***2***	***12***	***30***	***22***
Kindergarten №1	3	100%	100%	0	0	0	100%	100%	100%	100%	100%	100%
Kindergarten №2	5	100%	100%	0	0	0	100%	100%	100%	100%	100%	100%
Kindergarten №4	3	100%	100%	0	33.3%	100%	100%	100%	100%	100%	100%	100%
Kindergarten №5	5	100%	100%	0	0	0	0	100%	100%	100%	0	40%
Kindergarten №6	4	100%	100%	0	0	0	0	0	100%	0	0	0
School №1	4	100%	100%	0	100%	100%	100%	100%	100%	100%	100%	100%
School №4	3	100%	100%	0	0	0	0	33.3%	100%	100%	0	0
School №7	5	100%	100%	0	0	0	0	100%	100%	100%	0	100%
School №12	5	100%	100%	0	0	0	0	100%	100%	100%	0	60%

Figure 9. Cadmium Measurements

School/ kindergarten	Total number of tests	% of tests exceeding SS and US EPA screening level for Cd										
		Armenia	Russia	Belgium	Netherlands	Germany	France	Sweden	Norway	Canada	China	US EPA
Soil Standard (mg/kg)		*****	*****	***6***	***12***	***20***	***20***	***0.4***	***3***	***14***	***0.3***	***85***
Kindergarten №1	3	-	-	0	0	0	0	100%	0	0	100%	0
Kindergarten №2	5	-	-	0	0	0	0	100%	0	0	100%	0
Kindergarten №4	3	-	-	0	0	0	0	100%	0	0	100%	0
Kindergarten №5	5	-	-	0	0	0	0	100%	0	0	100%	0
Kindergarten №6	4	-	-	0	0	0	0	100%	0	0	100%	0
School №1	4	-	-	100%	0	0	0	100%	100%	0	100%	0
School №4	3	-	-	0	0	0	0	100%	0	0	100%	0
School №7	5	-	-	0	0	0	0	100%	0	0	100%	0
School №12	5	-	-	0	0	0	0	100%	0	0	100%	0

(*) Soil standard has not established.

[24]The references to international soil standards and US EPA soil screening levels of metals are given in Bibliography section.

Figure 10. Copper Measurements

School/ kindergarten	Total number of tests	% of tests exceeding SS and US EPA screening level for Cu										
		Armenia	Russia	Belgium	Netherlands	Germany	France	Sweden	Norway	Canada	China	US EPA
Soil Standard (mg/kg)		*3*	*3*	*400*	*190*	*N.A.*	*190*	*100*	*100*	*63*	*50*	*250*
Kindergarten №1	3	100%	100%	100%	100%	-	100%	100%	100%	100%	100%	100%
Kindergarten №2	5	100%	100%	100%	100%	-	100%	100%	100%	100%	100%	100%
Kindergarten №4	3	100%	100%	100%	100%	-	100%	100%	100%	100%	100%	100%
Kindergarten №5	5	100%	100%	0	0	-	0	100%	100%	100%	100%	0
Kindergarten №6	4	100%	100%	0	0	-	0	0	0	0	0	0
School №1	4	100%	100%	100%	100%	-	100%	100%	100%	100%	100%	100%
School №4	3	100%	100%	0	33.3%	-	33.3%	100%	100%	100%	100%	0
School №7	5	100%	100%	0	0	-	0	100%	100%	100%	100%	0
School №12	5	100%	100%	0	40	-	40	100%	100%	100%	100%	0

