International Journal of Arts & Sciences,
CD-ROM. ISSN: 1944-6934 :: 07(03):97–105 (2014)

MONITORING OF SOILS IN ECOLOGICALLY VULNERABLE MINING AREAS AROUND SHAMLUGH TOWN IN ARMENIA

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The physicochemical parameters of the soils around Shamlugh town and the degree of landdegradation in this area were studied.Shamlugh town is situated in the north-east of the Republic of Armenia.The location of the main sources of pollution considered, two of the most risky sites in this area (surroundings of open mine and active tailing dam of) and an unpolluted site as a control were selected for the study. The studies revealed that the surface of soils was well covered by vegetation in this area and the naked soils generally made only 0-25% in all (only in three site observed a to 50% naked soils). The studied soils are basically non eroded or weakly eroded (only in one site observed a medium level of erosion) and they are classified from fine to medium according to texture (Clay Loam, Clay, Silty Clay and Loam). In some soil samples much stoniness has been observed. At the time of studies the root systems were comparatively well-developed almost in all soil samples. The pH of studied soil samples was from slightly acidic to slightly alkaline. The content of humus ranged from 3.91 to 12.26 % in the upper A horizon. The study of pollution of soils with heavy metals and metalloids revealed the significant increase in contents of the following metals: Co, Ni, Cu, Zn, Cr, Sr, Mo, Cd, Pb compared with control sample. Experiments have led us to the assumption that pollution of soils with mentioned elements in studied territory is conditioned by human activities, particularly by mining and smelting industries.

Keywords: Heavy metals, Soil pollution, Landdegradation, Mining and metallurgical industries.

Introduction

Mining industry is a developed branch of the Armenian economy. Since the last decades of the 20th century, the mining and beneficiation of a variety of minerals, in particular copper and gold, have been the driving force behind economic development, particularly in Syunik and Lorimarzes (districts) ofRA. Shamlugh town is situated in the north-east of Armenia (Lorimarz). Mining and smelting industry is developed in this area. This economic sphere is one of the main sources of soil pollution with heavy metals (Pb, Cu, Ni, Cd, As, Mo, etc) which are considered as dangerous pollutants causing the desertification of soils [6].

In the environment, heavy metals at high concentration are toxic to most organisms. Heavy metals are defined as elements with densities greater than 5 g/cm^3[4]. Many studies have shown that heavy metals are extremely persistent in the environment, non biodegradable and readily accumulate to toxic levels [1, 7, 8, 11]. Even low concentrations of heavy metals are toxic because there is no good mechanism for their elimination from a body. Human activities such as mining and metallurgical industries have continuously increased the concentration of these metals in the environment (soils, waters, sediments) [9]. The presence of high amounts of heavy metals in the environment, induced by human activity, is one of the most important tasks of the present environmental issues. Soils are usually regarded as the ultimate sink for heavy metals discharged into the environment [3]. Heavy metals frequently reported in literature with regards to potential hazards and occurrences in contaminated soils are Cd, Cr, Pb, Zn, Fe and Cu [2]. The total content of elements depends on chemical and physical properties of both the soil and the elements. The metal content in soil is a sum of metals originating from natural processes and human activity. It is estimated that the contribution of metals from anthropogenic sources in soil is higher than the contribution from natural ones [12]. Significant increases in soil metal content are found in areas of high industrial activity where accumulation may be several times higher than the average content in noncontaminated areas. Additionally, areas distant from industrial centres also show increased metal concentrations due to long-range atmospheric transport. This fact has been observed by numerous authors [13, 14].

The bioavailable metal content in soil exerts a decisive impact on soil quality and its use in food production. According to soil parameters, heavy metals may enter the food chain in significantly elevated amounts [10]. The heavy metals act upon the health either indirectly, by consuming vegetables grown on contaminated soils, or directly by dust inhalation or drinking of contaminated water.

