AMERICAN UNIVERSITY OF ARMENIA
Center *for*
Responsible Mining

Results of Soil and Water Testing in Kindergarten and School of Agarak City, Syuniq 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

September 2016

TABLE OF CONTENTS

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, Syuniq Marz, Agarak 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—sixth 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, Alaverdi and Akhtala in the Lori Marz, as well as Kapan, Kajaran, Artsvanik 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 water[3] monitoring for heavy-metal pollution in the kindergarten and school of the City of Agarak (Syuniq Marz, Republic of Armenia) performed by the American University of Armenia (AUA) Center for Responsible Mining (CRM). Agarak is considered a miners' city since the 1950s. It has one of the largest mining companies in Armenia, the "Agarak Copper Molybdenum Combine" CJSC, which operates Agarak mine and three tailing ponds.

The soil monitoring in the City of Agarak was performed for one kindergarten and one secondary school. A total of 830 children study in the kindergarten and school. Permissions were obtained from authorized bodies to conduct the sampling and testing. This included permissions from the Agarak municipality for kindergarten and the Marz government for the school.

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.[4] A total of 14 soil samples were collected from the playgrounds and exterior common spaces of Agarak's kindergarten and school. The surface water sample was collected from the Karchevan River. The soil and water 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 sample, 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)[5] for each metal in the soil 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 one soil sample and one reference sample in the qualified laboratories of the RA Ministry of Nature Protection's Environmental Impact Monitoring Center SNCO and EcoAtom LLC research center. 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. Complete soil test results are shown in Annex 10.

Key Findings

With respect to drinking water, the heavy metals in drinking water in Agarak community were not measured (Annex 5). The drinking water for the Agarak community is supplied from the mountain spring waters that are collected in the Agarak Water Treatment plant (Agarak WTP). Agarak WTP is located at a height of 1950 m above sea level and about 20 km far from mining activities. In 2010-2011, the Armenian Water Supply and Sewerage CJSC established a new water supply pipes in Agarak city, which do not contain lead.[6] However, the drinking water in Agarak city is distributed

[3] The information available at http://armwater.am/en/current-activities.html

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

[5] The BLs for metals were determined based on the results of preliminary study that was performed for soil at depth 5 cm and 10 cm and distance site. These preliminary study is not sufficient for establishing the exact BLs for each metal in soil of Agarak community. The determination of BL needs further deep investigation (identification more than one reference sites, seasonal sampling, soil testing at 20cm and 50 cm depth).

[6] See https://www.adb.org/projects/documents/water-supply-and-sanitation-sector-project-additional-financing-syunik-region-water-supply-systems-iee.

several hours during the day. Drinking water sampling was not available when we made our site visits on 11 May 2016.

With respect to surface water, the water quality of the Karchevan River downstream of Agarak city corresponds to Bad (V) class by iron, nickel and copper. The results are presented in Annex 5.

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 Agarak city'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	8	37.06	100%	0.32	-	153.99	100%	23.16	37.5%	<0.1	0%
School №1	6	21.35	100%	0.44	-	104.50	100%	31.16	50%	<0.1	0%
Total GM	***14***	***29.26***	***100%***	***0.37***	***-***	***130.42***	***100%***	***26.30***	***42.9%***	<0.1	***0%***
Standard deviation	-	***9.46***	***-***	***0.16***	***-***	***63.97***	***-***	***16.82***	***-***	***<0.1***	***-***
Minimum	-	***12.40***	***-***	***0.26***	***-***	***52.86***	***-***	***12.53***	***-***	***<0.1***	***-***
Maximum	-	***45.98***	***-***	***0.71***	***-***	***290.92***	***-***	***53.87***	***-***	***<0.1***	***-***
Background level***	***2***	***16.7***		***0.35***		***85.8***		***17.4***		***<0.1***	
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 12.40 to 45.98 mg/kg. The geometric means (GMs) of all samples exceeded the Armenian Soil Standard (SS)[7] by 14.6 times.

  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.

[7] 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 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.

The soil test data for Agarak city 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 the city. Our reference area study (Annex 6) shows that the BL for arsenic in the soil of Agarak is 16.7 mg/kg. The GM of all soil samples exceeded the BL by 1.8 times. Based on our current level of BL analysis, it is not possible for us to link the level of arsenic in the soil to industrial and mineral processing activities in the city. Further analysis would have to be done to find or exclude a causal link.

Our findings, however, compel us to conclude that arsenic is a heavy metal of high concern in the Agarak city. Arsenic exceeded majority of the international comparatives in Annex 8. Our recommendation is that the playgrounds in kindergarten and school 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 0.26 to 0.71 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). Other comparatives we've studied have significantly higher allowable concentrations: Norway 3 mg/kg, Belgium 6 mg/kg, 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 in Agarak city's soil shows an average of 0.35 mg/kg (Annex 6), relatively equal to Chinese soil standard.