Figure 11. Lead Measurements

School/ kindergarten	Total number of tests	% of tests exceeding SS and US EPA screening level for Pb										
		Armenia	Russia	Belgium	Netherlands	Germany	France	Sweden	Norway	Canada	China	US EPA
Soil Standard (mg/kg)		*32*	*30*	*700*	*530*	*400*	*400*	*80*	*60*	*140*	*250*	*400*
Kindergarten №1	3	100%	100%	0	0	0	0	0	33.3%	0	0	0
Kindergarten №2	5	100%	100%	0	0	0	0	60%	100%	0	0	0
Kindergarten №4	3	100%	100%	0	0	0	0	0	100%	0	0	0
Kindergarten №5	5	100%	100%	0	0	0	0	0	0	0	0	0
Kindergarten №6	4	25%	25%	0	0	0	0	0	0	0	0	0
School №1	4	100%	100%	0	0	0	0	100%	100%	100%	0	0
School №4	3	33.3%	33.3%	0	0	0	0	0	0	0	0	0
School №7	5	0	20%	0	0	0	0	0	0	0	0	0
School №12	5	40%	40%	0	0	0	0	0	0	0	0	0

Figure 12. Mercury Measurements

School/ kindergarten	Total number of tests	% of tests exceeding SS and US EPA screening level for Hg										
		Armenia	Russia	Belgium	Netherlands	Germany	France	Sweden	Norway	Canada	China	US EPA
Soil Standard (mg/kg)		*2.1*	*2.1*	*15*	*10*	*20*	*7*	*1*	*1*	*6.6*	*0.3*	*
Kindergarten №1	3	0	0	0	0	0	0	0	0	0	0	-
Kindergarten №2	5	0	0	0	0	0	0	0	0	0	0	-
Kindergarten №4	3	0	0	0	0	0	0	0	0	0	0	-
Kindergarten №5	5	0	0	0	0	0	0	0	0	0	0	-
Kindergarten №6	4	0	0	0	0	0	0	0	0	0	0	-
School №1	4	0	0	0	0	0	0	0	0	0	0	-
School №4	3	0	0	0	0	0	0	0	0	0	0	-
School №7	5	0	0	0	0	0	0	0	0	0	0	-
School №12	5	0	0	0	0	0	0	0	0	0	0	-

Annex 9. Soil Test Results for Each Kindergarten and School

Kindergarten №1

The Kindergarten after Zoravar Andranik is located in the west part of Alaverdi city. Totally 60 children attend this kindergarten. The kindergarten is the nearest to the Alaverdi copper smelter, the distance is about 0.9 km.

The soil monitoring for the kindergarten was conducted for the soil-covered area, particularly flowerbeds that belongs to the kindergarten and separated by a fence (Figure 13a and 13b). Totally 3 soil samples were collected that shown in Figures 13b. The soil testing results are presented in Annex 4.

Figure 13. The Kindergarten №1 (a) main view and (b) soil sampling points' location

(a) (b)

The concentrations of arsenic, copper and lead exceeded the Armenian SS in the soil of the entire area of the kindergarten by 20.3-21.9, 184.0-186.7 and 1.5-2.5 times, accordingly. The concentrations of cadmium exceeded China's SS by 2.7-3.2 times in all soil samples collected from the flowerbeds of the kindergarten. China has the most stringent cadmium MAC (0.3 mg/kg) known to us. Mercury didn't detected in the soil samples.[25]

Kindergarten №2

The Kindergarten №2 is located in the "Jravazan" sub-district, the west of Alaverdi city. Totally 145 children attend this kindergarten. The distance from the kindergarten to the Alaverdi copper smelter is 0.9 km.

The soil monitoring for the kindergarten was conducted for the soil-covered area that belongs to the kindergarten and separated by a fence (Figure 14a). Totally 5 soil samples were collected that shown in Figure 14b and 15.

[25]Arsenic, cadmium and copper in all soil samples exceeded the BLs by 2.2-2.4 times, 3.6-4.3 times and 2.4-2.6 times, accordingly. Lead didn't exceed the BLs.