The aim of the present study was the monitoring of soils(particularly heavy metals) in ecologically vulnerable mining areas around Shamlugh town in Armenia. The problem under study in this region is very urgent and actual because it concerns the preservation of sensitive natural resources, prevention of inadmissible contamination of food products and the protection of the health of inhabitants in this region.

Materials and Methods

The lands of the area belong to the type of mountain cambisol. In Armenia this soil type is distributed 500-1700 meters above sea level, and on arid southern slopes, it reaches up to 2400 meters [5]. The soils of two riskiestsites of this region were studied (Figure 1):

1. surroundings of open mine near Shamlugh town (samples №№ 1-16);
2. surroundings of Chochkan active tailing dam (samples №№ 17-19).

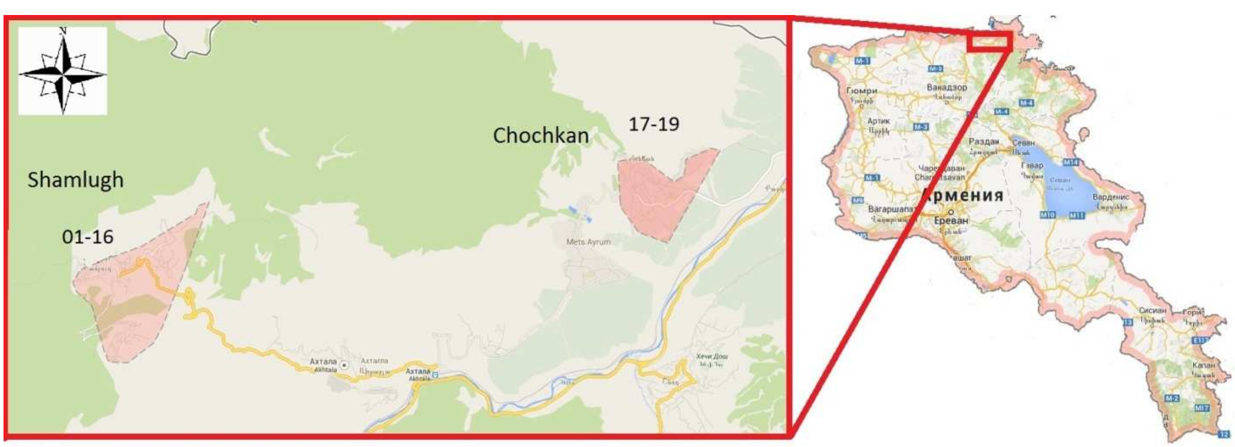

Figure1. The map of Armenia showing two sampling areas.

The 19 sections of only horizon A of soil (0-20 cm) were done in selected sites. The control section was done in the site which was2 km away from the open mine near Shamlugh town. The sections were done manually. The coordinates of sampling sites were recorded by GPS.

The sampling of soils was carried out in a traditional way, well-known in soil science. All labware and sampling apparatus were pre-soaked in 5% nitric acid solution followed by distilled water for a day prior to sampling for removing trace concentrations of metals.

The samples of soils were taken from a depth of 0-20 cm at 5 m intervals on a grid measuring 20 m x 20 m and with the center point of the grid at the sample location. After homogenization and removal of unwanted content (stones, plant material, etc.),the samples were air-dried at room temperature, sieved to pass a 1 mm mesh and stored in an all-glass jar for analysis of their properties.

The pH of the soil was measured potentiometrically with the pH-meter (Hanna, Checker). Determination of soil texture was carried out by “Feel Method”.

The content of heavy metals was determined by means of “PG990”atomic-absorption spectrometer (PG Instruments LTD, UK).

Results and Discussion

The data of field studies indicate that the 20 sections of soil can be classified into types and subtypes. The main soil type in the study sites was the mountain cambisol with its subtypes. The main soil type in the study sites was the mountain cambisol with its subtypes:

1. a) mountain cambisol, decalcified, with medium and high capacity (samples №№ 1-8 and the control sample),
   b) mountaincambisol, decalcified,steppificated, with weak capacity, weakly eroded (samples №№ 9-16);
2. mountaincambisol, calcareous, steppificated, with medium capacity, weakly eroded(samples №№ 17-19).

