AMERICAN UNIVERSITY OF ARMENIA
Center *for*
Responsible Mining

Results of Soil and Drinking-Water Testing in the School of Armanis Village, Lori Marz, Republic of Armenia

Prepared by

AUA Center for Responsible Mining

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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

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[1] Other communities included in the soil monitoring series include Ararat in the Ararat Marz, Akhtala and Alaverdi 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 school of the Village of Armanis (Lori Marz, Republic of Armenia) performed by the American University of Armenia (AUA) Center for Responsible Mining (CRM). The one of the largest gold-polymetallic mines in Armenia is located in the Village of Armanis, which is exploited by "Sagamar" CJSC of Global Metals (ARM) Limited Company.

The soil monitoring in the Village of Armanis was performed for only one existing school, where a total of 25 children study. Permission was obtained from the Marz government to conduct the sampling and testing.

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 5 soil samples were collected from the playgrounds and exterior common spaces. The drinking water sample was collected from the water tap located in front of the School, in the middle of the water distribution system of the community. 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 1 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 the Trace2o Company (see Annex 2 for Methodology of Water Sampling and Testing).

The determination of background level (BL)[5] for each metal is given in Annex 4. Quality control of the results was carried out by conducting inter-laboratory comparisons (Annex 5). The comparison tests were conducted for 2 soil samples and 2 reference samples in the qualified laboratories of the RA Ministry of Nature Protection's Environmental Impact Monitoring Center SNCO, the RA Ministry of Health's National Center for Disease Control and Prevention SNCO and EcoAtom LLC research center. The comparison of soil test results with International Soil Standards is shown in Annex 6. Soil test results for Armanis primary school are presented in Annex 7. Complete test results of soil samples are presented in Annex 8.

Key Findings

With respect to drinking water, high levels of heavy metals in drinking water were not detected (Annex 3). The drinking water for the Armanis community is supplied from the Getavan-Stepanavan distribution

[3] Surface water, such as the Dzoraget and Chknagh rivers, which is used for irrigation, was not investigated due to no operation of Armanis's mine and absence of wastewater discharge from the industrial processing, when we made our site visit in November 2015. Also as the scope of the study was limited to the school, agricultural soil and water will have to be studied separately.

[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 10 and 20cm and distance site. These preliminary study is not sufficient for establishing the exact BLs for each metal in soil of Armanis community. The determination of BL needs further deep investigation (seasonal sampling, soil testing at 50cm depth).

system with intake structure located in Getavan Pumping station, 5km far from mineral processing or other industrial activities. Also, reportedly, the pipes distributing water were replaced to new pipes in 2013 and do not contain lead.[6]

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

Figure 1. Heavy metals concentrations in soil samples from Armanis primary school, % out of exceeding Armenian SS, statistical summary, and international comparatives.

Sampling points	Arsenic, mg/kg	Cadmium, mg/kg	Copper, mg/kg	Lead, mg/kg	Mercury, mg/kg
Armenian Soil Standard	***2***	*****	***3***	***32***	***2.1***
05-Nov-15-0607-s01-01	32.42	0.32	187.10	827.94	2.32
05-Nov-15-0607-s01-02	36.41	0.39	192.67	310.57	1.70
05-Nov-15-0607-s01-03	41.61	0.22	276.17	168.74	2.01
05-Nov-15-0607-s01-04	35.92	0.28	220.36	197.05	2.08
05-Nov-15-0607-s01-05	36.02	0.23	150.56	220.39	2.51
Total GM **	***36.36***	***0.28***	***201.27***	***285.12***	***2.11***
Standard deviation	***3.29***	***0.07***	***46.73***	***275.18***	***0.31***
Minimum	***32.42***	***0.22***	***150.56***	***168.74***	***1.70***
Maximum	***41.61***	***0.39***	***276.17***	***827.94***	***2.51***
Background level* **	***18.3***	***0.22***	***227.2***	***146.3***	***0.23***
% of total measurements that exceeded the Armenian SS	***100%***	***-***	***100%***	***100%***	***40%***
International maximum allowable concentrations****					
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 4 for methodology for calculating background levels.
(****) See Annex 6 for percentage of soil samples exceeding international standards.