  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.

- **Copper** concentrations ranged from 52.86 to 290.92 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 43.5 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 exceeded the almost 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 85.8 mg/kg for copper in Agarak, significantly higher than Armenian SS.

Our findings, however, compel us to conclude that copper is a heavy metal of concern in the Agarak city. Worldwide evidence suggests that it is not able to predict the extent of exposure or potential health effects of the high levels of copper in the soil,[8] even though they are toxic to aquatic organisms. 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 12.53 to 53.87 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. The GM of all samples didn't exceed the Armenian SS. Notwithstanding, lead exceeded the Armenian SS by 1.4-1.7 times in 42.9% (6/14) of soil samples.

  It should be noted that our analysis shows a background level for lead in Agarak is 17.4 mg/kg, about 1.8 times less than the Armenian SS.

  These findings compel us to conclude that Armenian SS for lead are in need of evaluation and possible updating. Moreover, based on knowledge of international research on lead contamination in soil and background levels, the amounts detected in Agarak community do not raise immediate alarm although lead is a toxic metal and needs to be monitored.

- **Mercury** levels in the soil samples collected from Agarak city, as well as from the reference sites were not detected.

Recommendations

- Discuss findings with community leaders as well as school and kindergarten heads to determine effective action needed.
- Investigate the Karchevan river pollution by heavy metals due to mining activity and its suitability for irrigation in the community.
- Apply this study method for other parts of Agarak city (park, yard, public places, playing fields), whenever possible increasing the list of investigated metals, such as chromium, zinc, nickel, manganese, etc.
- Implement continuing soil monitoring every couple of years in Agarak city to monitor changes in soil contamination by heavy metals due to mining activities.
- Check the source and quality of a new soil to be brought to the playground of kindergarten and school.
- 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.

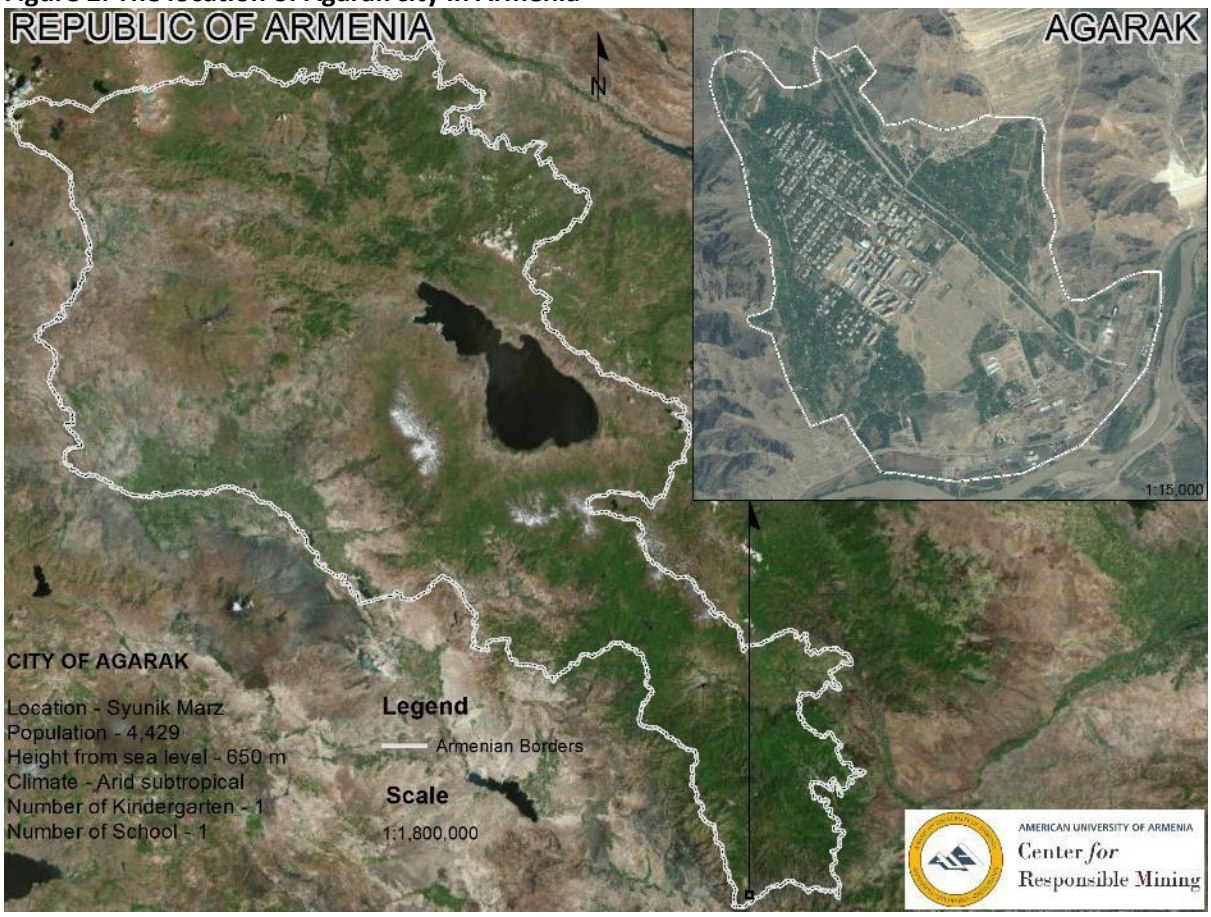
[8] http://www.atsdr.cdc.gov/phs/phs.asp?id=204&tid=37#bookmark06 accessed April 22, 2016.