The properties of studied objects are described hereinafter (Table 1). Decalcified mountain cambisol is the first subtype with its two variations. Decalcified mountain cambisol is distributed in comparatively high sites. This subtype of soils in the studied territories is distributed 937-1287 meters above sea level. Calcareous mountain cambisol is the second subtype. This subtype of soils in the studied territories is 705-783 meters above sea level.The reliefs of the areas of the distribution of the two soil subtypes are rather complex and disjointed, and the gradients of the slopes vary from 3^0 to 41^0.

The description of each section and their general properties clarified during the field studies are presented in Table 1. According to data of studies, the soil surface was well covered by plants, and the naked soils generally made 0-20% in all except the sections 1 and 11 where the 50% of surface is uncovered and in the sections 10 and 17 where accordingly the 30 and 35% of surface was uncovered. The main vegetation in surroundings of sections № 1, 2, 3, 4, 5, 7, 12, 16 and control section was presented by trees, and nearby the sections № 6, 8,9, 10, 11, 13, 14, 15, 17, 18 and 19 - by herbages. The studied soils were basically weakly eroded, except the sections 5 and 9 where due to good mechanical composition of soil, sufficient vegetation and small surface gradient, the erosion processes weren’t developed. The samples 1 and 15 in contrast to already mentioned were medium eroded, which was conditioned by the bad mechanical composition of soil, the large surface gradient,the slope location and the comparatively bad vegetation cover.

Table 1. The general characteristic of the sampling areas.

Sample number	Soil type and subtype	Basin	Sampling coordinates	Surface altitude above sea level (m)	Surface gradient	Microrelief	Soil surface cover	Erosion degree (0-4)

01	Decalcified mountain cambisol	Debed river	N 41.17231″ E 44.72758″	1115	38^0	Mounds	Trees - 30%, shrubs - 5%, herbage - 10%, naked soil - 50%, stones - 5%	3
02	Decalcified mountain cambisol	Debed river	N 41.17055″ E 44.72913″	1212	25^0	Small mounds	Trees - 60%, shrubs - 10%, herbage - 10%, naked soil - 20%	1
03	Decalcified mountain cambisol	Debed river	N 41.17049″ E 44.73263″	1269	11^0	Small mounds	Trees - 60%, shrubs - 15%, herbage - 10%, naked soil - 15%	1
04	Decalcified mountain cambisol	Debed river	N 41.17382″ E 44.73255″	1287	25^0	Small mounds	Trees - 45%, shrubs - 10%, herbage - 35%, naked soil - 10%	1
05	Decalcified mountain cambisol	Debed river	N 41.17616″ E 44.73605″	1219	3^0	Smooth	Trees - 40%, shrubs - 15%, herbage - 25%, naked soil - 20%	0
06	Decalcified mountain cambisol	Debed river	N 41.17336″ E 44.72726″	1211	17^0	Mounds	Trees - 35%, shrubs - 5%, herbage - 55%, naked soil - 5%	1
07	Decalcified mountain cambisol	Debed river	N 41.17331″ E 44.72525″	1218	24^0	Small mounds	Trees - 55%, shrubs - 5%, herbage - 30%, naked soil - 10%	1
08	Decalcified mountain cambisol	Debed river	N 41.17497″ E 44.72288″	1234	28^0	Small mounds	Trees - 40%, shrubs - 10%, herbage - 50%	1
09	Decalcified mountain cambisol	Debed river	E 41.17177″ N 44.72540″	1246	5^0	Smooth	Trees - 15%, herbage - 80%, naked soil - 5%,	0
10	Decalcified mountain cambisol	Debed river	N 41.17057″ E 44.72136″	1210	10^0	Smooth	Herbage - 70% naked soil - 30%,	1
11	Decalcified mountain cambisol	Debed river	N 41.16648″ E 44.42787″	1217	10^0	Smooth	Trees - 20%, herbage - 30%, naked soil - 50%	1
12	Decalcified mountain cambisol	Debed river	N 41.16810″ E 44.71713″	1194	20^0	Small mounds	Trees - 50%, shrubs - 20%, herbage - 25%, naked soil - 5%	1
13	Decalcified mountain cambisol	Debed river	N 41.16750″ E 44.72103″	1185	9^0	Smooth	Trees - 20%, shrubs - 30%, herbage - 40%, naked soil - 10%	1
14	Decalcified mountain cambisol	Debed river	N 41.16315″ E 44.72528″	1099	40^0	Small mounds	Trees - 15%, shrubs - 10%, herbage - 60%, naked soil - 15%	1
15	Decalcified mountain cambisol	Debed river	N 41.161770″ E 44.72785″	1150	31^0	Mounds	Trees - 10%, shrubs - 20%, herbage - 50%, naked soil - 20%	2