[6] The pipes distributing water in Armanis community 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

- **Arsenic** concentrations in our soil samples ranged from 32.42 to 41.61 mg/kg. The geometric mean (GM) of all samples exceeded the Armenian Soil Standard (SS)[7] by 18.2 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. All soil samples also exceeded standards set by Canada (12 mg/kg), Sweden (15 mg/kg), United States EPA (22 mg/kg) and China (30mg/kg), some of them exceeded standard set by France (37 mg/kg), as well. Annex 6 details the percentage of soil samples exceeding these international standards.

  Another critical factor to take into account is 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. Our background level analysis (Annex 4) shows that the arsenic level is 18.3 mg/kg, about 9 times higher than the Armenian SS and about 2 times less than the GM of soil samples. Based on our current level of 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 concern in the Armanis village. While it may be reasonably argued that soil cannot be expected to be cleaner than background level, our recommendation is that school soil has to be kept to a higher standard. The playgrounds 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 0.22 to 0.39 mg/kg. As the Armenian SS does not specify allowable concentrations for cadmium, it is not possible to draw conclusions based on Armenian law.

  A few of our soil samples, however, had cadmium at levels exceeding standards set by China (0.3 mg/kg) with most stringent standards internationally (Figure 1). Other comparatives we've studied have higher allowable concentrations: Sweden 0.4 mg/kg, Norway 3 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.

  Our background level analysis for cadmium shows an average of 0.22 mg/kg, lower than the most stringent soil standards internationally (Annex 4).

  These findings compel us to conclude that: a) Armenian SS for cadmium are in need of updating and b) if Armenia concludes that the Chinese standard or even more stringent ones are the relevant

[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.

ones for Armenia, then the solution for arsenic specified above—viz., covering playgrounds with materials that reduce children's exposure to soil and dust containing metals of concern—will also minimize exposure risk to cadmium.

- **Copper** concentrations ranged from 150.56 to 276.17 mg/kg. The Armenian SS for copper is 3 mg/kg. Hence, all soil samples exceeded Armenian SS for copper, with the GM for all samples 67.1 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). China (50 mg/kg), Canada (63 mg/kg), Norway and Sweden (both 100 mg/kg) are the next most stringent. All soil samples from Armanis exceeded these standards as well.

  Our analysis shows a background level of 227.2 mg/kg for copper in Armanis, about 76 times higher than Armenian SS. The maximum level of copper detected in our samples (viz., 276.17 mg/kg) is slightly higher than the background level. But evidence suggests that copper at these levels in soil may not pose a health risk for children.[8] We do, however, recommend that discussion on acceptable levels in the environment take place in Armenia as part of revising the Armenian SS.

- **Lead** concentrations in soil samples ranged from 168.74 to 827.94 mg/kg. The Armenian SS for lead is 32 mg/kg. This is among the most stringent standards among international comparatives presented in Figure 1. However, all soil samples exceeded the Norwegian (60 mg/kg), Swedish (80 mg/kg), Canadian (140 mg/kg) standards, and some of the samples also exceeded the other international comparatives in Annex 6.

  It should be noted that our preliminary background level analysis for lead shows an average of 146.3 mg/kg, about 4-5 times higher than Armenian SS. However, an additional research is needed to establish a causal relationship between the level of lead in soil and industrial and mineral processing activity in Armanis.

  These findings compel us to conclude that lead is a heavy metal of concern in the Armanis village. Based on knowledge of international research on lead contamination in soil and background levels, the amounts detected in Armanis raise immediate alarm for children's health risk insofar as lead is a toxic metal. The playground should be covered by surface materials that reduce children's exposure to soil and dust containing metals of concern and minimize exposure risk to lead.