Figure 15. The Kindergarten №2 (a) main view and (b) soil sampling points' location

(a)

(b)

Figure 15. The Kindergarten №2 playfield

Arsenic, copper and lead exceeded the Armenian SS by 20.6-24.8 times, 237.3-244.1 times and 2.4-3.0 times, accordingly, in all soil samples taken from entire area of the kindergarten. The concentrations of cadmium exceeded China's SS by 5.1-5.8 times in all soil sample. China has the most stringent cadmium MAC known to us. Mercury didn't detected in the soil samples.[26]

Kindergarten №4

The Kindergarten №4 is located in the "Sanahin-Sarahart" district, the south part of Alaverdi city. Totally 110 children attend this kindergarten. The distance from the kindergarten to the Alaverdi copper smelter is 1.4 km.

The soil monitoring for the kindergarten was conducted for the soil-covered area, particularly the flowerbeds that belongs to the kindergarten and separated by a fence (Figure 16a). The main area of the kindergarten was covered by asphalt. Totally 3 soil samples were collected from a soil-covered area that shown in Figure 16b and 17.

[26]Arsenic, cadmium and copper exceeded the BLs by 2.3-2.7 times, 6.9-7.9 times and 3.1-3.2 times, accordingly. Lead didn't exceed the BLs.

Figure 16. The Kindergarten №4 (a) main entrance and (b) soil sampling points' location

(a)

(b)

Figure 17. The Kindergarten №4 flowerbed

Arsenic, copper and lead exceeded the Armenian SS by 26.2-29.0 times, 207.2-211.6 times and 2.0-2.1 times, accordingly, in all soil samples collected from entire area of the kindergarten. The concentrations of cadmium exceeded China's SS by 6.0-6.4 times in all soil samples. China has the most stringent cadmium MAC known to us. Mercury didn't detected in the soil samples. [27]

Kindergarten №5

The Kindergarten №5 is located in the "Sanahin" district, the south part of Alaverdi city. Totally 20 children attend this kindergarten. The distance from the kindergarten to the Alaverdi copper smelter is 1.4 km.

The soil monitoring for the kindergarten was conducted for the soil-covered area that belongs to the kindergarten and separated by a fence (Figure 18a). Totally 5 soil samples were collected from a soil-covered area that shown in Figure 18b and 19.

[27]Arsenic, cadmium and copper exceeded the BLs by 2.9-3.2 times, 8.2-8.7 times and 2.7-2.8, accordingly. Lead didn't exceed the BL.

Figure 18. The Kindergarten №5 (a) main entrance and (b) soil sampling points' location

(a)

(b)

Figure 19. The Kindergarten №5 yard

Arsenic and copper exceeded the Armenian SS by 10.2-12.3 times and 52.0-57.5 times, accordingly, in all soil samples collected from entire area of the kindergarten. Lead slightly exceeded the Armenian SS by 1.1-1.2 times in all samples. The concentrations of cadmium exceeded China's SS by 2.7-3.4 times in all soil samples. China has the most stringent cadmium MAC known to us. Mercury didn't detected in the soil samples [28]

Kindergarten №6

The Kindergarten №6 is located in the "Sanahin-Sarahart" district, the east part of Alaverdi city. Totally 150 children attend this kindergarten. The distance from the kindergarten to the Alaverdi copper smelter is about 1 km.

The soil monitoring for the kindergarten was conducted for the soil-covered area that belongs to the kindergarten and separated by a fence (Figure 20a). Totally 4 soil samples were collected from a soil-covered area that shown in Figure 20b and 21.

[28] Arsenic and cadmium exceeded the BLs by 1.1-1.3 times and 3.7-4.6 times, accordingly. Lead and copper didn't exceed the BLs.