16	Decalcified mountain cambisol	Debed river	N41.15866″ E 44.72781″	937	41^0	Mounds	Trees - 50%, shrubs - 20%, herbage - 20%, naked soil -10%	1
17	Calcareous mountain cambisol	Debed river	N 41.1812″ E 44.8431″	783	5^0	Smooth	Trees - 15%, herbage - 50%, naked soil - 35%	1
18	Calcareous mountain cambisol	Debed river	N 41.1800″ E 44.8185″	720	8^0	Small mounds	Trees - 10%, shrubs - 15%, herbage - 65%, naked soil - 20%	1
19	Calcareous mountain cambisol	Debed river	N 41.1812″ E 44.8431″	705	5^0	Smooth	Trees - 20%, shrubs - 5%, herbage - 60% naked soil - 15%,	1
Control	Decalcified mountain cambisol	Debed river	N 41.17933″ E 44.74795″	1223	10^0	Small mounds	Trees - 55%, shrubs - 20%, herbage - 15%, naked soil - 10%	1

The general characteristic of the studied soils is presented in Table 2. Except the soil samples 01 and 07, the good quantitative ratio of clay – sand - silt was observed in other soil samples, therefore,according to the texture classification,these soil sampleswere characterized as good, and the soil samples 01 and 07 were characterized as medium.Much stoniness was observed in the soil samples 01, 03, 06, and 14. The soil samples 05, 08, 17, 18 and 19 had the best structural properties, and the soil samples 05 and 08 had comparatively bad structural properties. The pH of the studied soil samples varied from acidic to slightly alkaline and ranged from 5.27 to 8.46. The content of humus ranged from 3.91 to 12.26% in the upper A horizon. The highest content of humus was observed in the section 04. The lowest content of humus was in the section 01, where higher than medium erosion degree and comparatively bad developed vegetation were observed (naked soil - 50%).

Table 2. The general characteristic of the studied soils.

Sample number	Mechanical composition			Texture	Texture classification	Stones	Structure	pH	Humus content, %
	clay	sand	silt						
01	25%	50%	25 %	Loam	Medium	2-5 mm -30% 5-20 mm -40% >20 mm -30%	Granular weak 1-2mm -90% 2-5 mm -10%	5,27	3.91
02	40%	12%	48 %	Clay Loam	Good	2-5 mm -60% 5-20 mm -30% >20 mm -10%	Granular cloddy 1-2 mm -45% 2-5 mm -45% >5 mm -10%	7,33	7,21
03	70%	10%	20 %	Clay	Good	2-5 mm -50% 5-20 mm -30% >20 mm -20%	Granular cloddy 1-2mm -40% 2-5 mm -40% >5 mm -20%	5,70	7,79
04	40%	20%	40 %	Clay Loam	Good	2-5 mm -70% 5-20 mm -25% 20 mm -5%	Granular cloddy 1-2mm -50% 2-5 mm -40% >5 mm -10%	5,83	12.26
05	80%	5%	15	Silty	Good	2-5 mm -75% 5-20 mm -25%	Cloddy 1-2mm -10%	5,11	4,29