- **Mercury** concentrations in Armanis soil samples range from 1.70 to 2.51 mg/kg. Our analysis shows that the background level for mercury is 1.14 mg/kg.

  These amounts, for the most part, do not exceed or slightly exceeded (1.2 times) the Armenian SS, which is set at 2.10 mg/kg. They do, however, exceed standards set by China (0.30 mg/kg), Norway and Sweden (both 1 mg/kg). US EPA has not established an allowable level for mercury. Our comparative countries have soil standards ranging from 6.6 mg/kg in Canada to 20 mg/kg in Germany (Figure 1).

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

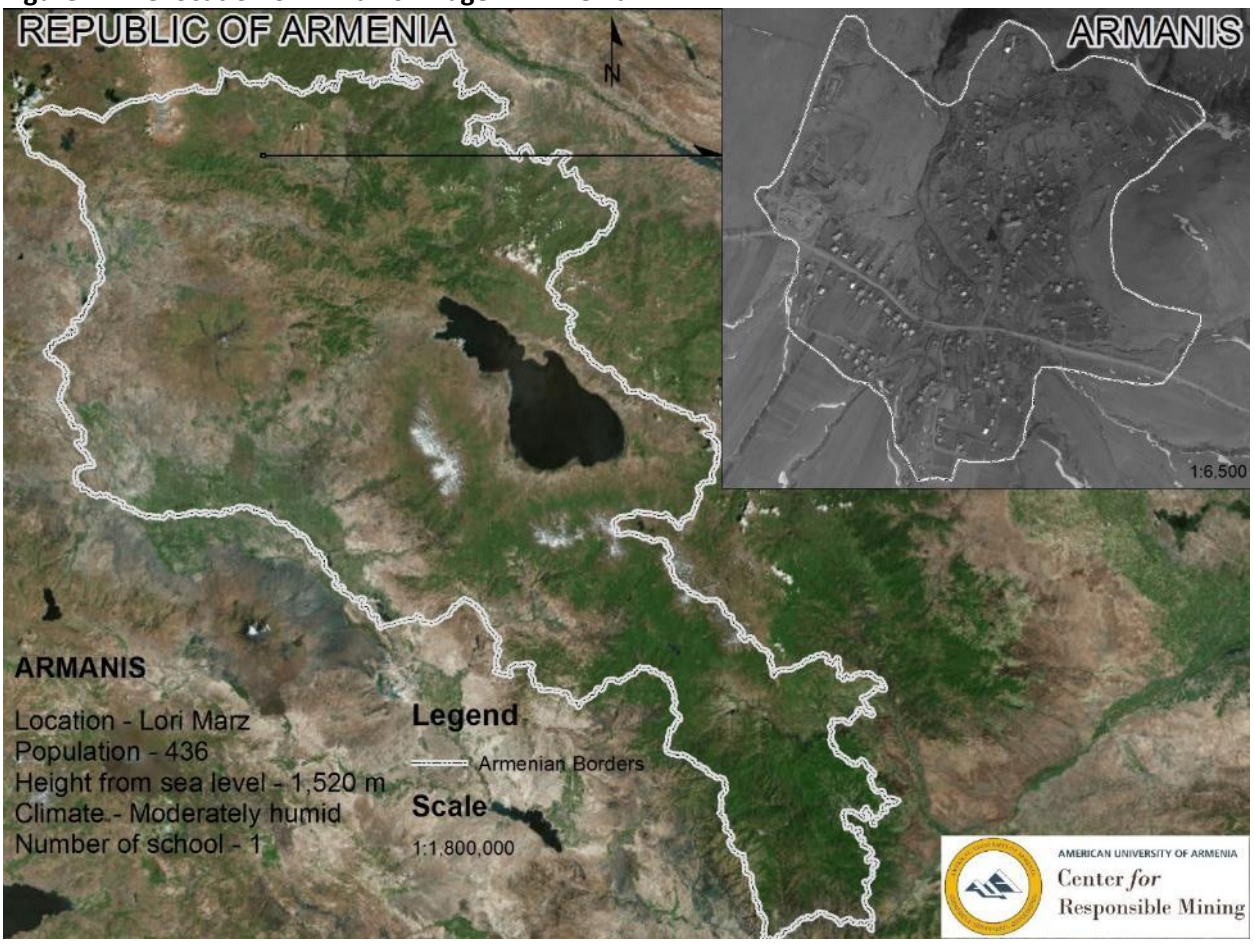
Recommendations

- Discuss findings with community leaders as well as the school head to determine effective action needed.
- Investigate the Dzoraget and Chknagh rivers pollution by heavy metals due to wastewater discharge from mining activities in the Armanis community.
- Apply this study method for other parts of Armanis village (yards, public place), whenever possible increasing the list of investigated metals, such as chromium, zinc, nickel, manganese, etc.
- Determine and evaluate the data for the background levels of metals in the soil in Armanis village with additional samples.
- Implement continuing soil monitoring every couple of years in Armanis village 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 the 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.

BACKGROUND ON ARMANIS COMMUNITY

Village of Armanis is located at 1520m above sea level in Lori Marz in the North part of Armenia (Figure 2). It is about about 90 km north-east of the City of Yerevan and 4 km away from the City of Stepanavan. Currently, the Village of Armanis is a part of the administrative territory of Stepanavan city with 436 permanent population size.

Figure 2. The location of Armanis village in Armenia