Figure 20. The Kindergarten №6 (a) main view and (b) soil sampling points' location

(a)

(b)

Figure 21. The Kindergarten №6 yard

Arsenic and copper exceeded the Armenian SS by 5.2-6.2 times and 29.3-36.1 times, accordingly, in all soil samples collected from entire area of the kindergarten. Lead slightly exceeded the Armenian SS by 1.2-1.3 times in 50% (2/2) of total samples. The concentrations of cadmium exceeded China's SS by 1.7-1.9 times in all soil samples. China has the most stringent cadmium MAC known to us. Mercury didn't detected in the soil samples.[29]

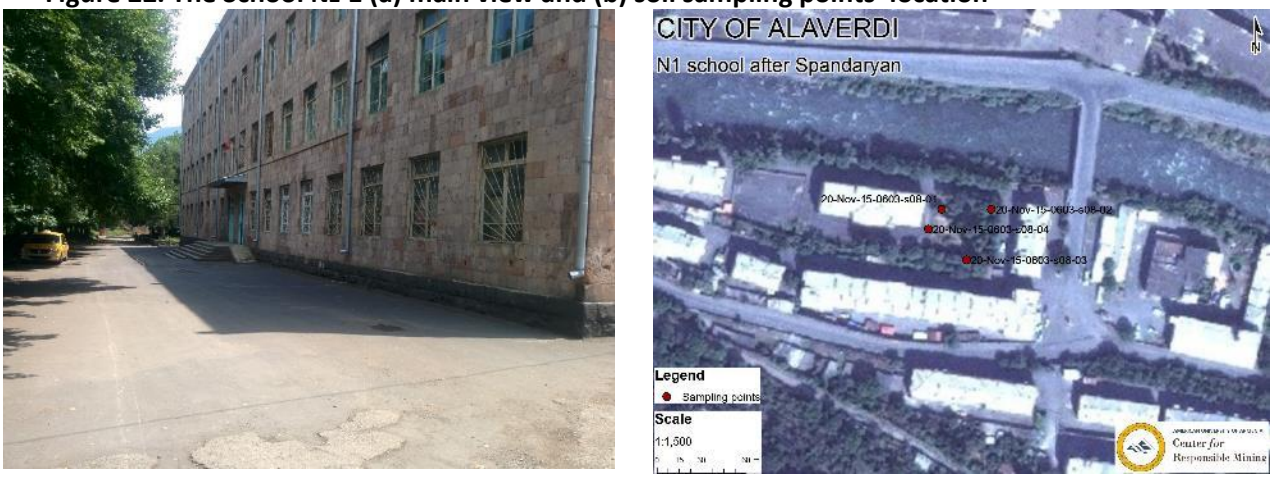
School №1

The Primary School №1, after S. Spandaryan is located in the "Engels" sub-district, the north of Alaverdi city. Totally 47 children attend this school. The school is the nearest to the Alaverdi copper smelter, the distance is about 0.5 km.

The soil monitoring for School №1 was conducted for the soil-covered area, particularly flowerbeds of the school. Another part of the ground that belongs to the school is covered by asphalt (Figure 22a). Totally 4 soil samples were collected from the soil-covered ground of the School №1, which locations are shown on Figure 22b and 23.

[29] Cadmium exceeded the BL by 2.3-2.6 times. Arsenic, lead and copper didn't exceed the BLs.

Figure 22. The School № 1 (a) main view and (b) soil sampling points' location



(a) (b)

Figure 23. The School № 1 flowerbed

Arsenic, copper and lead exceeded the Armenian SS by 51.0-53.8 times, 986.1-995.7 times and 5.5-6.0 times, accordingly, in all soil samples taken from the soil covered area of the school. The concentrations of cadmium exceeded China's SS by 21.5-26.1 times in all soil samples. China has the most stringent cadmium MAC known to us. Mercury didn't detected in the soil samples.[30]

School №4

The Secondary School №4 is located in the "Sanahin" district, the north-east part of Alaverdi city. Totally 103 children attend this school. The distance from the school to the Alaverdi copper smelter is 1.5 km.

[30]Arsenic, cadmium, copper and lead exceeded the BLs by 5.6-5.9 times, 29.3-35.6 times, 13.0-13.1 times and 1.2-1.3 times, accordingly. Mercury didn't detected in the soil samples.