BACKGROUND ON AGARAK COMMUNITY

The City of Agarak is located at 650 m above sea level in the Syunik Marz in the south part of Armenia, on the left bank of river Araks River and near the border with Iran (Figure 2). It is about 410 km south of the City of Yerevan and 94 km from the Syunik Marz capital, City of Kapan.

The city of Agarak that was historically known for its copper and lead mines was founded in 1949. The current name of the city is derived from the nearby village of Agarak. In 1954, it gained the status of an urban-type settlement. The population of the city was brought from the nearby villages, turning the town into an important industrial center, and in the 1970s it was considered as an important center for non-ferrous metallurgy.

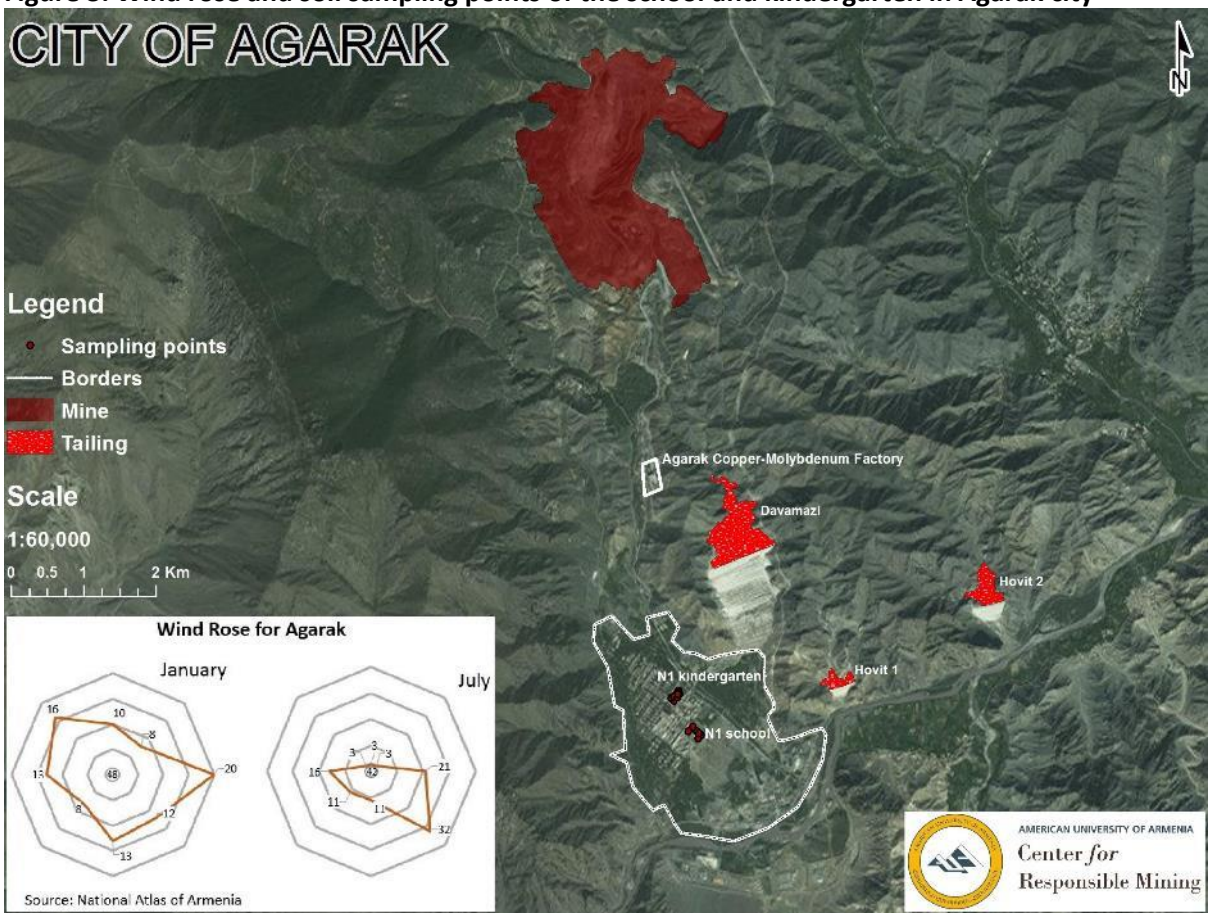
Figure 2. The location of Agarak city in Armenia