Climate and landscapes. The village is distinguished by moderately humid climate from the east to west movement of air masses. The average annual temperature is 6.6°C (average temperature in January is -4.2°C while in July it makes 16.7°C). The annual atmospheric precipitation is 683mm with snowy winters.

The region is rich in mineral waters, peat and other medicinal soil, there are favorable conditions and places for climatic treatment, as well as historical, cultural, archaeological monuments.

Industry.[9] Armanis village is well known for its metal mine, which is one of the largest gold-polymetallic deposits in Armenia. It is located 7.5 km to the west of Stepanavan city and 1.5km to the north-west of Armanis village. Its exploration began in 1966 and continued until 1990. In 2007 supplementary exploration of the mine started by "Sagamar" CJSC, who had the mining right for 1.8 km^2 area of Armanis gold-polymetallic mine. In 2010, after corporate restructuring, the shares of "Sagamar" CJSC were transferred to Global Metals (ARM) Limited Company.

Photograph 1. Armanis Mine in Lori Marz, Armenia

Source: http://avvmining.com/index.php/media-centre/pic

The approved mine reserves are around 18 mln tons, with the following average metal content: 0.9g/t of gold, 10g/t of silver, 0.9% of copper, 2.2% of zinc and 1.0% lead. The deposit is to be exploited by the integrated method: open pit and underground mine. The concentrator processes polymetallic ore by the flotation method, with the extraction of base metals (gold, copper, lead, zinc) producing 3 types of concentrates, the total of about 34-37 thousand tons per year. The dry storage of the tail is provided. The tailing dumps were not constructed due to natural uniqueness and environmental protection importance of the territory. Since august 2015, the exploitation of the Armanis mine is suspended due to the global economic crisis.

Wind patterns. Geodesy and Cartography SNCO prepares the wind rose[10] for Armanis village based on long-term meteorological data. The wind rose indicates that the 32-40% of total winds over the year are in the east to west direction (Figure 3).