			%	Clay			2-5 mm -40% > 5 mm -50%		
06	40%	20%	40 %	Clay Loam	Good	2-5 mm -50% 5-20 mm -35% >20 mm -15%	Granular cloddy 1-2mm -50% 2-5 mm -40% >5 mm -10%	6,18	8,98
07	20%	50%	30 %	Loam	Medium	2-5 mm -50% 5-20 mm -40% >20 mm -10%	Granular weak 1-2mm -90% 2-5 mm -10	7,83	4,41
08	80%	5%	15 %	Clay	Good	2-5 mm -60% 5-20 mm -30% >20 mm -10%	Cloddy nutlike 1-2mm -15% 2-5 mm -40% >5 mm -45%	7,66	4,32
09	40%	10%	50 %	Clay Loam	Good	2-5 mm -90% 5-20 mm -10%	Granular cloddy 1-2mm -50% 2-5 mm -35% >5 mm -15%	7,75	7,36
10	67%	13%	20 %	Clay	Good	2-5 mm -85% 5-20 mm -15%	Granular cloddy 1-2mm -55% 2-5 mm -35% > 5 mm -10%	7.85	6,00
11	40%	30%	30 %	Clay Loam	Good	2-5 mm -70% 5-20 mm -25% >20 mm -5%	Granular cloddy 1-2mm -40% 2-5 mm -50% 5 mm -10%	8,46	8,14
12	60%	25%	15 %	Clay	Good	2-5 mm -80% 5-20 mm -15% > 20 mm -5%	Granular cloddy 1-2mm -50% 2-5 mm -45% > 5 mm -5%	7,71	5,56
13	70%	15%	15 %	Clay	Good	2-5 mm -85% 5-20 mm -15%	Granular cloddy 1-2mm -45% 2-5 mm -40% > 5 mm -15%	7,50	6,62
14	70%	10%	20 %	Clay	Good	2-5 mm -50% 5-20 mm -30% 20 mm -20%	Granular cloddy 1-2mm -40% 2-5 mm -50% >5 mm -10%	7,28	4,97
15	85%	0%	15 %	Silty Clay	Good	2-5 mm -60% 5-20 mm -30% 20 mm -10%	Granular cloddy 1-2mm -60% 2-5 mm -35% > 5 mm -5%	7,40	8,13
16	65%	30%	5%	Clay	Good	2-5 mm -65% 5-20 mm -25% 20 mm -10%	Granular cloddy 1-2mm -55% 2-5 mm -35% > 5 mm -10%	7,44	4,76
17	40%	15%	45 %	Clay Loam	Good	2-5 mm -65% 5-20 mm -35%	Cloddy nutlike 1-2mm -20% 2-5 mm -40% >5 mm -40%	7,94	6,61
18	43%	16%	41 %	Clay Loam	Good	2-5 mm -70% 5-20 mm -30%	Cloddy 1-2mm -25% 2-5 mm -45% > 5 mm -30%	7,89	6,58
19	42%	14%	44	Clay	Good	2-5 mm -65% 5-20 mm -30% >20 mm -5%	Cloddy nutlike 1-2mm -25% 2-5 mm -40%	7,84	6,52

			%	Loam			> 5 mm -35%		
Control	72%	12%	16 %	Clay	Good	2-5 mm -50% 5-20 mm -40% >20 mm -10%	Granular cloddy 1-2mm -40% 2-5 մմ-45% >5 mm -15%	5,64	7,75

The content (mg/kg) of some heavy metals in the studied samples of soil is presented in Table 3. Since the contents of metals in soils are specific and depend on the compound of rocks producing the soil and the conditions of soil formation, for the determination of pollution level, the obtained results were compared to control sample which was considered as a background. The study revealed the appreciable increase (1.5 to 6.6 times) in the contents of following heavy metals: Cu (samples №№ 1-4, 6-19), Zn (samples №№ 1-2, 4, 10-11, 13-19), Pb (samples №№ 5, 8, 10-11, 13-16,), Ni (samples №№ 17-18), Co (samples № 16).Compared to the control sample, the significant increase (approximately 6.6 times) in the content of heavy metals was observed only for copper which was due to the high content of this metal in ores (Table 4). In general, the soil samples №№1-3, 7, 10-19 were highly pollutedby Cu and to some extent - by other metals, while the sample №№4-5 was not so much polluted.