Climate and landscapes. Agarak city is located in an arid subtropical climate zone and is characterized by hot summers and calm winters. The average annual temperature is +14.2°C, with the absolute maximum of +43°C and the absolute minimum of -18°C. The length of the frost-free period is 252 days per annum on average. The annual precipitation level is 280 mm, mostly occurring in March-June.

The Agarak city is located on the submontane semidesert zone that is poor in river waters and springs. Due to the highly rugged topography and physical weathering, brown skeletal rocky soils predominate here. Soils are shallow and do not contain organic substances. Having been affected by Iranian desert landscape, this zone is poor in vegetation.

Figure 3. Wind rose and soil sampling points of the school and kindergarten in Agarak city



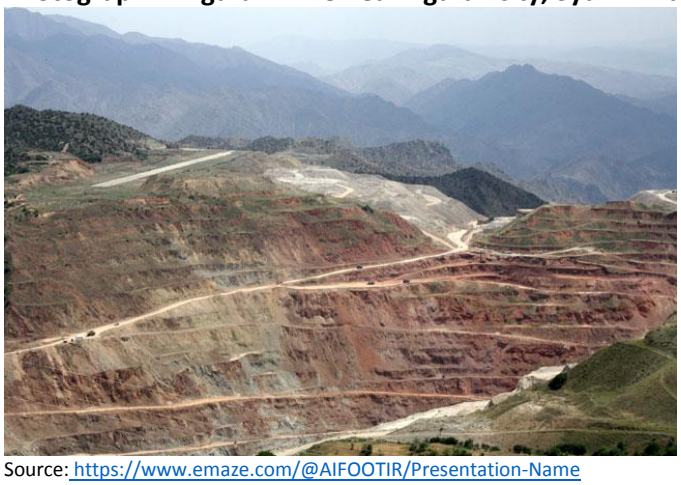
Wind patterns. Geodesy and Cartography Center SNCO prepares the wind rose[9] for the Agarak city based on long-term meteorological data. The wind rose indicates that the 20-32% of total winds over the year are in the west to east direction (Figure 3).

Population. As of the 2011 census, the permanent population of the Agarak city is 4,429 with 2,201 males and 2,228 females. The population in the age group 0-19 is 1,159 (Annex 1).

Industry. The copper-molybdenum industry in Agarak has been started in 1958 and recovered since 2001. Since 2007 Agarak mine is operated by "Agarak Copper and Molybdenum Combine" CJSC that belongs to “GeoProMining Gold” LLC.

[9] The wind rose map for Agarak city was given in the National Atlas of Armenia, prepared by Geodesy and Cartography SNCO. 2007.

Photograph 1. Agarak mine near Agarak city, Syunik Marz



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

The Agarak copper-molybdenum mine is an open-pit copper-molybdenum deposit and combine extracts 3.5 Mt of ore per year (Photograph 1). The pit is mined using conventional methods to dig out the pit which later is processed at the adjacent processing plant into an end-product of concentrate. Copper and molybdenum concentrates are packed in 2.3 tons weight bags and transported to Georgia through Yerevan by train.[10]

Agarak mine is located 4 km north to the Agarak city, and the approved mine reserves are around 0.48 km^2, with the following average metal content: 0.0096% of molybdenum, 0.374% of copper, 0.025g/t of gold, 1.19g/t of silver.[11]

Photograph 2. The tailing ponds of (a) "Hovit-2", (b) "Davamazi" and (c) "Hovit-1"

(a) (b) (c)

Source: http://www.armecofront.net/lrahos/vtangavor-pochambarner/

The Agarak Copper-Molybdenum Combine's wastewater system is centralized, and tailings generated from leaching of ores flow into the tailing ponds through pipelines and concrete structures. The combine uses 12 million m^3 of water per year for the mining processes and about 80-85% of water is discharged into existing 3 tailing ponds, the "Davamazi", "Hovit-1" and "Hovit-2" (Photograph 2).[12]

[10] The data was available at http://www.geopromining.com/en/our-business/operations/agarak/.