Environmental issues of the village. Armanis village environmental issues related to exploitation of the Armanis mine. Based on the Environmental Impact Assessment (EIA) report of the mine, total 621.51 tons/year of substances (inorganic dust, carbon monoxide, hydrocarbons, nitrogen oxides, solid particles, sulfur dioxide) emission to the air basin and 4655.7m^3/year wastewater discharge to the

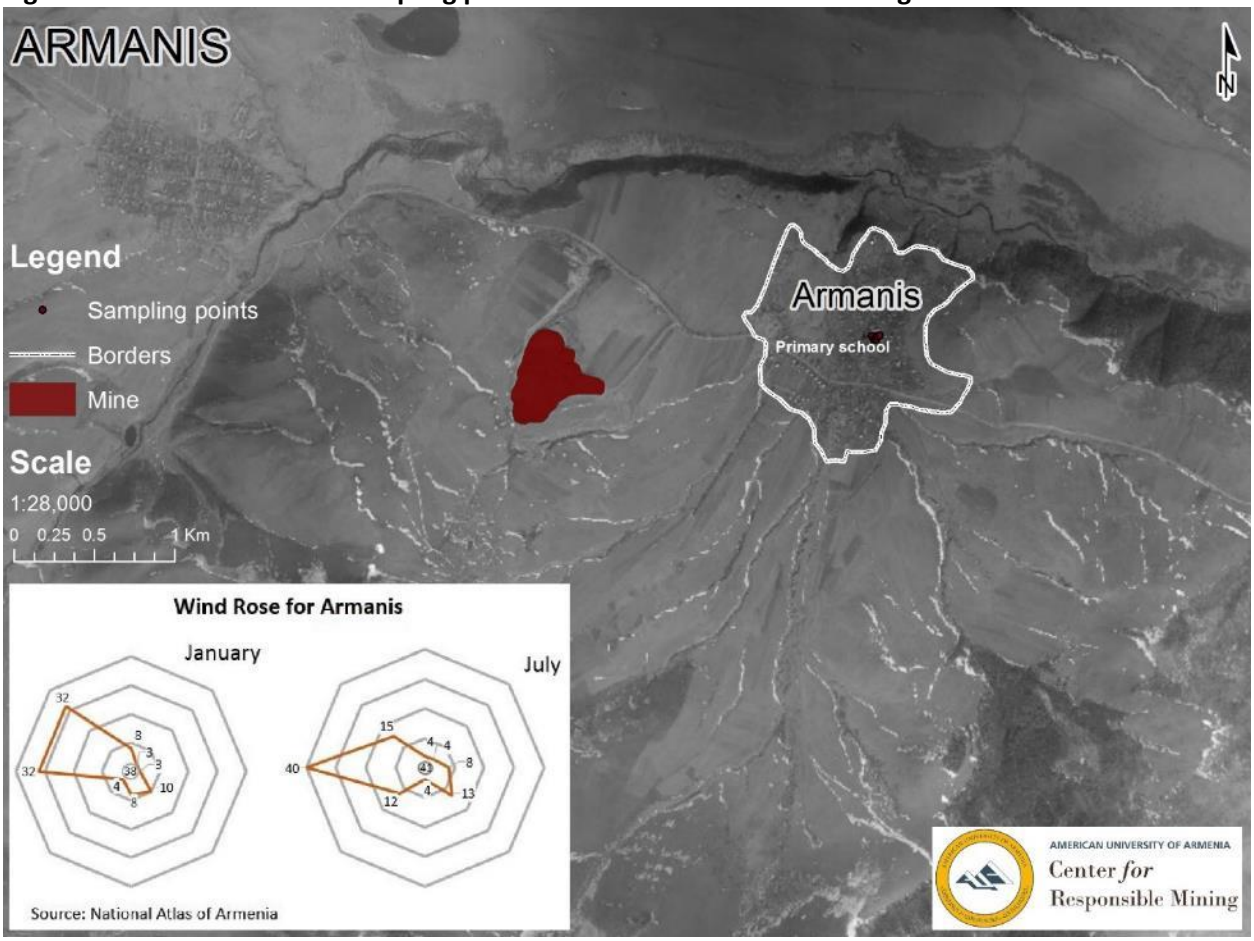
[9] The information about industrial activities in Armanis's mine is provided by Global Metals Limited company and is available at http://www.globalmetals.am/en/projects/sagamar/armanis/

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

Dzoraget and Chknagh Rivers are expected.[11] Being of a sustainable nature, emissions change the chemical composition of the air basin and surface water[12], which in turn affects human health, and negatively impacts flora and fauna. Dust spreads around and pollutes soil by heavy metals; the increase in content of nitrogen oxides and sulfur dioxides in air creates acid rain.