Table 3. The content (mg/kg) of some heavy metals in the studied samples of soil.

Sample number	Cu	Zn	Pb	Ni	Co
01	53.0	600.0	4.2	17.0	18.5
02	55.0	800.0	3.4	15.0	21.6
03	60.0	400.0	5.7	17.0	14.8
04	35.0	600.0	4.6	20.0	14.8
05	18.0	500.0	6.9	30.0	18.8
06	50.0	500.0	4.5	18.0	14.8
07	51.0	450.0	5.3	20.0	16.1
08	25.0	400.0	9.0	30.0	18.8
09	52.0	400.0	6.0	18.0	14.8
10	85.1	600.0	9.2	19.0	16.5
11	62.0	550.0	8.0	16.0	15.6
12	90.0	650.0	11.0	20.0	17.2
13	100.0	600.0	10.0	15.0	21.6
14	105.0	650.0	8.8	18.0	22.5
15	113.0	600.0	9.0	22.0	10.8
16	100.0	700.0	8.1	18.0	30.4
17	65.0	600.0	4.6	33.0	17.2
18	70.0	650.0	5.2	37.0	18.4
19	59.0	580.0	4.4	28.0	15.9
Control	17.0	400.0	4.3	21.0	16.7

Table 4. The degree of the exceedings of the background concentrations of heavy metals (experimental variant/control)

Samplenumber	Cu	Zn	Pb	Ni	Co
01	3.1	1.5	1.0	0.8	1.1
02	3.2	2.0	0.8	0.7	1.3
03	3.5	1.0	1.3	0.8	0.9
04	2.1	1.5	1.1	1.0	0.9

05	1.1	1.3	1.6	1.4	1.1
06	2.9	1.3	1.0	0.9	0.9
07	3.0	1.1	1.2	1.0	1.0
08	1.5	1.0	2.1	1.4	1.1
09	3.1	1.0	1.4	0.9	0.9
10	5.0	1.5	2.1	0.9	1.0
11	3.6	1.4	1.9	0.8	0.9
12	5.3	1.6	2.6	1.0	1.0
13	5.9	1.5	2.3	0.7	1.3
14	6.2	1.6	2.0	0.9	1.3
15	6.6	1.5	2.1	1.0	0.6
16	5.9	1.8	1.9	0.9	1.8
17	3.8	1.5	1.1	1.6	1.0
18	4.1	1.6	1.2	1.8	1.1
19	3.5	1.5	1.0	1.3	1.0

Conclusion

It should be noted that such kind of heavy metal pollution of soils in the studied territory was directly due to human activities, particularlymining and smelting industry. The variation of high pollution with Cu and some heavy metals near the open mine and the surroundings of Chochkan active tailing dam was due to the character of industrial activities, the moving direction of airstreams as well as the physicochemical peculiarities of soils.Also, it is necessary to mention that comparatively low pollution of the northern and eastern regions of the open mine may have been conditioned by the well-developed forest biomasses of these regions and the high locationcompared tothe open mine, which are considered as hindering factors for the movement of heavy metal containing dust to these regions and vice versa, in the southern and western regions of the open mine and the surroundings of the tailing dam, where forest biomass density was lower, the degree of the soil pollutionwith heavy metals was higher. It is necessary to state that this issue becomes actual as the some parts of these highly polluted regions are inhabited by population, and agriculture is highly developed there, therefore heavy metals can enter human body through soil-plant-human or soil-plant-animal-human chain causing various diseases.

Acknowledgement

This work was supported by the Young Scientists Support Program and the National Foundation of Science and Advanced Technologies, in the frames of research project№ YSSP-13-47.

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