[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 given in the report of the Meghriget River Basin Management plant preapered by USAID Clean Energy and Water Project.

According to the inventory of toxic waste sites in Armenia conducted by AUA School of Public Health and the AUA Acopian Center for the Environment partnered with the Blacksmith Institute[13], the "Davamazi" tailing pond is located in the bank of the Darazami river, the north-east part of the Agarak city. The two other smaller tailing ponds, the "Hovit-1" and "Hovit-2", are located about 1 km and 3 km east to the city, accordingly. The designed volumes of the "Davamazi", "Hovit-1" and "Hovit-2" tailing ponds are 40.9 million m^3, 9.08 million m^3 and 17 million m^3, accordingly, of which 38.6 million m^3, 0.9 million m^3 and 3.5 million m^3 was already filled as of 2012.

Environmental issues of the community. Agarak city faces several environmental issues due to human activities in the area, such as mining industry, domestic and industrial wastewater leakages. Based on the report[14] of the Southern Basin Management plan prepared by USAID Clean Energy and Water Project, the sewage system of the Agarak city are 50 years old and in poor condition-- the domestic wastewater often washes the streets of the city. In addition, due to regular pipeline leaks, the Agarak copper-molybdenum combine's wastewater is discharged directly into the Karchevan and Araks Rivers and surrounding area caused pollution of rivers and agricultural lands by heavy metals.

Based on the monthly and annual reports[15] of RA Ministry of Nature Protection's Environmental Impact Monitoring Center SNCO, the water quality of Karchevan River correspond to bed (V) class due to high level of water contamination by heavy metals, such as copper, iron, molybdenum, vanadium and antimony. Due to high level of sulphate ion, sodium and conductivity, the river's water is not suitable for irrigation purpose.

According to 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 Agarak city is contaminated by toxic metals, such as arsenic, chromium and lead.

In addition, a number of NGOs, including the Kapan Aarhus Center, and scientific researches[17] expressed their concerns about air, soil and water pollution in Agarak community. The stakeholders indicate that environmental pollution in these communities leads the plants and livestock pollution by heavy metals, which increase health risks.

---

[13] The inventory was a part of the Toxic Site Identification Program (TSIP) in Armenia that was led by the Blacksmith Institute and AUA School of Public Health. 2012.

[14] The reports are available at http://www.mendezengland.com/site/index.php/news/312-government-of-armenia-adopts-southern-basin-water-management-plan

[15] The reports are available at http://www.armmonitoring.am/

[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://www.ysu.am/files/4%20POLLUTION%20LEVEL%20OF%20THE%20MEGHRIGET,%20VOGHCHI%20AND.pdf
http://ysu.am/files/8.%20ASSESSMENT%20OF%20HEAVY%20METAL%20CONTAMINATION%20IN%20SOILS%20AROUND%20AGARAK%20COPPER-MOLYBDENUM%20MINE%20COMPLEX,%20ARMENIA.pdf
http://www.armecofront.net/lrahos/vtangavor-pochambarner/
http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2016/06/08/090224b0843a4316/1_0/Rendered/PDF/Armenia000Stra0inability0assessment.pdf?cid=ECA_FB_%20Armenia_EN_EXT
http://www.ecolur.org/hy/news/water/save-water-for-tomorrow/1832/

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 Syuniq Marz, Agarak Regional Administration. (2016) Retrieved from http://syunik.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 (2016). 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 Agarak city by age and sex

Age	Total	Male	Female
0-4	340	172	168
5-9	285	155	130
10-14	272	145	127
15-19	262	148	114
20-24	355	191	164
25-29	377	202	175
30-34	322	166	156
35-39	320	152	168
40-44	264	135	129
45-49	293	153	140
50-54	363	181	182
55-59	268	124	144
60-64	229	101	128
65-69	91	46	45
70-74	176	68	108
75-79	110	49	61
80-84	72	28	44
85+	30	12	18
Total	***4429***	***2228***	***2201***

Source: Population Census 2011 for Armenia, National Statistic Service of the Republic of Armenia, http://armstat.am/file/doc/99483288.pdf