According to the reports of the Stepanavan Aarhus Center and several NGOs[13], as well as local population, who was interviewed by us during our site visit, the waste rock of Armanis's mine were several times dumped during the 2012-2014 in the school football field where children play. This information was not provided by RA Ministry of Natural Protection and RA Ministry of Health.

Figure 3. Wind rose and soil sampling points of the school in Armanis village



[11] EIA data for Armanis mine was given in a comprehensive overview of the Mining in Armenia, prepared as part of the Promoting Environmental and Social Accountability in the Mining Sector in the Caucasus project, implemented by American University of Armenia Center for Responsible Mining (AUA CRM) and Caucasus Environmental NGO Network (CENN) with financial support from Bread for the World (Brot für die Welt) and are available at http://w3.cenn.org/wssl/uploads/documents/Mining_in_Armenia_A_Comprehensive_Overview_Eng.pdf

[12] The groundwater is located about 5-7km far from mining activities.

[13] The reports are available at http://aarhus.am/?page_id=8999
http://www.ecolur.org/en/news/mining/children-play-in-industrial-wastes-of-armanis-gold-mine-in-school-yard/4141/

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ANNEXES

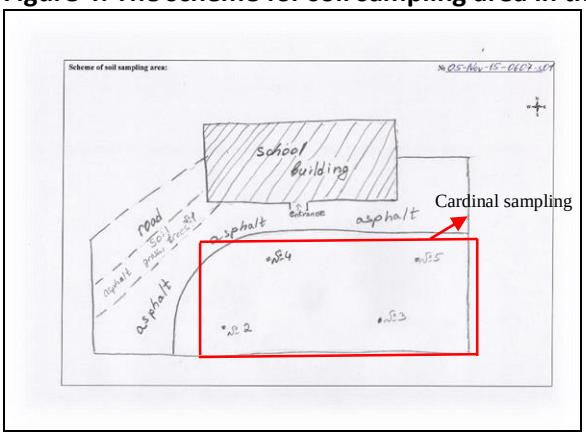
Annex 1. Methodology on Soil and Water Sampling and Testing

The methodology on soil and water sampling and testing for Armanis village is based on the appropriate standard protocols and forms developed by the AUA Center for Responsible Mining based on international standards and guidance[14], in particular, ISO 17025, ISO 5667, ISO 10381, EPA IWRG 701-2009, EPA 540-R-01-00.

Soil sampling. The soil monitoring in the Village of Armanis was implemented during November 2015. Total of 20 soil samples were collected from the 5 sampling points (5cm) in the school and 5 reference sampling points (5cm, 10cm, 20cm) for determination of metals' Background Levels in Armanis, Alaverdy 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 the school, was determined by the size of sampling site. 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 5cm 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 4.

Figure 4. The scheme for soil sampling area in the school of Armanis



The cardinal sampling layout as shown in Figure 4 was used for collecting the soil samples from football field of the school. 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.

[14] 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 samples were dried in the oven at 100°C, for an hour. Then, the soil samples were 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 concentrations.

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 2. Methodology on Water Sampling and Testing

The methodology for drinking water sampling and testing is based on the appropriate standard protocols and forms[15] 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 sample in the Armanis village was collected in November 2015. The representative water sample was collected from the water tap in front of the Armanis primary school (Figure 6). The water sampling was done according to ISO 5667 and the requirements of the developed protocols and forms.

Figure 6. Water sampling point location

The collected water sample was labeled and transported to the laboratory in the special cooler box (under the <6°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 sample were measured using the Metalyser Deluxe HM2000 and Metalometer portable heavy metals 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.