The soil monitoring for School №2 was conducted for the soil-covered area, particularly large flowerbed of the school. Another part of the ground that belongs to the school is covered by asphalt (Figure 24a). Totally 3 soil samples were collected that shown in Figure 24b and 25.

Figure 24. The School №4 (a) main entrance and (b) soil sampling points' location

(a) (b)

Figure 25. The School №4 flowerbed

Arsenic and copper exceeded the Armenian SS by 6.2-9.4 times and 36.8-81.8 times, accordingly, in all soil samples collected from the soil-covered area of the School №4. Lead exceeded the Armenian SS by 1.5 times in one soil sample. The concentrations of cadmium exceeded China's SS by 1.6-1.8 times in all soil samples. China has the most stringent cadmium MAC known to us. Mercury didn't exceed the Armenian SS.[31]

School №7

The Secondary School №7 after Myasnikyan is located in the north-west part of Alaverdi city. Totally 113 children attend this school. The distance from the school to the Alaverdi copper smelter is 5 km.

The soil monitoring for School №7 was conducted for the soil-covered area, particularly flowerbeds and yards of the school (Figure 26a). Totally 5 soil samples were collected that shown in Figure 26b and 27.

[31]Cadmium exceeded the BL by 2.1-2.5 times in all soil samples. Arsenic, copper, lead and mercury didn't exceed the BLs.

Figure 26. The School №7 (a) main entrance and (b) soil sampling points' location

(a)

(b)

Figure 27. The School №7 yard

Arsenic and copper exceeded the Armenian SS by 13.8-14.7 times and 46.5-53.6 times, accordingly, in all soil samples collected from the soil-covered area of the School №7. Lead didn't exceed the Armenian SS. The concentrations of cadmium exceeded China's SS by 2.1-3.0 times in all soil samples. China has the most stringent cadmium MAC known to us. Mercury didn't detected in the soil samples.[32]

School №12

The Primary School №12 is located in the "Sanahin-Sarahart" district, the east part of Alaverdi city. Totally 529 children attend this school. The distance from the school to the Alaverdi copper smelter is about 1 km.

The soil monitoring for School №12 was conducted for the soil-covered area, particularly flowerbeds, garden and yards of the school (Figure 28a). Totally 5 soil samples were collected that shown in Figure 28b and 29.

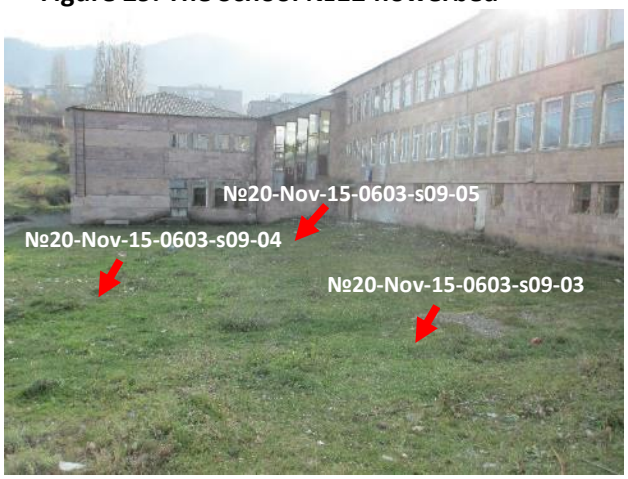
[32] Arsenic and cadmium exceeded the BLs by 1.5-1.6 times and 2.8-4.1 times, accordingly. Copper and lead didn't exceed the BLs.

Figure 28. The School №12 (a) main view and (b) soil sampling points' location

(a)

(b)

Figure 29. The School №12 flowerbed



Arsenic and copper exceeded the Armenian SS by 10.4-13.8 times and 49.5-82.2 times, accordingly, in all soil samples collected from the soil-covered area of the School №12. Lead exceeded the Armenian SS by 1.5 times in 40% (2/5) of soil samples. The concentrations of cadmium exceeded China's SS by 1.6-3.8 times in all soil samples. China has the most stringent cadmium MAC known to us. Mercury didn't exceed the Armenian SS.[33]

[33] Arsenic and cadmium exceeded the BLs by 1.1-1.5 times and 2.1-5.1 times, accordingly. Copper, lead and mercury didn't exceed the BLs.