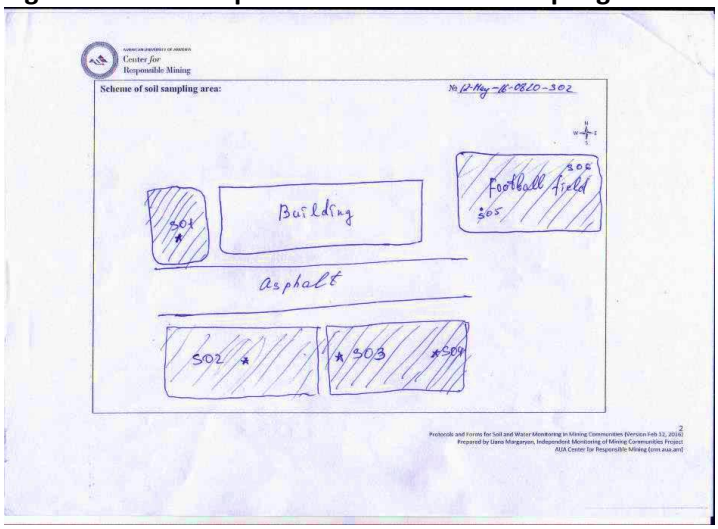
Annex 2. Methodology on Soil Sampling and Testing

The methodology on soil sampling and testing for Agarak city was based on the appropriate standard protocols and forms developed by the AUA Center for Responsible Mining based on international standards and guidance[18], 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 Agarak was implemented during May 2016. A total of 16 soil samples were collected from the kindergarten, school and one reference sampling point (5 cm, 10 cm) for determination of metals' Background Levels in Agarak community. 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 4 samples and average 6 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 example of scheme for soil sampling area in kindergarten and school



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

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

[18]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 3.5 ml 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 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 surface water sampling and testing is based on the appropriate standard protocols and forms[19] 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 surface water sample in the Agarak city was collected in May 2016. The surface water sample was collected from the Karchevan River downstream the Agarak city. The water sampling was done according to ISO 5667 and the requirements of the developed protocols and forms.

The collected water sample was labeled and transported to the laboratory in the special cooler box (under the <6 ^{o}C) for the further test. In the laboratory, the water sample was 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 sample 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.

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

Annex 4. Soil Independent Monitoring Data

Kindergarten №1

Sampling point №	pH	Arsenic, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Mercury, mg/kg
11-May-16-0803-s01-01	3.0	32.59	0.26	66.72	12.65	<0.1
11-May-16-0803-s01-02	3.5	34.64	0.29	142.52	15.91	<0.1
11-May-16-0803-s01-03	3.0	38.61	0.35	133.18	12.53	<0.1
11-May-16-0803-s01-04	4.5	45.98	0.36	198.12	46.75	<0.1
11-May-16-0803-s01-05	7.0	38.28	0.4	290.92	53.87	<0.1
11-May-16-0803-s01-06	6.0	42.53	0.38	208.02	50.26	<0.1
11-May-16-0803-s01-07	7.5	33.83	0.28	138.78	15.49	<0.1
11-May-16-0803-s01-08	7.5	32.22	0.27	150.03	16.75	<0.1
Geometric mean	**4.9**	**37.06**	**0.32**	**153.99**	**23.16**	**<0.1**

Secondary school №1

Sampling point №	pH	Arsenic, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Mercury, mg/kg
11-May-16-0803-s02-01	7.5	19.18	0.67	52.86	50.29	<0.1
11-May-16-0803-s02-02	6.0	20.14	0.64	55.58	47.78	<0.1
11-May-16-0803-s02-03	6.8	30.4	0.71	143.38	43.36	<0.1
11-May-16-0803-s02-04	4.0	27.35	0.31	181.82	28.62	<0.1
11-May-16-0803-s02-05	6.0	23.8	0.28	148.29	22.64	<0.1
11-May-16-0803-s02-06	6.5	12.4	0.27	114.67	13.56	<0.1
Geometric mean	**6.0**	**8.65**	**21.35**	**0.44**	**104.50**	**<0.1**

Annex 5. Water Monitoring Data

Karchevan river water test data

Metals	Measurement results, mg/l	Armenian background concentration for Meghriget River Basin,[20] mg/l
Aluminum	0.01	0.031
Boron	<0.1	0.080
Chromium (VI)	0.02	0.001*
Iron	1.04	0.071
Nickel	0.3	0.00064
Copper	0.35	0.004
Manganese	<0.1	0.004

* defined for total chromium

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

[20] The Armenian background concentrations for Meghriget River Basin are specified in the RA Government decision # 75-N adopted on January 27, 2011 "On defining water quality norms for each water basin management area taking into consideration the peculiarities of the Locality".

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

The determination of the background level for each metal in soil of Agarak city 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.[21] The background reference area was selected by horizontal sampling at depths 5 cm and 10 cm and distance sampling from about 1.4-1.5 km far from mining activity in the Agarak city. [22]

In total, 2 reference samples from 5 cm and 10 cm depth were collected from the site that was located the public football field of the Agarak city. The calculation of BLs for each metal are shown Figure 6 below.