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

Annex 3. Drinking Water Monitoring Data

Metals	Measurement results, mg/l	Armenian Drinking Water Standard,[16] mg/l
Aluminum	<0.01	0.5
Boron	<0.1	0.5
Chromium (VI)	0.02	0.05
Iron	0.07	0.3
Nickel	<0.1	0.1
Copper	<0.05	1.0
Manganese	<0.1	0.1

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

[16] 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 4. Determination of Background Levels of Metals in Soil of Armanis Village

The determination of background level for each metal in soil of Armanis, Akhtala and Alaverdy 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.[17] The background reference area was selected by horizontal sampling at depth 5 cm, 10 cm and 20 cm and distance sampling from about 24 km out of the Village of Armanis.

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.[18] The calculation of BLs for each metal are shown the Figure 7 below.

Figure 7. The calculation of metals' BLs in soil for Armanis village

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.

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

[18] BLs for metals were calculated by the tests results for 10cm and 20cm depth only.

Annex 5. 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 2 soil samples collected form the Armanis primary school and 2 reference samples in the qualified laboratories of RA Ministry of Nature Protection's Environmental Impact Monitoring Center (EIMC) SNCO, RA Ministry of Health's National Center for Disease Control and Prevention (NCDCP) 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 the laboratories of EIMC and EcoAtom and by Atomic Adsorption Spectrometric Method (by Agilent AAS device) in the NCDC's laboratory. The data is provided in the Figure 8 below.

Figure 8. The inter-laboratories tests results

Name of Laboratory	Metals, mg/kg				
	Arsenic	Cadmium	Lead	Copper	Mercury
Armenian SS	***2***	***-***	***32***	***3***	***2.1***
Background Level	***18.3***	***0.22***	***146.3***	***227.2***	***0.23***
	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	100.0	0.007
	Sampling point 05-Nov-15-0607-s01-01				
AUA CRM	32.42	0.32	827.94	187.10	2.32
EcoAtom	6.28	0.26	21.51	28.85	6.71
	Sampling point 05-Nov-15-0607-s01-05				
AUA CRM	36.02	0.23	220.39	150.56	2.51
EcoAtom	23.59	6.95	846.70	230.15	4.91

(*) n.d. stands for not detected

Annex 6. Measurements Exceeding the Armenian and International Soil Standard (SS)[19]

Country	Arsenic (mg/kg)		Cadmium (mg/kg)		Lead (mg/kg)		Copper (mg/kg)		Mercury (mg/kg)	
	SS	**% of tests exceeding the SS**	***SS***	**% of tests exceeding the SS**	***SS***	**% of tests exceeding the SS**	***SS***	**% of tests exceeding the SS**	***SS***	**% of tests exceeding the SS**
Armenia	***2***	100%	*******	-	***32***	100%	***3***	100%	***2.1***	20%
Russia	***2***	100%	*******	-	***30***	100%	***3***	100%	***2.1***	20%
Belgium	***110***	0%	***6***	0%	***700***	20%	***400***	0%	***15***	0%
Netherlands	***55***	0%	***12***	0%	***530***	20%	***190***	40%	***10***	0%
Germany	***50***	0%	***20***	0%	***400***	20%	*******	-	***20***	0%
France	***37***	20%	***20***	0%	***400***	20%	***190***	40%	***7***	0%
Sweden	***15***	100%	***0.4***	0%	***80***	100%	***100***	100%	***1***	100%
Norway	***2***	100%	***3***	0%	***60***	100%	***100***	100%	***1***	100%
Canada	***12***	100%	***14***	0%	***140***	100%	***63***	100%	***6.6***	0%
China	***30***	100%	***0.3***	20%	***250***	40%	***50***	100%	***0.3***	100%
US EPA soil screening level	***22***	100%	***85***	0%	***400***	20%	***250***	20%	*******	0%

(*) SS has not established for the metal.

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

Annex 7. Soil Test Results for Armanis Primary School

The Armanis Primary School is located in the center of Armanis village and about 1km far from the Armanis mine processing. Totally 25 children attend this school.