Annex 10. Complete Test Results of Soil Samples

Within the inter-laboratory comparison, the complete tests of metals were conducted for 3 soil samples. The total concentrations of 27 metals were measured in the qualified laboratory of RA Ministry of Nature Protection's EIMC SNCO using the ICP-Mass Spectrometric Method (by Perkin Elmer MS device). The test results and appropriate Armenian and International SS for each metals are given in Figure 30.

Figure 30. EIMC's laboratory complete test results

Metals	Measurement results, mg/kg			Armenian SS, mg/kg	Norwegian SS, mg/kg	Canadian SS, mg/kg	Chinese SS, mg/kg	US EPA screening level, mg/kg
	Sample number 06(01;03;07)-sRef-05(20cm)	Sample number 05-Nov-15-0603-s02-03	Sample number 20-Nov-15-0603-s08-02					
Antimony	1.47	4.73	10.37	4.5	-**	-	-	-
Arsenic	17.98	50.57	110.26	2.0	2.0	12	30	22
Barium	7.52	258.05	606.16	-	-	-	-	-
Beryllium	0.76	1.02	1.21	-	-	-	-	-
Bismuth	0.79	2.09	5.42	-	-	-	-	-
Boron	11.41	28.15	36.82	-	-	-	-	-
Cadmium	0.70	1.91	6.27	-	3.0	14	0.3	85
Calcium	162.51	32807.27	86014.62	-	-	-	-	-
Chromium	34.22	71.00	99.13	6.0	25	64	150	230
Cobalt	11.60	24.09	30.14	5.0	-	-	-	-
Copper	102.32	732.64	3034.93	3.0	100	63	50	250
Iron	7584.37	36032.47	72357.60	-	-	-	-	-
Lead	38.60	88.22	179.49	32.0	60	140	250	400
Lithium	4.53	21.01	45.86	-	-	-	-	-
Magnesium	n.m.	10528.58	25869.44	-	-	-	-	-
Manganese	462.74	922.21	1410.56	700.0	-	-	-	-
Molybdenum	1.22	4.91	8.33	-	-	-	-	-
Mercury	0.0038	0.0043	0.0168	2.1	1.0	6.6	0.3	-
Nickel	40.77	43.49	52.56	4.0	50	50	40	1,600
Potassium	6368.97	14126.76	20185.15	-	-	-	-	-
Selenium	2.18	0.63	1.49	-	-	-	-	-
Sodium	n.m.	12016.39	19974.59	-	-	-	-	-
Strontium	23.84	135.64	341.18	-	-	-	-	-
Tin	2.53	4.17	7.96	-	-	-	-	-
Titanium	2241.87	4258.50	4135.90	-	-	-	-	-
Vanadium	68.13	121.40	103.20	150.0	-	-	-	-
Zinc	77.38	284.79	423.18	23.0	100	200	200	23,000

(*) n.m. stands for not measured
(**) Soil standard has not established.

Arsenic, chromium, cobalt, nickel, zinc, copper and lead exceeded the Armenian SS by 9.0-55.1 times, 5.7-16.5 times, 2.3-6.0 times, 10.2-13.1 times, 3.4-18.4 times, 34.1-1011.6 and 1.2-5.6 times accordingly, in there soil samples collected from the reference site and soil-covered area of the Kindergarten №2 and School №1. Manganese and antimony exceeded the Armenian SS by 1.3-2.0 times and 1.1-2.3 times, accordingly, in two soil samples collected from the soil-covered area of the Kindergarten №2 and School №1. Vanadium and mercury didn't exceed the Armenian SS.