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

Number of sampling point	Metals, mg/kg				
	Arsenic	Cadmium	Copper	Lead	Mercury
Armenian SS	***2***	***-***	***3***	***32***	***2.1***
0803-sRef-01 (5cm)	20.18	0.39	127.4	20.11	<0.1
0803-sRef-01 (10cm)	13.18	0.31	44.24	14.73	<0.1
Number of samples	2	2	2	2	2
Arithmetic mean	16.68	0.35	85.82	17.42	-
Median	16.68	0.35	85.82	17.42	-
Standard deviation	4.95	0.06	58.80	3.80	-
Minimum	13.18	0.31	44.24	14.73	-
Maximum	20.18	0.39	127.4	20.11	-
Lower band	17.6	0.4	96.2	18.1	-
Upper band	15.8	0.3	75.4	16.7	-
Background Level	***16.7***	***0.35***	***85.8***	***17.4***	**<0.1**

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.

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

[22] The reference soil sampling from 20 cm depth was not possible due to the soil type of the area. The other reference sampling site was not possible to identify for the Agarak city.

Annex 7. Inter-laboratory Comparison Tests Results

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 2 soil samples in the qualified laboratories of RA Ministry of Nature Protection's Environmental Impact Monitoring Center (EIMC) SNCO and EcoAtom LLC research center.

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 both laboratories of EIMC and EcoAtom. The data is provided in Figure 7 below.

Figure 7. Inter-laboratories tests results

Name of Laboratory	Arsenic, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Mercury, mg/kg
Armenian SS	***2***	***-***	***3***	***32***	***2.1***
Background Level	***16.7***	***0.35***	***85.8***	***17.4***	***<0.1***
	0803-sRef-01 (10cm)				
AUA CRM	13.18	0.31	44.24	14.73	<0.1
EIMC	5.72	0.14	17.24	45.52	-
	Sampling point 11-May-16-0803-s02-03				
AUA CRM	30.4	0.71	143.38	43.36	<0.1
EcoAtom	3.88	0.31	168.58	45.81	0.16

Annex 8. Measurements Exceeding the Armenian and International Soil Standard (SS)[23]

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	8	100%	100%	0	0	0	50%	100%	100%	100%	100%	100%
Secondary school №1	6	100%	100%	0	0	0	0	83.3%	100%	83.3%	0	50%

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	8	-	-	0	0	0	0	0	0	0	50%	0
Secondary school №1	6	-	-	0	0	0	0	50%	0	0	50%	0

(*) Soil standard has not established.

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	8	100%	100%	0	37.5%	-	37.5%	87.5%	87.5%	100%	100%	12.5%
Secondary school №1	6	100%	100%	0	0	-	0	66.7%	66.7%	66.7%	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	8	37.5%	37.5%	0	0	0	0	0	0	0	0	0
Secondary school №1	6	50%	50%	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	8	0	0	0	0	0	0	0	0	0	0	-
Secondary school №1	6	0	0	0	0	0	0	0	0	0	0	-

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

Annex 9. Soil Test Results for Each Kindergarten and School

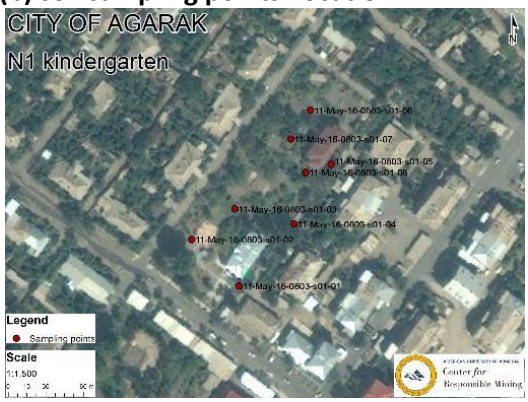
Kindergarten №1

The Kindergarten №1 is located in the central part of Agarak city. Totally 180 children attend this kindergarten. The distance from the kindergarten to the "Davamazi" tailing pond is about 1 km and to the "Hovit-1" tailing pond is 1.5 km.