The soil monitoring for the school was conducted for the soil-covered area, particularly in the flower-bed and play field (Figures 9a and 9b). Totally 5 soil samples were collected from the soil-covered ground of the school.

Figure 9. Armanis school (a) main view and (b) soil sampling points' location

(a)

(b)

Arsenic, lead and copper exceeded the Armenian SS by 16.2-20.8 times, 5.3-25.9 times and 50.2-92.1 times, accordingly, in all soil samples taken from the entire area of the school. The concentrations of mercury slightly exceeded Armenian SS by 1.1-1.2 times in 40% (2/5) of the soil samples.[20]

Cadmium in soil exceeded the Chinese standard by 1.1-1.3 times in 40% (2/5) of soil samples. China has the most stringent cadmium MAC known to us.

[20] In all soil samples, arsenic exceeded the BL (18.3mg/kg) by 1.8-2.3 times, lead exceeded the BL (146.3mg/kg) by 1.2-5.7 times, mercury exceeded the BL (1.14 mg/kg) by 1.5-2.2 times. In the 60% of total soil samples cadmium exceeded the BL (0.22 mg/kg) by 1.3-1.8 times and in the 20% of total soil samples copper exceeded the BL (227.2mg/kg) by 1.2 times.

Annex 8. Complete Test Results of Soil Samples

Within the inter-laboratory comparison, the complete tests of metals were conducted for 3 soil samples. Up to 25 metals' total concentrations were measured in the qualified laboratories of RA Ministry of Nature Protection's EIMC SNCO and EcoAtom research center 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-15-0607-s01-01	Sample number 05-Nov-15-0607-s01-05					
Antimony	1.47	-	-	4.5	-	-	-	-
Arsenic	17.98	6.28	23.59	2.0	2.0	12	30	22
Barium	7.52	-	-	-	-	-	-	-
Beryllium	0.76	-	-	-	-	-	-	-
Bismuth	0.79	-	-	-	-	-	-	-
Boron	11.41	-	-	-	-	-	-	-
Cadmium	0.70	0.25	6.95	-	3.0	14	0.3	85
Calcium	162.51	-	-	-	-	-	-	-
Chromium	34.22	31.30	14.39	6.0	25	64	150	230
Cobalt	11.60	7.53	6.21	5.0	-	-	-	-
Copper	102.32	28.85	230.15	3.0	100	63	50	250
Iron	7584.37	-	-	-	-	-	-	-
Lead	38.60	21.50	846.7	32.0	60	140	250	400
Lithium	4.53	-	-	-	-	-	-	-
Manganese	462.74	400.23	1664.70	700.0	-	-	-	-
Molybdenum	1.22	0.64	0.99	-	-	-	-	-
Mercury	0.0038	6.71	4.91	2.1	1.0	6.6	0.3	-
Nickel	40.77	21.60	18.36	4.0	50	50	40	1,600
Potassium	6368.97	-	-	-	-	-	-	-
Selenium	2.18	-	-	-	-	-	-	-
Strontium	23.84	-	-	-	-	-	-	-
Tin	2.53	0.83	0.34	-	-	-	-	-
Titanium	2241.87	-	-	-	-	-	-	-
Vanadium	68.13	45.86	33.05	150.0	-	-	-	-
Zinc	77.38	145.07	5284.04	23.0	100	200	200	23,000

Arsenic, chromium, cobalt, copper, nickel and zinc exceeded the Armenian SS by 3.1-11.8 times, 2.4-5.7 times, 1.2-2.3 times, 9.6-76.7 times, 4.6-10.2 times and 3.4-229.7 times, accordingly, in there soil samples collected from the reference site and soil-covered area of the Armanis School. Mercury exceeded the Armenian SS by 2.3-3.2 times in the entire soil-covered area of the school, as well as manganese and lead exceeded the Armenian SS by 2.4 and 26.5 times, accordingly, in the playfield of the school. Vanadium and antimony didn't exceed the Armenian SS.