The soil monitoring for the kindergarten was conducted for the soil-covered area, particularly flowerbeds and playfields that belongs to the kindergarten and separated by a fence (Figure 13a, 14b). Totally 8 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)

Figure 14. The Kindergarten №1 (a) playfield and (b) flowerbed

(a)

(b)

The concentrations of arsenic and copper exceeded the Armenian SS in the soil of the entire area of the kindergarten by 16.1-23.0 and 22.2-97.0 times, accordingly. Lead exceeded the Armenian SS by 1.5-1.7 times in 37.5% (3/8) of all soil samples. The concentrations of cadmium exceeded China's SS by 1.2-1.3 times in 50% (4/8) of soil samples collected from the kindergarten. China has the most stringent cadmium MAC (0.3 mg/kg) known to us. Mercury was not detected in the soil samples.[24]

[24] Arsenic and copper in all soil samples exceeded the BLs by 1.9-2.8 times and 1.6-3.4 times, accordingly. Lead exceeded the BL by 2.7-3.1 times in 37.5% (3/8) of all soil samples. Cadmium didn't exceeded the BL.

School №1

The Secondary School №1 is located in the central part of Agarak city. Totally 650 children attend this school. The distance from the school to the "Davamazi" tailing pond is about 1.7 km and to the "Hovit-1" tailing pond is 1.5 km.

The soil monitoring for School №1 was conducted for the soil-covered area, particularly flowerbeds and football field of the school (Figure 15a, 16). Totally 6 soil samples were collected from the soil-covered ground of the School №1, which locations are shown on Figure 15b.

Figure 15. The School № 1 (a) main view and (b) soil sampling points' location

(a)

(b)

Figure 16. The School № 1 (a) flowerbed and (b) football field

(a)

(b)

Arsenic and copper exceeded the Armenian SS by 6.2-15.2 and 17.6-60.6 times, accordingly, in all soil samples collected from the soil covered area of the school. Lead exceeded the Armenian SS by 1.4-1.6 times in 50% (3/6) of all soil samples. Cadmium exceeded China's SS by 2.1-2.4 times in 50% (3/6) of all soil samples. China has the most stringent cadmium MAC known to us. Mercury was not detected in the soil samples.[25]

[25] Arsenic, copper and lead exceeded the BLs by 1.1-1.8 times, 1.3-2.1 times and 1.3-2.9 times, accordingly, in all soil samples. Cadmium exceeded the BL by 1.8-2.0 in 50% (3/6) of all soil samples.

Annex 10. Complete Test Results of Soil Samples

Within the inter-laboratory comparison, the complete tests of metals were conducted for 2 soil samples. The total concentrations of 26 metals were measured in the qualified laboratories of RA Ministry of Nature Protection's EIMC SNCO and EcoAtom LLC 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 17.

Figure 17. Complete soil 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 0803-sRef-01(10cm)	Sample number 11-May-16-0803-s02-03					
Antimony	0.96	0.88	4.5	-**	-	-	-
Arsenic	5.72	3.88	2.0	2.0	12	30	22
Barium	73.85	56.08	-	-	-	-	-
Beryllium	0.40	n.m.	-	-	-	-	-
Bismuth	n.m.	0.23	-	-	-	-	-
Cadmium	0.14	0.31	-	3.0	14	0.3	85
Calcium	4387.84	2053.31	-	-	-	-	-
Chromium	9.60	13.78	6.0	25	64	150	230
Cobalt	7.01	6.25	5.0	-	-	-	-
Copper	45.52	168.58	3.0	100	63	50	250
Iron	9495.98	8786.19	-	-	-	-	-
Lead	17.24	45.81	32.0	60	140	250	400
Lithium	1.85	n.m.	-	-	-	-	-
Magnesium	627.91	379.35	-	-	-	-	-
Manganese	174.55	194.36	700.0	-	-	-	-
Molybdenum	2.92	9.57	-	-	-	-	-
Mercury	-	0.16	2.1	1.0	6.6	0.3	-
Nickel	10.63	12.99	4.0	50	50	40	1,600
Potassium	11203.12	10271.38	-	-	-	-	-
Selenium	2.81	1.51	-	-	-	-	-
Sodium	2594.41	2048.17	-	-	-	-	-
Strontium	40.55	22.51	-	-	-	-	-
Tin	0.32	1.55	-	-	-	-	-
Titanium	992.53	836.64	-	-	-	-	-
Vanadium	56.30	48.88	150.0	-	-	-	-
Zinc	33.36	81.62	23.0	100	200	200	23,000

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

Arsenic, chromium, cobalt, copper, nickel and zinc exceeded the Armenian SS by 1.9-2.9, 1.6-2.3, 1.3-1.4, 15.2-56.2, 2.7-3.2 and 1.5-3.5 times accordingly, in the soil samples collected from the reference site and soil-covered area of the School №1. Lead exceeded the Armenian SS by 1.4 times in the soil sample collected from the soil-covered area of the School. Antimony, manganese, mercury and vanadium didn't exceed the Armenian SS.